INITIAL ENVIRONMENTAL EVALUATION

MacTung Project

AMAX NORTHWEST MINING COMPANY LIMITED

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MacTung Project
Yukon and Northwest Territories

prepared by

AMAX Northwest Mining Company Limited

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Chairman
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Indian and Northern Affairs Canada
Box 1500
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Dear Sir,

re: Initial Environmental Evaluation of the MacTung Mining and Milling Project, Yukon and Northwest Territories

We are pleased to submit for your consideration and response the Initial Environmental Evaluation (IEE) for AMAX Northwest Mining Company Limited's proposed tungsten production facility at MacTung. This document will initiate the formal application process leading to an approval to proceed with development. In keeping with procedures established by the federal government this document is being submitted to the Regional Environmental Review Committee (RERC) for screening purposes so that the committee may determine whether the MacTung project will be subject to the normal regulatory approval processes or whether it will be required to go through the full Environmental Assessment and Review Process (EARP).

The project will be located on the border of the Yukon and Northwest Territories, a short distance to the north of the North Canol Road. This document is the culmination of several years of enquiry into physical and biological conditions at the project site and in the surrounding area. These endeavours have given rise to several dozen reports, the information from which has been organized into a number of background or component reports. These component reports will be filed along with the IEE and they will constitute attachments to the evaluation document.

The layout and contents of the IEE are in keeping with Government of Canada guidelines respecting the preparation of such a report for a proposed mining development. Thus there is a project rationale, a project description, an account of the existing biophysical character of the project area and a number of sections which describe environmental impacts and the opportunities to ameliorate these impacts through mitigating measures. The residual consequences of the project also are addressed.

The MacTung IEE describes conditions and effects associated with the construction of a 900 tonnes per day (1000 short tons per day), 350 days per year tungsten mining and milling facility with a life expectancy in excess of 25 years. At this time, however, AMAX is evaluating a systematic, staged approach to development at the site, perhaps initiating production at a 100-200 ton per day rate, progressing to the 1000 tpd facility and ultimately expanding to 2000 tpd. The timing for such a plan currently is from the latter half of the 1980's to the early 1990's depending solely on market conditions and factors.

AMAX wishes to stress that while the contents of this IEE focus principally on an account of the parameters and the consequences of introducing the MacTung project to the Macmillan Pass area, the company recognizes other, ongoing regional initiatives with potential for interaction with the AMAX project. Some of these other interests and activities are discussed in the evaluation. We would note too that we have participated in discussions and activities associated with regional development matters, notably through the Macmillan Pass Task Force. AMAX believes it to be important in terms of sound regional land use planning to acknowledge opportunities for cooperation and integration where these reasonably occur. We trust that the MacTung IEE is a constructive contribution to overall regional planning initiatives as well as being a statement on the project in its own right.

With respect to socio-economic matters, the document describes what will be the fundamental manpower requirements of the project during construction and operation. To better acquaint northern Canadians with AMAX's plans for MacTung in terms of manpower needs and other parameters, the company has embarked on a public communications program. Through a series of community meetings the program will outline in what ways northerners may benefit from the project. The public communications program also is intended to provide the basis for negotiations on a range of opportunities that may be available to the communities. The program will continue until an arrangement is reached which will maximize opportunities for northerners in the context of efficient, long-term project operation and management.

We acknowledge that there are ongoing enquiries by others whose findings will be useful additions to the information presented in this document. The traditional land use study being conducted by the Ross River Indian Band, is one such example. Also, AMAX is prepared to conduct post-construction monitoring programs where these will prove helpful in maintaining an ongoing check on the interrelationships between the project and its biophysical setting.

Yours truly,

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PREAMBLE

This document is an Initial Environmental Evaluation of the proposed MacTung mining project which lies in the vicinity of Macmillan Pass on the Yukon-Northwest Territories border. The evaluation has been prepared by AMAX Northwest Mining Company Limited, the proponent of the project. The company has actively explored the MacTung property for several years and it is now in a position to place its developmental proposal before the regulatory agencies for screening purposes.

The development proposal and the evaluation of the environmental impacts of the project are predicated on the underground mining of tungsten and the processing of that material on site at an initial capacity of 900 tonnes (t) (1000 tons) per day with a capability to expand to 1800 t (2000 tons) per day. At this time it is anticipated that full site development to accommodate a 900 t (1000 tons) per day plant and year-round operations will occur in the late 1980's and 1800 t (2000 tons) per day in the early 1990's. Between 1983 and the date that the project is fully commissioned, AMAX Northwest Mining Company Limited plans to initiate a staged, seasonal development program. This will culminate in the full-scale operations scheduled for the late 1980's.

The MacTung Initial Environmental Evaluation encapsulates the findings of several years of office and field studies. This, the main volume of the IEE, conforms to guidelines set down by the Federal Environmental Assessment and Review Office (FEARO) with respect to mining development proposals. Also, it seeks to meet the expectations of the Regional Environmental Review Committee (RERC) in respect of the location, constituents, scale, products, longevity of the project as well as the environmental consequences of the project's construction and operation.

Information pertinent to the socio-economic opportunities and consequences of the project also is presented to facilitate ongoing discussion with northern Canadians, public agencies and others through AMAX's public communications program.

To facilitate access to more detailed information on the project the main IEE is supplemented by a number of detailed component reports. The titles of these reports, together with other key pieces of information pertinent to the project, are set out in Chart I. The contents of this volume are described in the following paragraphs.

Chapter One provides an overview of the IEE in nine parts. The chapter may be read to determine the principal factors leading to the need for the project, key elements of the project, the key environmental consequences of MacTung and conditions leading to enhancement and mitigation and residual impacts. The chapter concludes with a statement on the completeness of the data used to prepare the IEE.

Chapter Two is a project rationale which identifies the proponent, outlines the need for the project and provides an account of possible alternatives to MacTung as presented here. An account is provided of associated projects which potentially may interrelate with MacTung.

Chapter Three first describes the project in terms of its geographical setting and its background. The chapter then systematically discusses the development concept, the orebody, the mine and process plant, tailing disposal, water supply and distribution, and several other components essential to the construction and operation of MacTung during the project's life of at least 25 years.

Chapter Four provides information on the existing biophysical environment of the project site and adjacent areas that in some way might be influenced by the facility. Physical and biological conditions are described by component.

Chapter Five provides an account of environmental impacts expected to arise from project implementation; and opportunities for enhancement and mitigation of these impacts are addressed in Chapter Six. Social and economic considerations are addressed in Chapter Seven, particularly in respect of MacTung's isolated, northern geographical setting and its locational relationship to both the Yukon and Northwest Territories.

Residual impacts associated with the project are addressed in Chapter Eight and the volume concludes with a set of appendices.

CHART I

KEY INFORMATION MACTUNG PROJECT

Project Location	:	Yukon - Northwest Territories border at 63° 17' Lat.; 130° 9' Long.
Project Proponent	:	AMAX Northwest Mining Company Limited.
Project Discovery	:	AMAX Exploration in 1962.
Land Holdings	:	206 mineral claims and leases (97 in Yukon; 109 in Northwest Territories).
Project characteristics	:	Tungsten production facility including mine, mill complex, process plant, warehousing, maintenance facilities, engineering and production offices, accommodation and recreation facilities.
Project area	:	Maximum estimated at 228 ha, including 90 ha (including peripheral disturbance) for tailing pond.
Mineable reserves	:	25,351,700 t (27.5 million tons)
Project scale	:	8 million t (9 million tons) of ore at 317, 500 t (350,000 tons) per year for life expectancy of "25 years.
Daily production rate	:	900 t (1000 short tons) per day.
Number of operating days	:	350 days per year.
Mine	:	Underground mine originating Yukon and Northwest Territories; access via adit in Northwest Territories.
Tailing pond	:	Upper Dale Creek valley - to accommodate 40 years of tailing solids.
Water supply	:	Cirque Lake.
Accommodation	:	On site camp with travel in/travel out on 4 day x 4 day schedule. Base of operations: Whitehorse.
Construction staff	:	Manpower maximum of 335 during the 30 month construction period.
Operation staff	:	174.
Transportation	:	Aircraft on new landing strip east of Macmillan Pass. Vehicles (including 2-3 trucks per day) on North Canol Road.
Information on project	:	Initial Environmental Evaluation main report and following component reports: 1) MacTung Meteorology and Air Quality Analysis and Assessment 2) Geomorphology and Vegetation of the MacTung Study Area 3) Aquatic Ecology of the MacTung Area 4) 1981-82 MacTung Wildlife Studies, Yukon/N.W.T. 5) Avifauna of the MacTung Project Area 6) Socio-Economic Overview Study - MacTung Project

1.0 OVERVIEW

CHAPTER ONE

OVERVIEW

1.1 INTRODUCTION

This document (with its attendant component reports) has been prepared by AMAX Northwest Mining Company Limited (AMAX) to conform with procedures set out by the Government of Canada for project development in northern Canada. Guidance on these procedures is set out in a number of guideline documents issued by the Federal Environmental Assessment and Review Office (FEARO). These materials include Guidelines for Preparing Initial Environmental Evaluations (1976), and Revised Guide for Environmental Screening (1979). The latter document forms the basis for the Department of Indian Affairs and Northern Development's environmental screening guidelines as expressed in "Implementation of the Federal Assessment and Review Process (EARP) in the Northern Program, DIAND" (n.d.). The submission of this Initial Environmental Evaluation (IEE) for the MacTung project heralds AMAX's initiation of project application for a 900 t (1000 tons) per day facility.

AMAX is actively pursuing a public communications program in northern Canada. Beyond initiating discussions with the government and regulatory agencies to identify and define specific areas of concern, it is hoped that documents such as this IEE will encourage all interested parties to familiarize themselves with the company's plans and contribute to the delineation of short and long-term programs and other mechanisms required to evaluate and to resolve relevant outstanding concerns.

The IEE reflects several years of environmental and related studies in the project area, as further defined later in this document. These enquires have been completed by or on behalf of the proponent, by government agencies and other institutions, and by individual researchers in response to the potential advent of the MacTung project.

A detailed timetable for commencement of full-scale site work has not yet been developed although it is intended that such action will commence in the mid 1980's. AMAX anticipates that the early release of this IEE will assist representatives of government agencies in determining the process and the procedures to be followed concerning environmental review and assessment. The report should provide an adequate base upon which to make recommendations for the necessary licences and leases; and it should serve as a document which may be updated as appropriate to meet the requirements for the necessary licences and leases.

The evaluation provides an outline of the project as proposed to date. There are summaries for the considerable physical and biological environmental data collected in the area of the mine site, an analysis of the potential impacts which the project could have on the environment, and suggestions for mitigating measures where necessary. In addition, this volume provides a summary of the social and economic aspects of the project, including information on a public communications program which will serve as a basis to inform, dialogue and negotiate with northern residents. The program is a mechanism to ensure that benefits to northern residents are optimized while at the same time possible concerns about the project are fully addressed.

1.2 DECLARATION

The initiator of this IEE and the proponent of a mine, mill complex and associated facilities at MacTung is AMAX Northwest Mining Company Limited. This company is a wholly - owned subsidiary of AMAX Inc., Greenwich, Connecticut, which, in turn, is a 65% owner of Canada Tungsten Mining Corporation. The latter company operates the Cantung mine at Tungsten, Northwest Territories and produces tungsten concentrate at that location.

1.3 NEED FOR PROJECT

AMAX Northwest Mining Company Limited is a wholly owned subsidiary of AMAX Inc. AMAX Inc. is a 65% owner of Canada Tungsten Mining Corporation Limited, a public company listed on the Toronto Stock Exchange. Canada Tungsten operates a 900 t per day underground mining operation producing scheelite concentrate at Tungsten, Northwest Territories.

Based on the AMAX experience in the tungsten business, it is predicted that tungsten supply/demand in the latter half of the decade will allow the MacTung Project to enter the tungsten market. As an operating mine MacTung will contribute additional jobs to the north, as well as the various indirect economic benefits to the north specifically and to Canada as a whole.

The Governments of the Yukon and the Northwest Territories both have indicated an interest in the development of mining projects which can provide significant economic benefits through employment and the development of new skills for northerners.

The intent of AMAX Northwest Mining Company Limited to maximize Canadian content in the development and operation of the mine will result in over 90% of the initial capital costs being spent in Canada. Essentially all of the projected $29 million annual operating costs will be spent in Canada.

1.4 CONTEXT

The MacTung project lies in a loosely defined region which centres upon a number of existing facilities and areas of potential resource development. Key constituents of this "region" are the North Canol Road, the community of Ross River, a battery of potential mineral development prospects in the vicinity of Macmillan Pass, and a lesser assemblage near Howard's Pass. Widespread recognition that the so-called Macmillan Pass area may become the focus of much land use activity in the years ahead has precipitated a range of studies which have sought to determine how best to accommodate resource developments within the context of prevailing environmental and socio-economic conditions in the region. The large number of studies has focussed on everything from project specifics, through multi-project infastructure strategies, to comprehensive regional land use planning. Much has been achieved with this data in the way of baseline inventory and monitoring.

1.5 PROJECT DESCRIPTION

The MacTung scheelite deposit was discovered in 1962 by J. Allan, an AMAX geologist. The property is located at 63°17' latitude and 130°9' longitude, almost precisely half way between the 60th parallel and the Arctic Circle (about 375 km each way), and approximately 225 km northeast of the community of Ross River, Yukon Territory. The deposit is located largely on the Yukon side of the Yukon/Northwest Territories border, but it does extend into the Northwest Territories.

Exploration programs have been carried out on a continuing basis since 1962, with the major bulk sampling and process testwork being conducted in 1973. An initial pre-feasibility study was performed by AMAX Exploration in 1974 and subsequently updated with extensive environmental work in 1975 and 1976. Indeed, work progressed to the stage of a Water Board Hearing and the drafting of a Water Licence in 1979 before economic factors dictated withdrawal of the company's application. Approximately 206 claims and leases, 97 in Yukon and 109 in the Northwest Territories, cover the mine site, proposed plant site, tailing disposal pond and water source areas.

Road access to the property is via the North Canol Road from the community of Ross River which lies beside the Pelly River. The road was built by the U.S. Army Corps of Engineers in 1942 to permit construction of a pipeline from Norman Wells to Whitehorse. At the present time the road is maintained during the summer only by the Yukon Department of Public Works.

The road is maintained only to the MacTung access road which, in turn, leads to the MacTung site. Some reconstruction and upgrading of the North Canol Road will be required, however, to fully service the project and initial steps in this direction are expected to be undertaken by government agencies through right-of-way clearing in 1983-84 fiscal year and actual grade construction the year after.

A very primitive airstrip exists at Mile 222 of the North Canol Road, some 10 km east of the junction of the North Canol Road and the MacTung access road. A new airstrip will be required closer to the MacTung site for construction and operations support.

Information obtained from the extensive drilling programs and bulk sampling leads AMAX Northwest Mining Company Limited to believe that there is a minimum life of 25 years to the orebody from the underground operation alone. This is based on a potential of developing approximately 8 million t (9 million tons) of ore with a mill designed to process a nominal 900 t (1,000 tons) per day. During development and operation, however, AMAX will continue to explore in anticipation of ascertaining additional reserves and thereby extending the life of the mine. Mine extension could be in the form of additional underground operation or alternatively, open-pit mining methods.

AMAX Northwest Mining Company Limited plans to construct a mine, mill complex and process plant as well as warehousing, maintenance facilities, engineering and production offices, accommodation and recreation facilities on site. In addition, a new 1980 m by 46 m airstrip large enough to land Hercules aircraft will be constructed adjacent to the junction of the MacTung access road and the North Canol Road. The total area required for the project will not exceed 228 ha.

At the site AMAX will mine the ore, mill it and produce a mixture of gravity and flotation concentrates of scheelite. Tungsten will be the only metal recovered in the proposed operation. The concentrates subsequently will be shipped by transport truck from the site to markets.

Almost all access to the site for goods, equipment and materials will be by road. The majority of personnel transportation, perishables and sensitive items will be flown in using appropriately sized aircraft.

Although a specific construction schedule has not been adopted as yet, AMAX anticipates approximately a 30 month schedule during the mid 1980's. (Some staged developments are anticipated prior to comprehensive development.) Initial plans are to mine underground, using the portal developed during bulk sampling, and principally blast hole stope mining methods, accompanied by a small amount of room and pillar at the extremities of the orebody. Primary crushing of the ore will also occur underground with crushed ore conveyed to the mill through a new access tunnel at a lower level which will surface about 225 m from the mill.

Processing of the ore will consist of a combination of separation on gravity tables and flotation cells. Two gravity and two flotation products will be produced with varying tungsten grades. About 23 t (25 tons) of concentrates will be produced each day.

Process, domestic and fire water will be obtained from Cirque Lake to the north of the mill site, and tailings and sewage will be disposed of in an area behind two earth-filled dams in the Dale Creek valley to the south. Diversion ditches on the upstream flanks of the disposal pond will be required to divert Dale Creek around the tailing pond and to minimize surface run-off water ingress into the pond from the adjacent mountain slopes.

1.6 PRINCIPAL ENVIRONMENTAL CONSEQUENCES

The principal environmental consequences of the MacTung project can be divided into two categories: primary or direct impacts, and secondary or indirect. The majority of the impacts resulting from project development will occur during the construction phase, although some will continue throughout operation and even beyond those dates. Surface disturbance largely will be concentrated around the mine site and will total approximately 228 ha.

Significant primary impacts include alteration of the surface water quality and hydrologic regime, and landscape modification. The surface water quality would be slightly degraded through sediment addition during the initial construction phase; chemical water quality changes will be experienced, notably when the tailing decant flow is introduced. These changes are expected in the watershed immediately downstream of the project and are not anticipated to seriously alter the overall water quality of the Tsichu River drainage. Modified hydrologic regimes in Cirque Lake, Cirque Creek and Dale Creek will result from water supply withdrawal and the creation of a tailing pond on Dale Creek with consequent diversion of flow. Tailing decant will ultimately enter the system as well. Changes such as these to the hydrology and water quality of the MacTung area will affect the aquatic resources, bringing about some alteration in habitat and benthic productivity, although it is not expected to be acute or chronic to fish in lower Dale Creek or the Tsichu River.

Landscape modification will have an impact on the surface topography and permafrost regime and cause some wildlife habitat loss or alteration although these effects are considered minor. Other primary environmental consequences of the project of less importance are increased noise, especially during construction, and minor air quality changes due to project operation.

Secondary impacts, mainly those relating to increased human presence and use of the area, have the potential of affecting the environment. These could include increased pressure on fisheries and the wildlife resource through fishing and hunting , displacement of wildlife, and greater possibility for human - bear contact. Pressure for improvement of recreational facilities may also be felt. Secondary impacts such as these may occur during the operation phase and beyond although they are not anticipated to significantly alter the environment of the area.

1.7 ENHANCEMENT AND MITIGATION

A number of measures are being designed into the project to abate, reduce, avoid and mitigate potential adverse effects on the physical and biological environments. Potential air emissions will be reduced by the installation of control equipment. Impacts on terrain and vegetation will be minimized through appropriate engineering, planning and design to reduce areal disturbance and erosion.

Impacts to the hydrologic regime and aquatic system will be minimized through adequate design of ditches and berms, maximum control of erosion and sedimentation during construction and revegetation of exposed soil surfaces which contribute sediment. Project impacts on wildlife can be minimized through controls on firearms and management programs and proper waste management. Overall, reclamation planning will serve to minimize impacts by reclaiming disturbances as soon as possible, both during the life of the mine and at abandonment.

1.8 RESIDUAL IMPACTS

Residual impacts (i.e. those evident 100 years following project completion) will be visual modifications in land form as a result of construction of roads and other mine facilities. The tailing pond will remain as a landscape feature in the form of a waterbody, marsh or moist meadow; it has the potential to cause siltation if tailing dams fail, and thereby affect water quality and aquatics. Although hydrology would be altered at the project site, effects would largely be attenuated below the Tsichu River. A residual impact on aquatics would be habitat alteration and potential loss of the area to be affected by tailing deposition. Vegetation communities would likely experience a slight change in species composition due to altered environment; likewise, avian species may shift slightly in composition and diversity. The secondary impacts of the project may lead to residual effects in that people may continue to frequent the area for recreational purposes, thereby initiating environmental changes.

1.9 STATUS OF KNOWLEDGE

Meteorological studies at MacTung date back to 1968. Studies on other aspects of the physical, biological and cultural environment have been conducted for the MacTung project since 1973. Studies have been conducted on climate, air quality, geomorphology, soils, surface water, groundwater, aquatic ecology, vegetation, large and small mammals, avifauna, heritage resources and socio-economics. The overall objectives of the studies have been to identify critical or important habitat and to provide a sound environmental base of knowledge to be taken into consideration along with other variables during detailed mine design.

The results of the various studies exist in the form of 87 reports and file documents, 48 of which are environmental reports, 6 of which are socio-economic reports, while the remaining 33 reports pertain mainly to engineering and metallurgical aspects of the project. Most recently, i.e. 1981 on, additional studies were performed on all aspects of the physical, biological and cultural environments listed above and significant effort has been expended to compile pre-existing information with results of the recent studies into comprehensive reports. Information in these reports provides the basis for most of the information summarized in this document. The reports are entitled:

MacTung Meteorology and Air Quality Analysis and Assessment,
Geomorphology and Vegetation of the MacTung Study Area, Yukon/N.W.T.,
Aquatic Ecology of the MacTung Area,
1981-82 MacTung Wildlife Studies, Yukon/N.W.T.,
Avifauna of the MacTung Project Area,
Socio-Economic Overview Study - MacTung Project.

Each of the reports contain the specific details of the various studies and is considered to be an integral element of this Initial Environmental Evaluation. Brief summaries of the contents and results of the studies are included herein. These summaries are intended to provide enough information to satisfy the needs of most individuals, organizations and agencies. However, for those who desire more detail, sets of the complete reports will be placed at various central locations for public review.

AMAX feels that the overall quality and quantity of much of the information developed for the MacTung project may go beyond what would normally be required for a project of this scope.

2.0 PROJECT RATIONALE

CHAPTER TWO

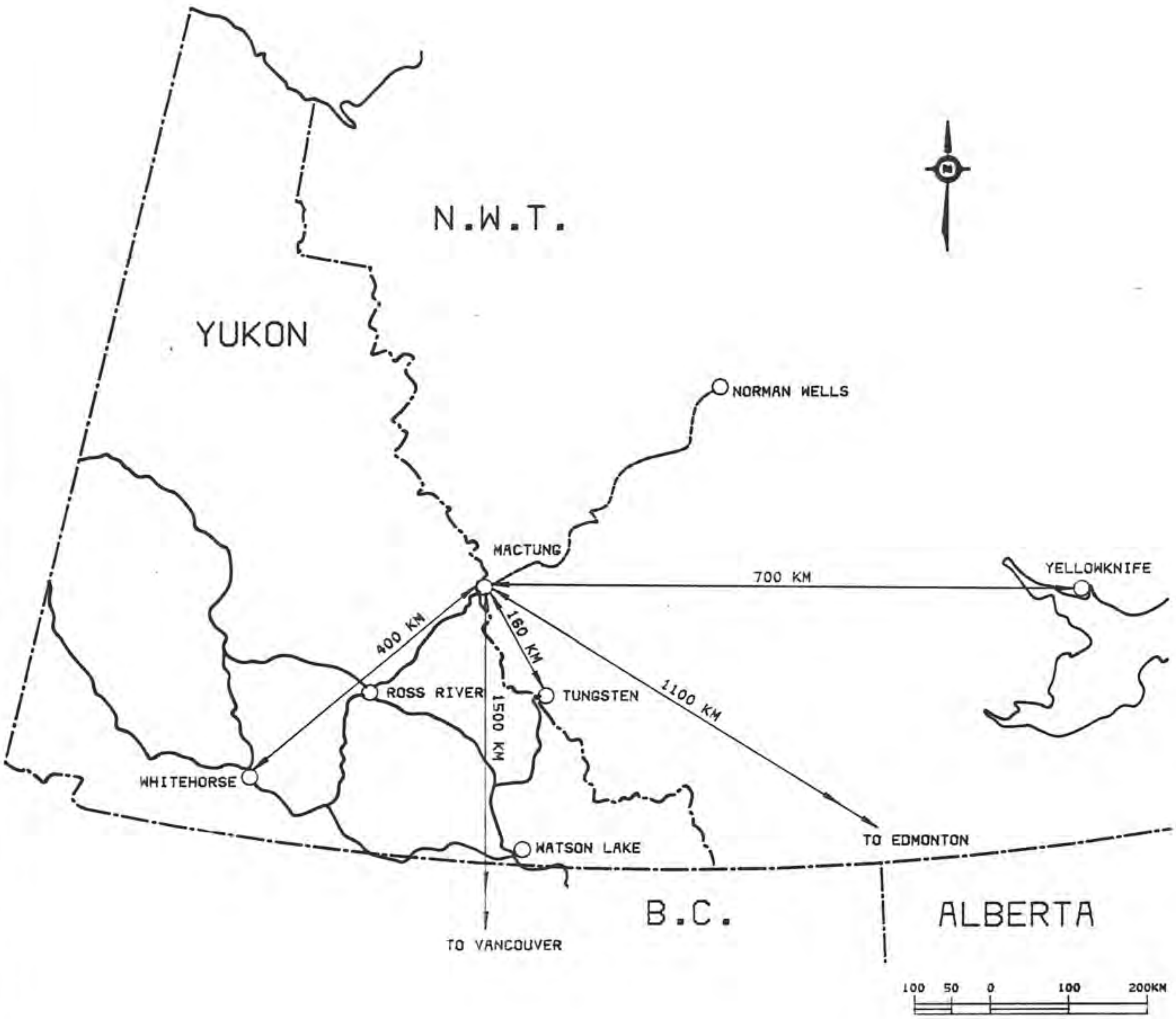
PROJECT RATIONALE

2.1 DECLARATION

The initiator of this Initial Environmental Evaluation (IEE) and the proponent of a mine, mill complex and associated facilities at MacTung is AMAX Northwest Mining Company Limited. This company is a wholly - owned subsidiary of AMAX Inc., which, in turn, is a 65% owner of Canada Tungsten Mining Corporation. The latter company operates the Cantung mine at Tungsten, Northwest Territories and produces tungsten concentrate at that location.

This IEE is a consideration of the potential environmental impacts and means for enhancement and mitigation of such impacts, resulting from the development of a tungsten mine, plant complex and support facilities at AMAX Northwest Mining Company's MacTung property near Macmillan Pass, Yukon and Northwest Territories (Figure 2-1). The plant complex includes maintenance facilities, warehouse space, engineering, geology and production offices, and a process plant for producing tungsten concentrates. The support facilities include a residential complex which houses a cookery, recreational facility and bunk-houses as well as a small, separate apartment-type complex. In addition to these facilities there will be constructed a gravel airstrip, fully equipped with modern navigational aids, and capable of accommodating Hercules aircraft; raw water supply works; and tailing and sewage disposal structures.

The IEE also provides a summary of the social and economic aspects of the project and describes a public communications program through which benefits accruing to northerners from the project will be discussed with residents of individual communities. The program is also designed to take into account any concerns that residents might have and to provide a basis for negotiation.



LOCATION OF
MACTUNG PROJECT

FIGURE 2-1

2.1.1 INTENT

This IEE has two purposes. First, it summarizes the findings of the large amount of environmental data that has been developed in the geographical area wherein the proposed project lies. Second, the IEE constitutes a working document to initiate constructive discussions with government and regulatory agencies to determine and to define:

a) specific areas of concern that the regulatory agencies might have regarding project effects;

b) short-term programs to be undertaken in parallel with construction and start-up plans for the project; and

c) long-term programs aimed at evaluation and resolution of long-term concerns, as for example, effluent quality.

2.1.2 BACKGROUND

The MacTung property near Macmillan Pass was discovered in 1962 by J. Allan, an AMAX geologist. In the late 1960's and early 1970's AMAX undertook an extensive drilling and surface sampling program, and in 1973 drove an adit into the orebody for purposes of bulk sampling. Some 140 holes were drilled for an accumulated length of over 16,000 m. The results indicated the presence of tungsten in a scheelite ore and in quantities and concentrations which were commercially viable.

Present mineable ore reserves are estimated at about 25 million t (27.5 million tons), with approximately two-thirds of that quantity as a lower grade material in an upper ore zone and one-third as a higher grade lower ore zone. Conventional open-pit methods of mining appear most logical for the upper ore zone while the development of the lower zone appears amenable to underground bulk mining methods. The results of the exploration work further indicated the potential for very much more ore than outlined by drilling, both to the south and to the west of the defined ore body.

In 1976 AMAX began to prepare plans to develop a commercial facility, and to that end initiated engineering feasibility studies, site test work and environmental licencing applications. Unfortunately, market conditions in 1978 and 1979 were such that the large forecast cost of the project could not be justified, and AMAX withdrew from an active development plan.

AMAX has undertaken a Conceptual Engineering phase of planning aimed at consolidating all technical and environmental information in an effort to be prepared for commercial development of MacTung as soon as economic and market conditions allow. This phase is scheduled for completion in 1983, and will include initial socio-economic discussions as well as application for Land Leases and a Water Licence.

2.1.3 STATEMENT ON PROJECT LIMITS

AMAX proposes to develop the MacTung orebody to the extent delineated by current drilling and as dictated by economic constraints. At present conditions appear to favour development of about 8 million t (9 million tons) of ore in the lower ore zone by underground mining methods, with ore grading about 1.1% WO_3 on average and producing approximately 100,000 t (110,000 tons) of WO_3 in the form of concentrates. With a mill design of 900 t (1000 tons/day) feed this amounts to approximately a 25 year mine life, without mining the upper ore zone. The areal requirements of the project are set out in Table 2-1.

AMAX also intends to evaluate the prospect of extending both to the west and south of the currently defined orebody in anticipation of being able to develop the ore reserves further. The discovery of additional reserves that are suitable in quantity and quality may result in extending

TABLE 2-1

MAXIMUM AREAL REQUIREMENTS OF MACTUNG

Facility	Estimated Area (ha)
1. Plant and Residence Complexes	
a) facilities	25
b) peripheral disturbance	10
2. Source of Mine Backfill	20
3. Tailing	
a) deposition area	70
b) diversion canals, maintenance roads, borrow, etc.	20
4. Access Roads (mean width, 24 m)	
a) mine site road (11.3 km)	27
b) Cirque Lake road (3.6 km)	9
c) Airstrip road (0.8 km)	2
d) borrow areas	10
5. Airstrip and Associated Facilities (excluding access road)	15
6. Miscellaneous Installations	
a) includes pipeline from Cirque Lake, pump stations, etc.	20
Maximum areal disturbance	228

the life of the mine. This extension might result in the possibility of further underground mining or open-pit operations, but not during the present mining plan period of 25 years.

2.2 THE NEED

Based on the AMAX experience in the tungsten business, it is predicted that tungsten supply/demand in the latter half of the decade will allow the MacTung project to enter the tungsten market. As an operating mine MacTung will contribute additional jobs to the north, as well as the various indirect economic benefits to the north specifically and to Canada as whole.

The intent of AMAX to maximize Canadian content in the development and operation of the MacTung project will result in over 90% of the initial capital costs being spent in Canada. Essentially all of the projected $29 million annual operating costs will be spent in Canada.

The Governments of Yukon and the Northwest Territories have expressed an interest in the development of suitable mining projects of this nature which could provide significant economic benefits to the territories through employment opportunities and the development of new skills for northerners.

2.3 ALTERNATIVES

Basically there are four alternative courses of action through which AMAX could respond to the anticipated growth in world market demand for tungsten:

a) Do nothing. The consequences of such an action include the loss of 174 permanent jobs, loss of revenue to government and the loss of profit potential to AMAX.

b) Develop alternative sources of tungsten ore. AMAX has other Canadian tungsten properties, but none of these are as attractive as MacTung.

c) Mine ore at MacTung and truck to Tungsten for processing. This is a possibility, but the distances travelled, lack of a direct route and high costs of transportation represent an impractical alternative to AMAX.

d) Build MacTung as proposed in this IEE.

Given the AMAX experience and knowledge of operations north of 60°, combined with favourable economic conditions, the MacTung project is obviously potentially advantageous both for AMAX and its employees, as well as Yukon, the Northwest Territories and Canada.

2.4 ASSOCIATED ACTIVITIES

There are several potential and a small number of ongoing land use activities in the Macmillan Pass "region" which potentially may interact with the MacTung project. Three main types of project can be identified: new mines; hydroelectric generating facilities; and highway improvements. The majority of these projects are in a much more preliminary state than MacTung, but nevertheless the potential does exist for interaction at some future point between MacTung and these other activities in matters such as transportation (road improvement, aircraft sharing, ore and concentrate hauling, etc.), accommodation of work forces, power generation, and in other ways. Information on these various undertakings is summarized on Figure 2-2. Recent up-to-date information on these projects is available in a number of reports.

2.4.1 MINING PROJECTS

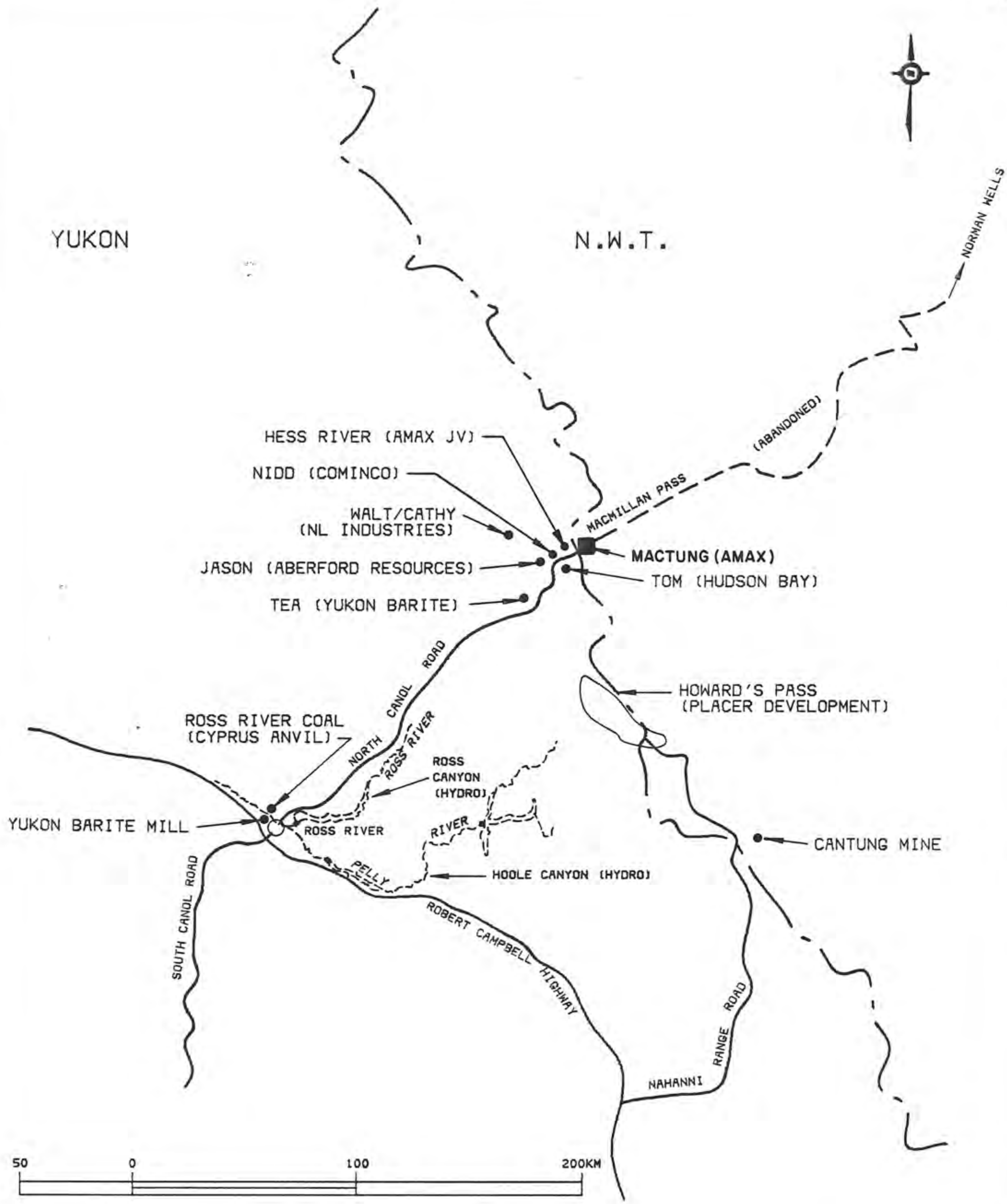
Known potential mineral development projects include metal mines (involving extraction of lead, zinc and tungsten) and non-metal mines which focus on barite and coal production. Metal mine development prospects are concentrated in the Macmillan Pass - Howard's Pass area of the Selwyn Mountains. With respect to the barite properties, one is located in the vicinity of Macmillan Pass; the other is located 200 km northeast of Ross River. And as to coal properties the potential of a small, surface coal mine near Ross River has been investigated (Figure 2-2).

2.4.2 HYDROELECTRIC PROJECTS

Reports have been completed in recent years for Northern Canada Power Commission on several potential hydroelectric generating sites in Yukon. Two of these sites are in the vicinity of Ross River - Hoole Canyon and Ross Canyon (Figure 2-2). These sites and the others have been investigated to determine the relative ranking of a range of alternative power sites in terms of delivered power costs and environmental impact.

2.4.3 TRANSPORTATION PROJECTS

Several studies have been commissioned by the Department of Indian and Northern Development Affairs Canada to determine appropriate levels of upgrading for the North Canol Road. These studies have been concerned, in part, with projecting future traffic volumes and the costs (capital and maintenance) of a range of road improvement alternatives. For even modest mineral development northeast of Ross River, some minimal upgrading would be required to correct road alignment and grade problems and improve road safety. For example, problems of poor visibility, steep grades and slippery road conditions during wet weather were encountered by truckers hauling barite ore during the autumn of 1982.



POTENTIAL DEVELOPMENT ACTIVITIES IN MACMILLAN PASS REGION

FIGURE 2-2

One upgrading alternative would involve minimal road improvements, with the focus on those sections where design deficiencies are greatest. With minimal upgrading, it is likely that modest traffic volumes generated by Yukon Barite and Mactung could be adequately accommodated. Development of one or more lead-zinc mines would probably require that major improvements be made to the North Canol Road. Upgrading to a DCU 80 standard (development collector undivided designed to an 80 km/hr standard), by transportation engineers has been recommended (together with a two-lane bridge crossing of the Pelly River to replace the existing cable ferry).

Current plans are to phase road reconstruction over a number of years. Highest priority has been assigned to the section from Km 225 to Km 281 in the vicinity of Gravel Creek.[1] Design of this section is nearing completion, and the expectation is that right-of-way clearing will be undertaken during the 1983-84 fiscal year and actual grade construction the year after. Wherever possible, reconstruction would be to the DCU 80 standard. An IEE also has been prepared for the North Canol Road by the Department of Indian Affairs and Northern Development.

(1) Kilometre posts are measured from the junction of the South Canol Road and Alaska Highway. Ross River is located at Km 230.

3.0 PROJECT DESCRIPTION

CHAPTER THREE

PROJECT DESCRIPTION

3.1 INTRODUCTION

The purpose of this section is to provide an account of the geographical setting in which the project will lie; and to describe the components of the project and the context in which each of these components (e.g., the mine and mine development plan) will be developed.

3.2 GEOGRAPHICAL SETTING

The MacTung property is located at 63°17' latitude and 130°9' longitude, within about 10 km of Macmillan Pass. The Arctic Circle is about 375 km to the north, and the City of Whitehorse about 400 km by air to the southwest. The North Canol Road, which was built in 1942 by the U.S. Army Corps of Engineers to pipe oil from Norman Wells to Whitehorse, passes within 10 km to the south of the project site (Figure 2-2). The overall project will occupy areas of the Dale Creek valley for tailing disposal and road access as well as the Cirque valley for raw water supply and road access. An air strip will occupy land adjacent to the North Canol Road and its junction with the mine access road. All areas are on mineral leases or claims held by AMAX Northwest Mining Company Limited. The planned layout of the mine and facilities is illustrated in Figure 3-1.

3.3 HISTORY OF THE PROJECT

The MacTung scheelite deposit was discovered in 1962 by J. Allan, an AMAX geologist. Exploration programs have been carried out on a continuing basis since 1962, with the major bulk sampling and process testwork being conducted in 1973. An initial pre-feasibility study was

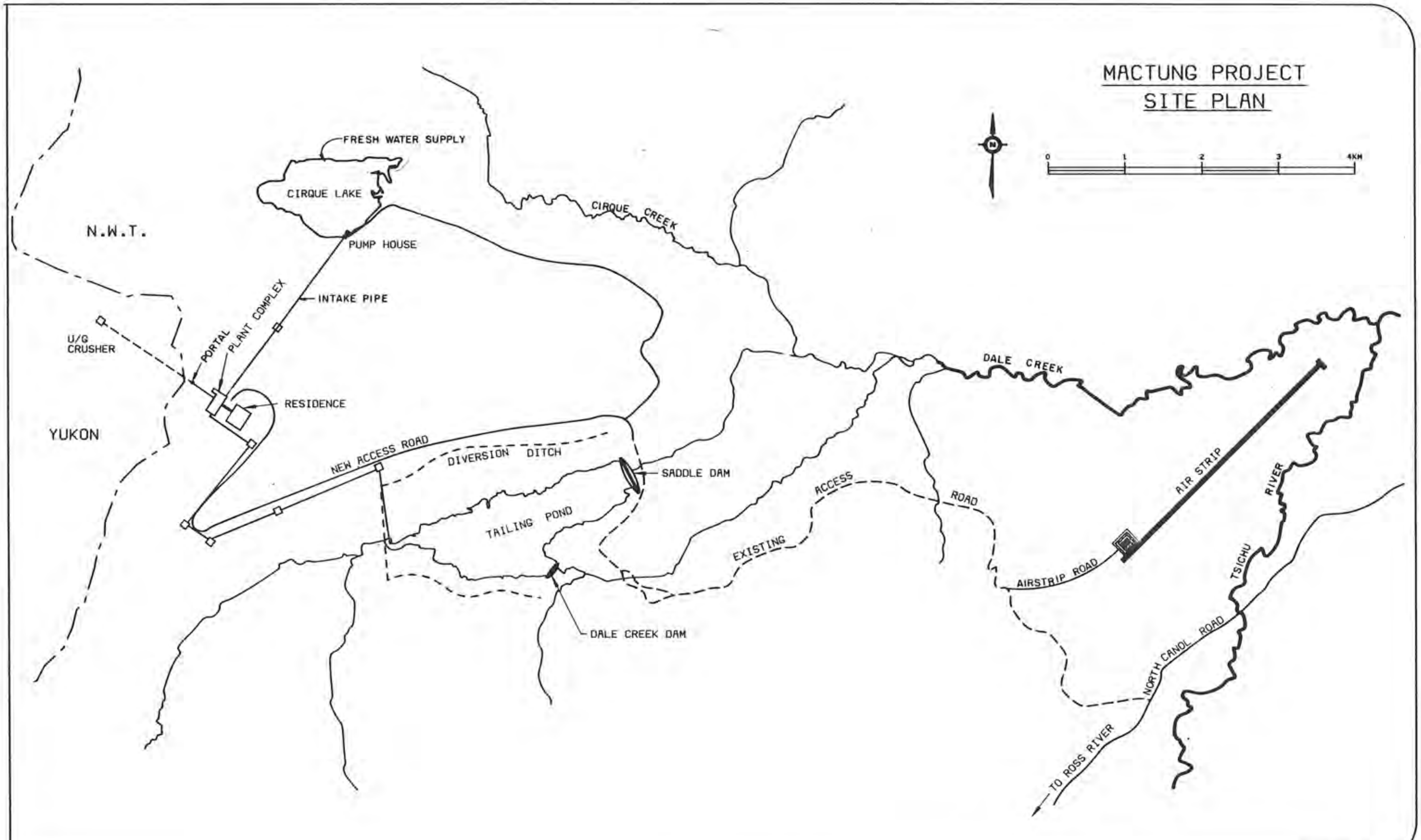

MACTUNG PROJECT
SITE PLAN
0
1
2
3
4KM
FRESH WATER SUPPLY
CIRQUE LAKE
CIRQUE CREEK
N.W.T.
PUMP HOUSE
PLANT COMPLEX
INTAKE PIPE
U/G CRUSHER
PORTAL
RESIDENCE
YUKON
NEW ACCESS ROAD
DIVERSION DITCH
SADDLE DAM
TAILING POND
DALE CREEK
EXISTING ACCESS ROAD
AIR STRIP
AIRSTRIP ROAD
RIVER
TSICHU
NORTH CANOL ROAD
TO ROSS RIVER
DALE CREEK DAM

FIGURE 3-1

performed by AMAX in 1974 with extensive environmental work in, 1974, 1975 and 1976. Work actually progressed to the stage of a Water Board Hearing and drafting of a Water Licence in 1979 before business factors dictated withdrawal of the Company's application.

3.3.1 LAND USE AND LAND TENURE

3.3.1.1 Land Use

Traditionally human occupancy of the Macmillan Pass area has been sparse and ephemeral. This condition is reflected today in the small number of land use activities that may be attributed to the area. These uses include some seasonal movements on the North Canol Road associated primarily with renewable and non-renewable resource exploitation and exploration respectively. Hunting and trapping reflect the former uses and working of mineral claims the latter. A small number of vehicles use the road for tourism and for research programs. There are outfitters cabins, and a seasonally operated naturalist's lodge. The lodge, open only during the summer months, lies about 31 km to the east of the minesite. The sole road access to the area is North Canol Road, which is maintained by the Yukon Department of Public Works during the summer months only, and only as far as the Yukon - Northwest Territories border. Travel from that point eastward is precarious even in 4-wheel drive vehicles.

Some 17 km east of the project site lie the remains of Camp 222 used during construction of the North Canol Road; (it is 222 miles from Norman Wells). Only a single dilapidated structure remains of the camp, this having been modified and occupied by a series of individuals and organizations, including AMAX from 1974 to 1982. Upon abandonment by AMAX, the company cleaned up the site and perserved the structure.

A very primitive airstrip, Tsichu River airstrip, also exists at Mile 222. It is constructed of local shale and measures about 10 m by

600 m. It is suitable only for very small, light aircraft and helicopters and requires frequent maintenance.

The capability of the land to support land uses centres on mineral developments, hunting and trapping, tourism, outdoor recreation and transportation. There is no potential for agriculture or forestry due to constraints imposed by climate, soils and terrain.

Limited trapping and hunting are taking place near the North Canol Road. More precise information on native activities will be determined upon completion of the ongoing traditional land use study being conducted by the Ross River Indian Band. However, some information can be provided on renewable resource harvesting by non-resident hunters. The project area is included in Yukon Guiding Area No.9. This is a large management area (about 20,000 km^2) and stretches from Ross River/Faro to Macmillan Pass (Figure 3-2). Recent harvest from this Guiding Area are shown in Table 3-1. The project area is located in the Northwest Territories Outfitter Zone E1 which is made up of eight distinct districts. Areas E/1-1 and E/1-2 may be within the sphere of influences of the project area. Table 3-2 shows recent game harvests from Zone E1; unfortunately, date are aggregated for the entire zone and are not broken down by individual areas within Zone E1.

Three outfitters presently operate in the project area. A Ross River resident works the Yukon side, and in the Northwest Territories Zone E1 is worked by a Norman Wells resident and Zone E2 is worked by a resident of Gleichen, Alberta. Trapping on the Yukon side of the border is carried out on Trapline 112 by a Ross River resident.

3.3.1.2 Land Tenure

Approximately 206 mineral claims and leases, 97 in Yukon and 109 in the Northwest Territories cover the mine site, proposed plant site, tailing disposal pond, water source areas and access roads.

TABLE 3-1

RECENT GAME HARVESTS FROM YUKON GUIDING AREA NO. 9[1] AND YUKON

NON-RESIDENT HUNTERS

Species	Area 9			Yukon		
	1978	1979	1980	1978	1979	1980
Moose	14	14	17	936	1,107	1,009
Caribou	15	12	17	341	581	395
Sheep	10	10	7	324	286	242
Grizzly	3	5	6	90	84	67
Black Bear	2	0	0	60	36	78
Goat	0	0	0	17	18	13
Wolverine	0	1	1		N/A	
Wolf	6	3	7		N/A	

NOTE:

1 Does not include harvests by trappers or Status Indians

TABLE 3-2

RECENT GAME HARVESTS FROM MACKENZIE MOUNTAINS,
NORTHWEST TERRITORIES

NON-RESIDENT HUNTERS

Species	Mackenzie Mountains				
	1975	1976	1977	1978	1979[1]
Moose	23	36	19	32	37
Caribou	60	97	97	90	106
Sheep	129	144	136	167	172
Grizzly	22	12	28	36	25
Black Bear	3	0	1	1	1
Goat	10	0	4	2	3
Wolverine	0	0	0	0	0
Wolf	8	11	19	15	10
No. of Hunters	147	187	205	238	223

NOTE:

[1] Missing data from one zone

Source: GNWT, Renewable Resources, 1982

FIG.3-2 GUIDING AREAS, YUKON AND NORTHWEST TERRITORIES

3.4 DEVELOPMENT CONCEPT

3.4.1 OVERALL SCHEDULE

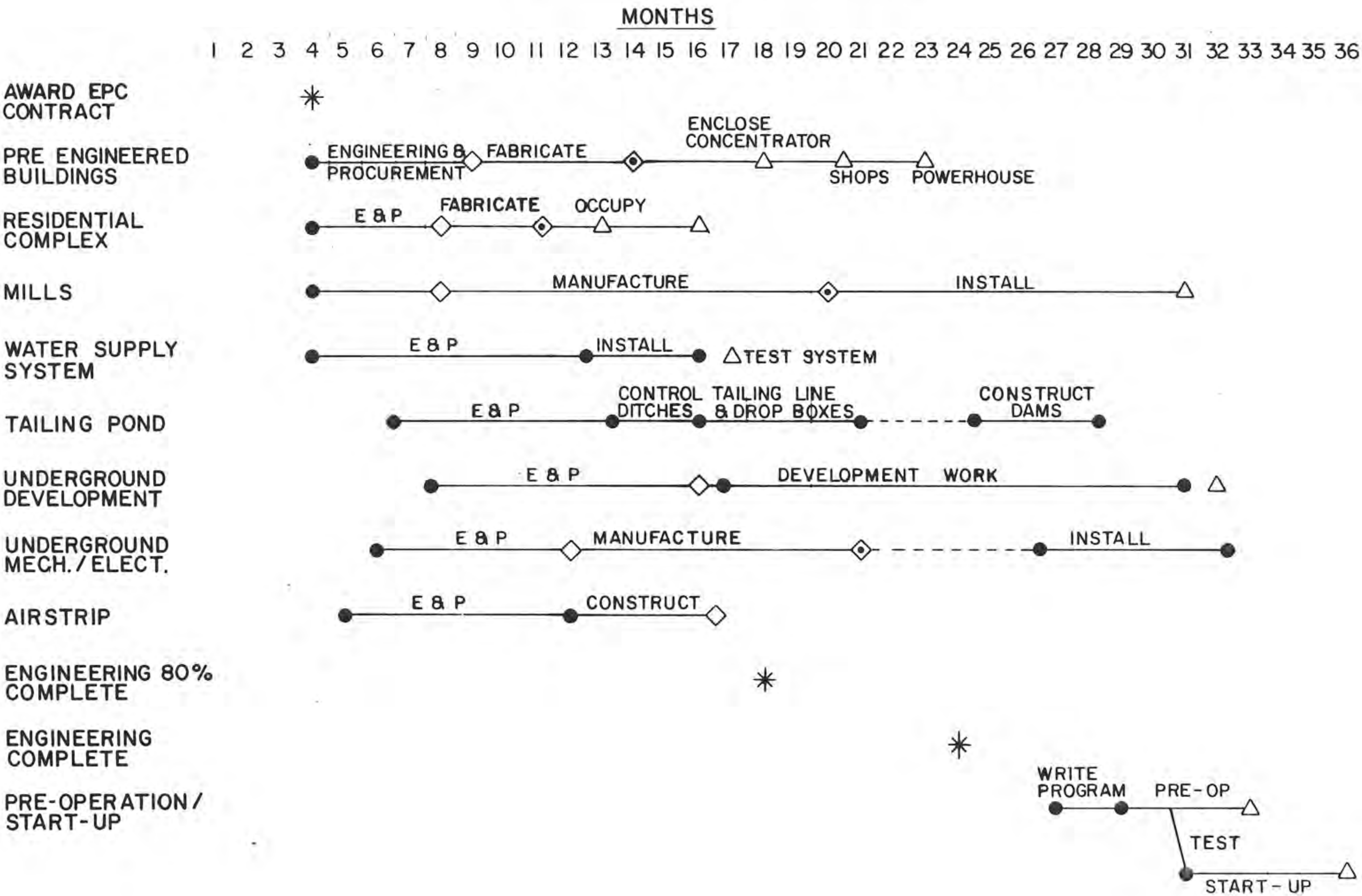
Although a specific construction schedule for staged development has not been adopted yet, AMAX has developed a detailed engineering and construction plan for the 900 t (1000 tons) per day facility which embraces a 30 month period, beginning in the summer of the first year and completing late in year three (Figure 3-3). Commissioning and start-up of the facilities would occur early in the fourth year. Most of the first year's program would consist of civil works for the plant complex, tailing dams, airstrip and access road. Construction is expected to peak 12 months after starting.

The overall production schedule includes 8 million t (9 million tons) of ore mined and processed at a rate of 317,500 t (350,000 tons) year. This creates a project life in excess of 25 years, but the mine life easily could be extended if the indicated ore reserves prove to be commercially viable.

The proposed tailing pond has been designed to accommodate nearly 40 years of tailing solids, with dam construction from the solids extending that life if necessary. It is expected that some time after plant start-up effluent can be discharged from the pond into Dale Creek without significant environmental damage.

Raw water will be supplied from Cirque Lake which has the capability to supply over two years of water without recharge by the runoff from the surrounding mountain slopes. The proposed plant layout is shown in Figure 3-4. The total area involved is about 228 ha (Table 2-1). The annual recharge of Cirque Lake is estimated to be 2 million m^3.

SUMMARY SCHEDULE FIG 3-3



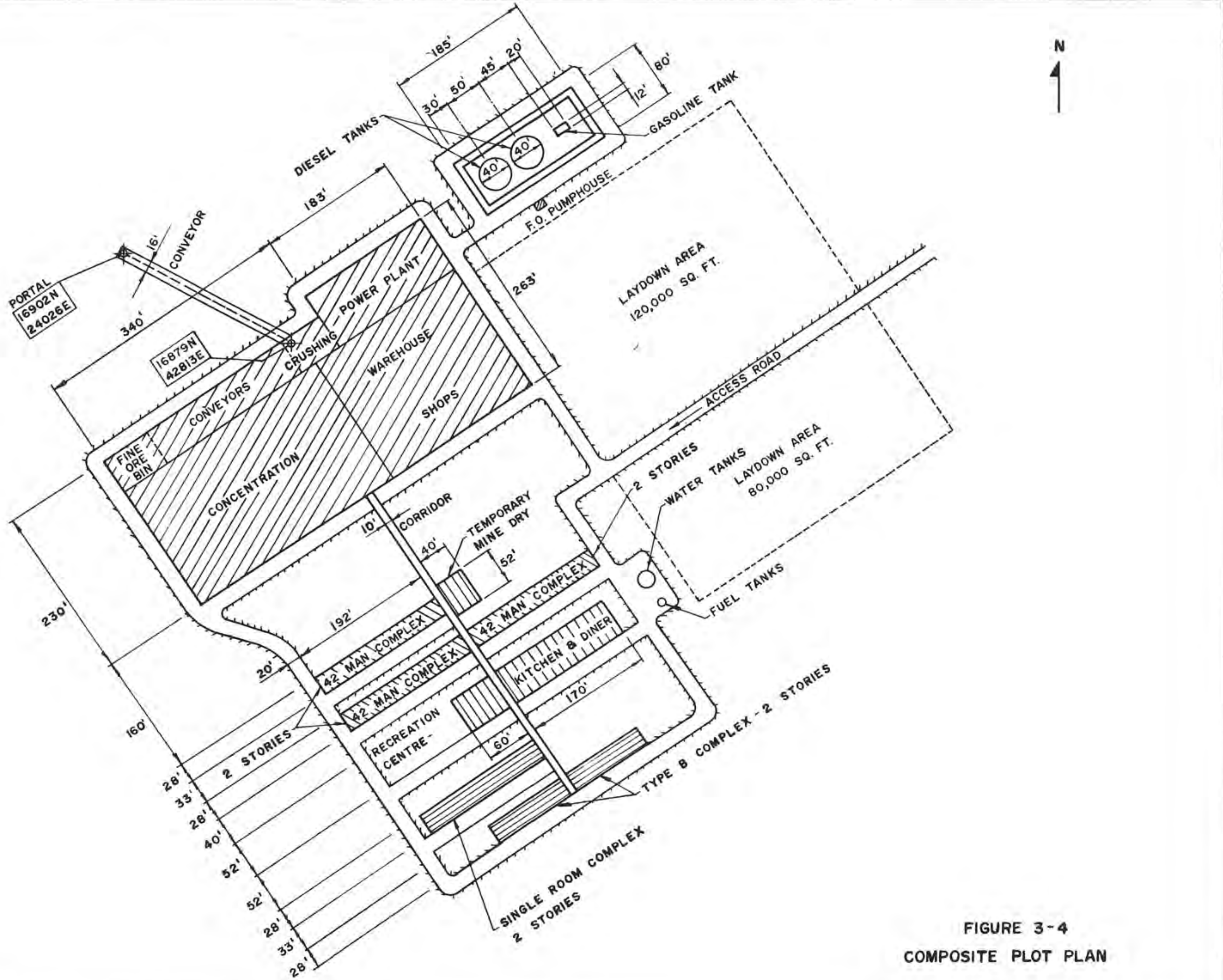


FIGURE 3-4
COMPOSITE PLOT PLAN

3.4.2 TRAVEL IN/TRAVEL OUT CONCEPT

During construction of MacTung, it is expected that workers will alternate time at the site with rest periods at their permanent residences. The same concept is intended for the operating facility with work crews on a rotational basis between home and single-status camp accommodation. Although the time period for these rotations has yet to be established, and will in large part depend on the labour market, it is expected the cycle will be relatively short, (e.g., 4 days on site, 4 days off the site), with transportation to and from the site by aircraft. A waiver will be required in respect of the normal eight-hour working day arrangement.

The construction phase is expected to produce a manpower peak in the order of 335 while operations will employ about 174. Hence, after construction the construction camp will be upgraded for permanent use by operations personnel. Furthermore, it is expected that AMAX will establish Whitehorse as the base for its MacTung operation, and thus the point-of-hire for most workers. This will produce the maximum benefit to workers, company and local government.

3.5 THE OREBODY

3.5.1 GEOLOGY AND ORE RESERVES

The MacTung tungsten deposit is within the Selwyn Tungsten Belt, a geologic province containing numerous skarn scheelite occurrences, the most significant of which are Cantung and MacTung.

At MacTung tungsten mineralization replaces carbonate units within a thick sequence of Lower Paleozoic limestones and shales that outcrop at Mt. Allan (elevation 2345 m). Alteration has produced skarns and hornfels in the carbonates and shales respectively. Two ore zones are recognized (Figure 3-5).

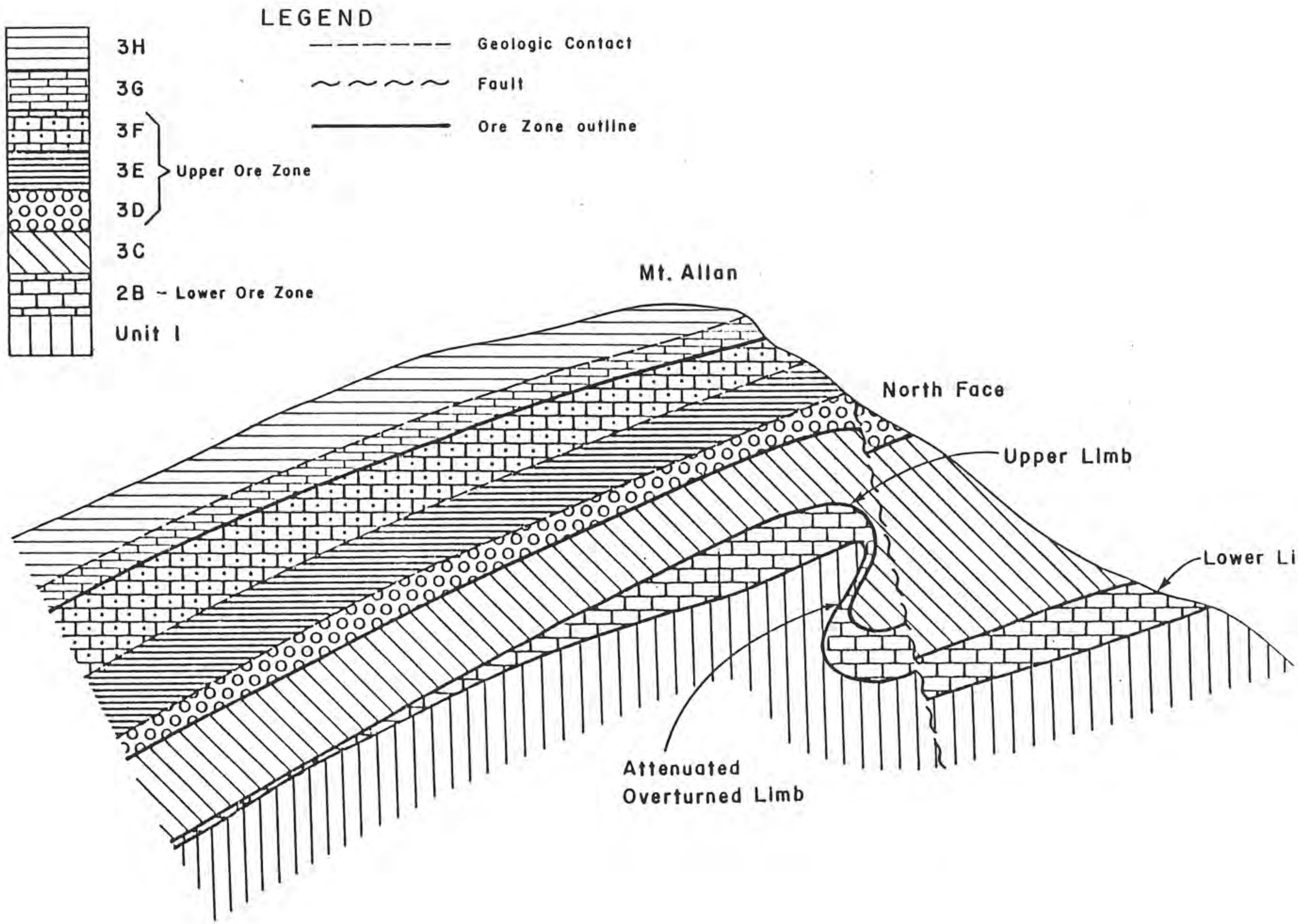


Figure 3-5 Generalized Cross Section looking west to show the geometry of the upper and lower ore zones.

a) The Lower Ore Zone is within Unit 2 rocks and ranges from 0 to 35 m in thickness. Unit 2 consists of skarned limestone breccia, limestone and calcareous shale and hornfelsed siltstone containing lenses of skarned limestone, marble and limestone. Unit 2 rocks outcrop on the north face of Mt. Allan between 1830 and 1900 m elevation.

b) The Upper Ore Zone is within Units 3D, 3E and 3F. 3D is 10 to 30 m thick and consists of breccia or conglomerate containing phosphatic, carbonate and shaly fragments in a skarned lime-rich matrix and hornfelsed argillaceous shale and siltstone. 3E and 3F are interbedded skarned limestone and hornfelsed shale and vary from a combined thickness of 70 to 120 m. Each of these three units contains a tungsten mineralized skarn horizon. 3D, 3E and 3F outcrop on the north face of Mt. Allan between 1980 and 2100 m.

The Upper and Lower Ore Zones are separated by Unit 3C consisting of 60 to 1500 m barren hornfelsed shale. The ore zones are underlain by Unit 1, consisting of Proterozoic schists and phyllite and overlain by an apparently conformable alternating sequence of limestone and shales, called Units 3G, 3H, 4 and 5. Some of these units may contain skarn and hornfelsic horizons.

3.5.1.1 The Lower Orebody

Within Unit 2 measured reserves, the 2B rock unit has been completely altered to skarn and is mineralized throughout, from the foot-wall phyllite and schist (Unit 1) to the hanging wall hornfelsed shale (Unit 3C). The 2B unit is cut off to the east by steep faults and pinches out to the south; it is open to the west, where it has been found in widely spaced drill holes.

The 2B unit is folded in an S-shape. For extraction purposes, tungsten mineralization within this S-fold is treated as three separate bodies:

i) The upper limb, as defined by drilling is a roughly tabular body 600 m long east-west, 150 m wide north-south, with an average thickness of 20 m. The body is conformable to the enclosing strata, and dips at about 20 degrees to the south, with local dips of up to 50 degrees.

ii) The Lower or North limb is located about 40 m below and parallel to, the upper limb. This body is 275 m long east-west, 75 m wide north-south, with an average thickness of 23 m. The lower or north limb outcrops on the north face of Mt. Allan.

iii) The Central body is a thin zone of mineralized skarn connecting the limbs of the S-fold.

3.5.1.2 The Upper Orebody

Tungsten bearing skarn horizons within the Upper Ore Zone consist of Unit 3D and limestone-rich sections of 3E and 3F separated by barren hornfels. The beds are gently south dipping and offset by northeast trending faults. Widely spaced drill intersections have located the Upper Orebody over an area of 300 by 300 m and are open to the west at depths in excess of 300 m.

The 2B unit South limb and Units 3D, 3E and 3F are generally within permafrost. The average underground temperature of the rock in the 1900 m adit is about -2°C.

With the exception of a single drill hole, the intrusive quartz monzonite stock, believed to be the source of the tungsten mineralization, has not been intercepted in drilling or in the underground development. Aplitic dykes, however, have been encountered in deeper holes. The major exposure of quartz monzonite at MacTung is the Cirque Lake Stock, about 300 m north of the deposit. This stock has been noted on surface exposures to contain very minor tungsten mineralization. It is age-dated at 89 million years, which is essentially the same age as the source stock at Cantung.

Ore reserves for the lower ore zone have been calculated as follows:

- the minimum cutoff grade is 0.4% WO_3 over a minimum width of 4.5 m.
- dilution during mining is calculated on a stope by stope basis, but averages between 10 and 15%.
- the deposit is estimated to be about 80% recoverable.

In place and mineable reserves for the MacTung deposit are presented in Table 3-3.

3.5.2 MINERALOGY

The MacTung tungsten deposit is of the contact metamorphic-metasomatic type, located in skarn zones that developed in the specific limestone horizons in rock units 2B, 3D, 3E and 3F, near the contact with an intrusive quartz monzonite stock.

TABLE 3-3

IN PLACE AND MINEABLE RESERVES

In Place Reserves

Lower Ore Zone	tonnes	% WO_3
Measured	2,377,000	1.34
Indicated	3,387,000	1.39
Inferred	4,172,000	0.91
Sub-total	9,936,000	1.18
Upper Ore Zone		
Sub-total	22,055,700	0.80
TOTAL	31,991,700	0.92

Mineable Reserves

	tonnes	% WO_3
Lower Ore Zone	8,118,100	1.10
Upper Ore Zone	17,233,600	0.78
TOTAL	25,351,700	0.88

A complete mineralogical analysis of a composited 1895 m elevation adit ore sample from the 2B zone south limb was determined using microscopic techniques and x-ray diffraction analysis. Mineral constituents of the sample include the non-sulphide gangue minerals pyroxene (diopside-hedenbergite), amphibole (tremolite-actinolite), quartz, plagioclase, mica (muscovitebiotite), chlorite, garnet (grossular-andradite), calcite, apatite and collophane. Sulphide gangue minerals included pyrrhotite, pyrite and chalcopyrite. The tungsten mineral is scheelite ($CaWO_4$) with minor amounts of ferberite ($FeWO_4$) as an accessory mineral.

The calculated head analysis of this composite consists of non-sulphide gangue minerals (81.8% by weight); sulphide gangue minerals pyrrhotite (12.6% by weight), pyrite (3.3% by weight) and chalcopyrite (0.6% by weight); and scheelite (1.7% by weight).

As determined by microscopic examination of drill core, the Upper Ore Zone skarns consist of pyroxenes and lesser amounts of quartz, felspar, garnet, epidote and calcite. Some of the skarns contain up to 80% collophane (phosphonite) which has been recrystallized as apatite. Scheelite is the principal mineral of economic interest. Sulphide minerals include pyrrhotite and chalcopyrite with minor pyrite.

No detailed examination of 3C and other waste rock units has been undertaken. Thin section examination of the barren hornfelsed shale units including 3C, indicate they consist of fine grained quartz with dispersed pyroxene and occasionally garnet, chlorite and andalusite.

As in other tungsten deposits of this type, copper mineralization as chalcopyrite is present in minor amounts. The average grade of the underground bulk sampling program was 0.24% copper (with 1.66% WO_3).

3.6 THE MINE

3.6.1.1 Mine Development Prior to Production

It is planned to develop the mine for production largely by blasthole, open stope methods augmented with some room and pillar. Prior to the start of production, it is planned to develop two or three blasthole stopes and portions of the room and pillar stopes in the east end of the upper limb of the lower ore zone.

The mine development prior to production will be undertaken from the existing adit and from a new portal at a lower level. Development will be mostly in waste rock for drill drifts and haulage drifts as well as underground primary crushing facilities and a conveyor for ore transport to surface via the lower portal. This development will commence as soon as mining crews can be accommodated on site, and will proceed as rapidly as possible to ensure the availability of stopes for production by the time the mill is ready to accept feed. Some 75,000 t of ore are expected to be produced during this phase, and will be stockpiled on the surface for initial plant feed during start-up of the mill. Primary crushing will be done with a mobile surface crusher during this period.

3.6.1.2 Ongoing Development

During the preparation of stopes during pre-production, most of the major waste development will be completed. However, ongoing development will be required to prepare up to 20 more stopes as mining progresses. On the average, approximately two stopes per year will be mined out, requiring development of two new stopes each year as well. Hence, the ongoing development is neither extensive nor rapid.

To permit maximum recovery of ore from the mine, backfill will be placed into mined-out stopes to permit recovery of most pillars.

This will require development of surface rock sources to be used as the backfill material. It is anticipated this rock will be mined in summer and trucked underground in winter.

3.6.1.3 Future Development

Although mining of the upper limb of the lower ore zone is the planned initial mining area, and will provide nearly 15 years of ore by itself, some development of the lower limb of the lower ore zone will likely take place with a modest extension of the underground workings accompanied by an additional portal for access. Mined ore would still be crushed and transported with the initial handling system.

Development beyond the underground zone requires mining of the upper ore zone by open pit methods, at least initially, and probably only so long as the economic conditions are favourable to the increasing stripping ratios expected. It is possible though, that some development in this area could take place in conjunction with the underground operation at a later stage. Surface ore would still utilize the underground crushing and conveying system in this event.

3.6.2 MINING PLAN

Diamond drilling and bulk sampling programs have indicated the tabular nature of the upper limb of the lower ore zone which plunges gently to the west and dips to the south. However, due to the large open areas expected to be created during mining, artificial support in the form of the backfill will be required to permit recovery of pillars. Mining will take place under the following conditions:

- rock conditions will be such that an open stoping or room and pillar method can be used

- delayed backfilling to permit recovery of the pillars will be required

- freezing rock temperatures, (about -2°C), will help produce adequate rock competency in stope walls and backs and assist in strengthening backfill support

- the mine will be dry due to the permafrost and no major pumping facilities will be required for groundwater. The only water expected could be drilling water if required, but dry drilling is preferred if possible

- calcium chloride (brine) would be used as drilling fluid if necessary

- some flexibility in sequencing of stope development will be required to maintain grade control.

3.6.3 UNDERGROUND FACILITIES

3.6.3.1 Ore and Waste Transportation

During the mining operation, mined ore and waste will be picked up by 6 m^3 diesel powered LHD units and hauled to ore or waste passes. Rock will be taken from the ore and waste passes and passed through a jaw crusher at the bottom level of the mine to reduce the material to less than 127 mm (5 in) nominal diameter. The crushed rock will then be stored in a 5000 t coarse ore bin underground from which it will be transported by a belt feeder and conveyor system through an underground tunnel to the surface and subsequently to the mill.

3.6.3.2 Personnel Transportation

Approximately 33 people will be underground each working day, on a two-shift basis. Personnel will either walk to their working places through the plant feed conveyor tunnel or in some instances drive the same route in diesel-powered underground vehicles.

3.6.3.3 Materials Transportation

Materials to be used in the mine will be transported by diesel vehicles operating through the conveyor ramp or the upper level adit. These materials will then be distributed through the mine by the same vehicles, with an emphasis on minimizing rehandling of items.

3.6.3.4 Mine Ventilation

Prior to the installation of a permanent ventilation system, an auxiliary system of axial flow fans located at available fresh air sources will be used to supply air through canvas ducting to the trackless development headings.

During the production phase, air volumes will be based largely on equipment diesel power at 228 m^3/hr/kW (100 CFM per horsepower). Air will be supplied to areas where no diesel equipment is working in order to maintain ventilation. The system will be designed to take inlet air from surface to the upper levels, pass through the workings and exhaust at the lower level. The total anticipated air volume requirement during production is approximately 34,000 m^3/hr (200,000 CFM).

Respirable silica levels experienced in the mine will be kept below acceptable standards.

3.6.4 BACKFILL

Mine backfill requirements have not yet been fully determined, and will depend on rock conditions which will not be known until further underground excavation has been completed. However, the basic mine plan consists of leaving alternate slopes unmined for pillar support and then recovering those pillars only after adjacent stopes have been backfilled.

It is expected that overburden from the potential open pit mine area and development waste rock, as mined, will be suitable backfill material, and once placed in the mined-out stopes will freeze and provide competent support which will allow the ore pillars to be recovered with the blast-hole stoping method, and with a minimum of dilution from the backfill material. Although backfilling with mill tailings has been considered, and may eventually prove to be an effective, preferable and economic method, current plans do not anticipate this procedure being employed.

3.7 THE PROCESS PLANT

3.7.1 GENERAL DESCRIPTION

A process plant has been designed that will treat 317,500 t (350,000 tons) of ore per year at a nominal daily rate of 900 t (1000 tons), with a capability to be expanded to 1800 t (2000 tons) per day. The plant is designed to treat ore at 1.30% WO_3 with an average recovery of 85%. The expected range in grades varies from 0.7% to 2% WO_3. The process and surface facilities are intended to operate 24 hours per day, 7 days per week, on 12 hour shifts.

The position of the plant complex which houses the processing facilities has already been presented in Figure 3-1, together with the accommodation and recreational facilities. A block flow diagram of the process plant is shown in Figure 3-6, and a plant water block flow diagram is shown in Figure 3-7.

The process plant has been designed on the basis that all primary crushing will be performed underground. Secondary and tertiary crushing will be carried out in the surface process plant using cone crushers in closed circuit with vibrating screens. The fine ore will then be ground in conventional rod mills in closed circuit with vibrating

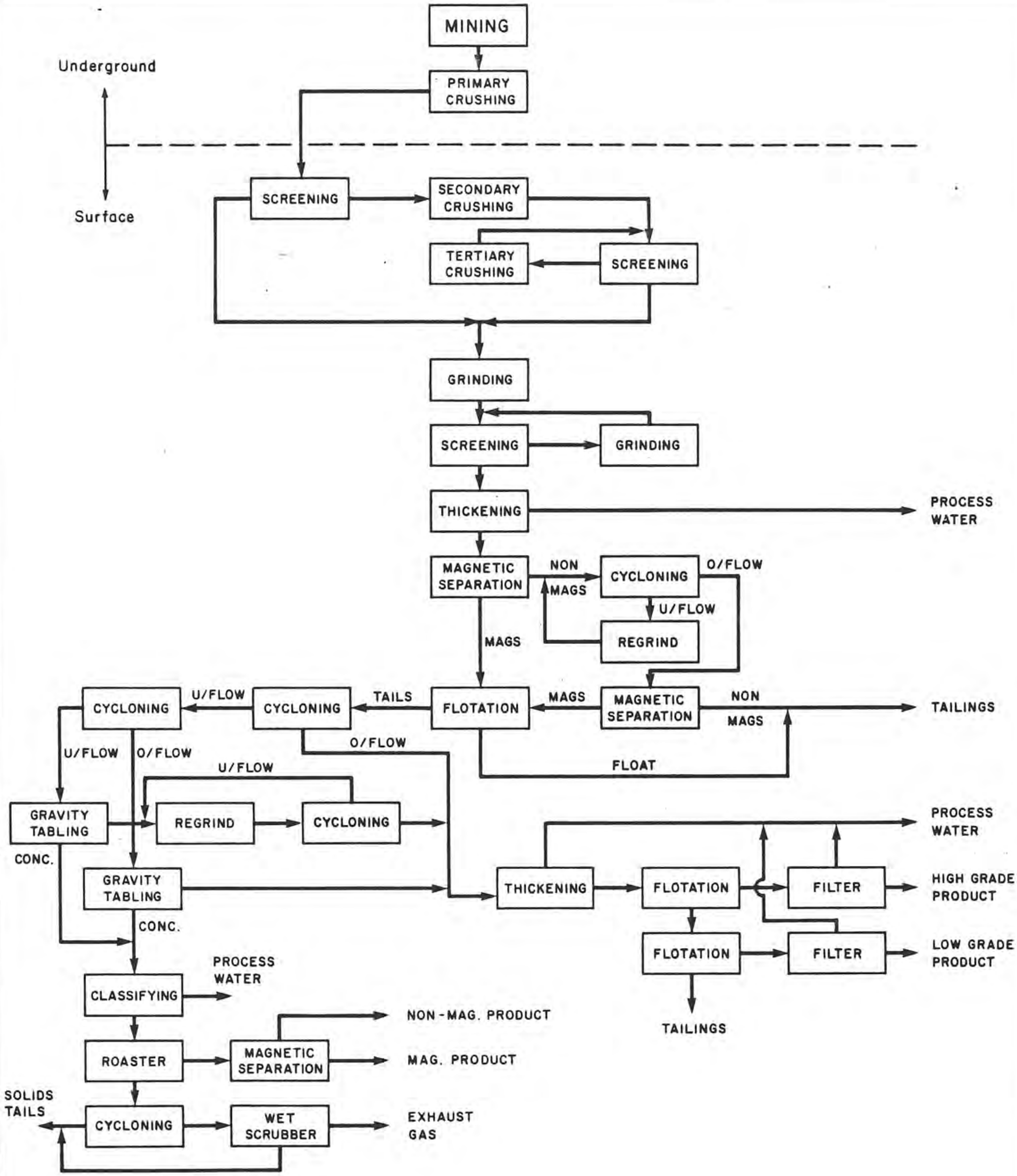


FIGURE 3-6

PROCESS BLOCK FLOW DIAGRAM

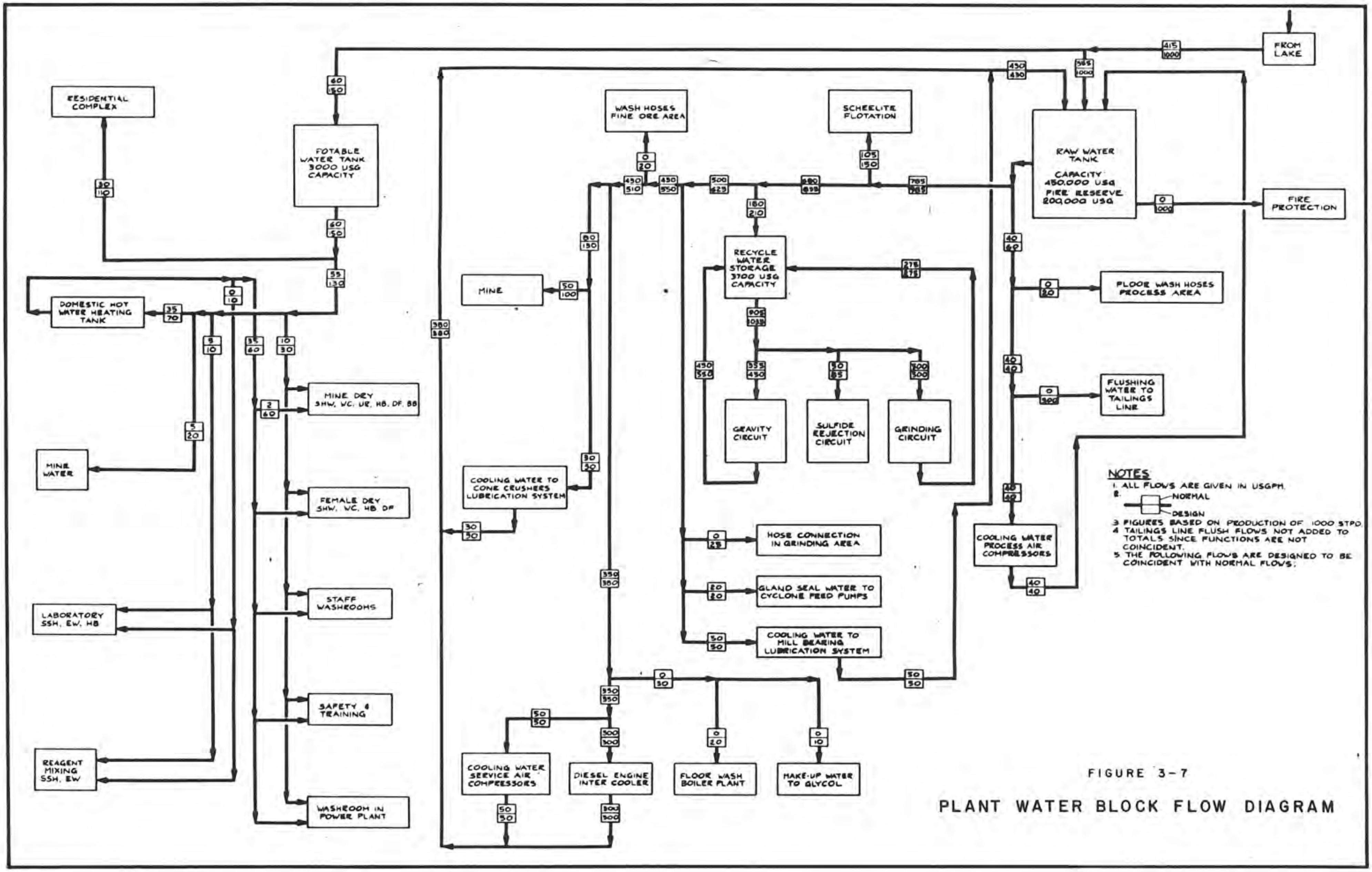


FIGURE 3-7

PLANT WATER BLOCK FLOW DIAGRAM

screens. The magnetic fraction of the screen undersize material will feed a sulphide rejection flotation circuit consisting of thickening, magnetic separation, and aeration/flotation stages. The non-magnetic portion is further treated by cycloning, regrinding in a ball mill and a second stage of magnetic separation. The non-magnetic sulphides are rejected to tailing while the magnetic portion is returned to the sulphide rejection flotation circuit. The flotation circuit produces a flotation product which is discarded as tailing while the non-floating fraction feeds a gravity concentration circuit.

Feed to the gravity circuit is split initially in a cyclone to produce an overflow feed stream for scheelite flotation and an underflow stream which is cycloned further to produce slimes and sands feed streams to respective conventional gravity table separator circuits. The table concentrates are combined from both the slimes and sands circuits for further gravity refining. Tailing from the sands circuit is reground and cycloned in closed circuit before being fed to scheelite flotation, while the slimes circuit tailing is fed directly to scheelite flotation.

The table concentrates, after combining, are fed to a spiral classifier for dewatering and subsequently through a dryer for drying. Dryer off-gases are subjected to cycloning and wet scrubbing before being exhausted to the atmosphere. The dried product is screened and magnetically separated into a magnetic and a non-magnetic product stream, ready for shipment.

The feed stream to the scheelite flotation circuit is thickened and conditioned chemically before entering two stages of conventional aerated flotation cells. The first stage produces a high grade product and the second stage produces a low grade product. After filtering for water removal, these products are ready for packaging and shipment.

All thickener and filter water streams are combined in a plant process reclaim water system for internal use in the process.

3.7.2 CRUSHING AND SCREENING

Primary crushing of the ore to minus 127 mm (5 in) will be performed underground and material transported to the surface as described in Section 3.6.3.1. Ore conveyed from underground will enter the process plant and pass directly through a 1.2 m x 2.4 m (4 ft x 8 ft) vibrating screen. The screen oversize will discharge into a 1.4 m (4.5 ft) standard stone crusher, the product of which will feed a second vibrating screen which measures 1.8 m x 3.7 m (6 ft x 12 ft). The undersize product of the second screen will be conveyed to a 1270 t (1400 ton) fine ore storage bin while the oversize material will be returned in closed circuit through a 1.7 m (5.5 ft) short head cone crusher.

3.7.3 FINE ORE STORAGE

The crushed ore will be stored in a 10.7 m (35 ft) diameter by 12.2 m (40 ft) high fine ore storage bin which has been designed to provide live storage of 1270 t (1400 tons). The ore will be withdrawn from the bin by three slot feeders and conveyed to the grinding circuit.

3.7.4 GRINDING, SIZING AND THICKENING

Fine ore is fed to a 2.7 m (9 ft) diameter by 3.7 m (12 ft) long rod mill which discharges to a bank of vibrating slurry screens. The screen oversize material is returned to a 2.4 m (8 ft) diameter by 3.1 m (10 ft) long rod mill in closed circuit with the screens, while the screen undersize is fed to a 12.2 m (40 ft) diameter triple tray thickener. The thickener overflow is returned to the plant process water reclaim system while the underflow is pumped to the sulphide rejection circuit.

3.7.5 SULPHIDE REJECTION CIRCUIT

Thickener underflow from the grinding circuit is passed through a magnetic separator to separate the non-magnetic sulphides from the ground ore. The magnetic portion is subjected to two stages of flotation in two banks of eight 2.8 m^3 (100 cu. ft) cells to float off any magnetic sulphides as tailing while the underflow passes to the gravity concentration circuit.

The non-magnetic sulphides are subjected to regrind in a 1.8 m (6 ft) diameter by 2.4 m (8 ft) long ball mill in closed circuit with a cyclone. The cyclone overflow is again passed through a magnetic separator with the non-magnetics being rejected as tailing and the magnetic portion being added to the feed stream to the sulphide flotation circuit.

3.7.6 GRAVITY CONCENTRATION CIRCUIT

Feed to the gravity concentration circuit is passed through a primary desliming cyclone to produce an overflow which is thickened in two triple tray, 12.2 m (40 ft) diameter thickeners. The thickener overflow is returned to the process water reclaim system while the underflow is pumped to the scheelite flotation circuit.

The underflow from the primary desliming cyclone is subsequently re-cycloned in a secondary classification cyclone to produce an underflow "sands" stream and an overflow "slimes" stream for gravity separation on vibrating tables respectively. The sands circuit consists of four sets of triple deck tables followed by four sets of single deck tables and one single deck table. The slimes circuit consists of six sets of triple deck tables followed by four sets of single deck tables and one single deck table. The gravity products off both circuits are combined as feed to the gravity refining circuit.

The tailing from the slimes circuit is fed directly to the gravity circuit thickeners which provide an underflow feed to the scheelite flotation circuit. The tailing from the sands circuit is ground in a 1.8 m

(6 ft) diameter by 2.4 m (8 ft) long ball mill in closed circuit with a cyclone. The cyclone overflow subsequently joins the slimes circuit tailing as feed to the gravity circuit thickeners.

3.7.7 GRAVITY REFINING CIRCUIT

Gravity products from the tabling circuits are essentially marketable, but require dewatering and separation into magnetic and non-magnetic products. Dewatering is accomplished by a dewatering spiral classifier and a 3.1 m (10 ft) diameter by 3.1 m high direct fuel-oil fired dryer. Water from the classifier is clarified in a 6.1 m (20 ft) diameter thickener before returning to the plant process water reclaim system. The roaster off-gases are cycloned for solids removal and then scrubbed with water in a wet scrubber before being exhausted to the atmosphere. The cyclone underflow joins the dried product stream while the scrubber underflow returns to the clarifying thickener.

The dried product from the dryer is screw conveyed to a surge bin and then passed through a magnetic separator to produce magnetic and non-magnetic product streams.

3.7.8 SCHEELITE FLOTATION CIRCUIT

The underflows from the gravity concentration circuit thickeners are conditioned in a series of four 2.1 m (7 ft) diameter by 2.1 m (7 ft) high tanks before being fed to two stages of flotation cells. The first stage cells consist of a bank of eight 1.8 m^3 (100 cu. ft) units followed by one bank of two 1.4 m^3 (50 cu. ft) and three banks of two 0.7 m^3 (25 cu. ft) cells, all in series. The high grade flotation product off the last cells is thickened in a 3.1 m (10 ft) diameter thickener before being stored in a Pachuca tank as a surge vessel. Dewatering of the material on a 0.6 m x 2.1 m (2 ft x 7 ft) long belt filter produces a moist high grade flotation product.

The underflow outlet stream from the high grade flotation circuit is reconditioned in a 2.1 m (7 ft) diameter by 2.1 m high tank before entering a low grade flotation circuit.

This circuit consists of one bank of eight 2.8 m^3 (100 cu. ft) cells followed by one bank of two 1.4 m^3 (50 cu. ft) cells, one bank of two 0.7 m^3 (25 cu. ft) cells and one 0.7 m^3 cell, all in series. The low grade flotation product follows a similar route to the high grade product, through a separate 3.1 m (10 ft) thickener and Pachuca tank to a shared belt filter to produce a moist low grade product. The circuit underflow joins the process tailing stream for discard.

3.8 TAILING DISPOSAL

This section examines the recommended design of the tailing management system, including construction of the tailing containment area and its operation during the production period. The system has been designed so that during the first few years of operation, if necessary, no effluent will be discharged to the environment. This will permit sufficient time to ensure adequate settlement of fine solids and permit discharge of a clarified effluent in later years. The system of ponding has also been designed to minimize inflow of surface run-off water thereby maximizing the capability for total tailing impoundment and extending the ultimate pond life.

The milling process for this ore produces a relatively coarse grind of approximately 65% passing a 200 mesh screen. Therefore it is entirely feasible that any future requirement for dyke construction could utilize tailing solids as fill material. Initially, however, all dyke construction required to form an impoundment area will be constructed of native borrow material in the form of silty sand for upstream construction and compacted, crushed talus for downstream construction. Upper slopes will be at a 3 horizontal to 2 vertical ratio, while outside slopes will be at a

2/1 ratio. Starter dykes will be adequate for three years total retention. Refer to Figure 3-8 for the tailing disposal system layout and a generalized tailing dyke cross-section.

3.8.1 DESIGN CRITERIA

The following are the basic criteria used to design the tailing disposal facilities required for the proposed mining development.

Daily production rate	900 t (1000 short tons)
Number of operating days	350 days/year
Anticipated mine life	over 25 years
Annual discharge of tailing	993,900 m^3 (1,300,000 cu.yds)
Annual precipitation	635 mm (25 inches)
Annual evapotranspiration	203 mm (8 inches) (estimated)
Runoff	negligible
Annual permanent storage volume required	152,900 m^3 (200,000 cu.yd/year)

The design of the tailing pond has included capacity for total storage of all liquid and solids for the first 3 years without discharge, and permanent storage for compacted solids for up to 25 years. Furthermore, dykes have been designed to maintain a minimum of 1.5 m (5 ft) of freeboard over water level.

3.8.2 COMPARISON OF ALTERNATIVE TAILING DISPOSAL SITES

The selection of an economically and environmentally feasible site for the location of the proposed tailing impoundment area involved consideration of the following factors:

- topography in favour of a natural basin

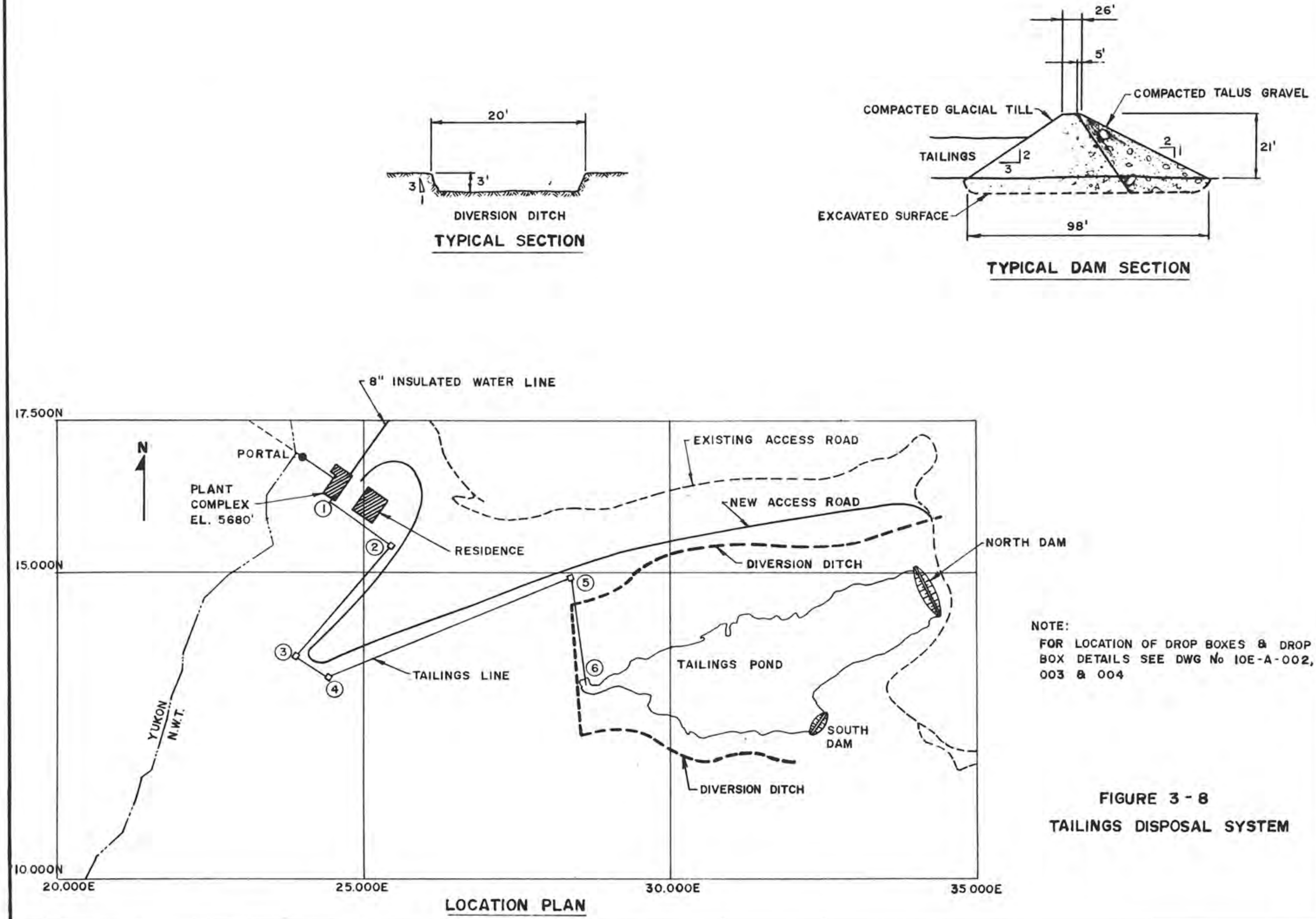


FIGURE 3 - 8

TAILINGS DISPOSAL SYSTEM

- proximity to the proposed plant site; suitability for abandonment upon termination of tailing disposal system

- minimum dyke construction

- maximum control of pond discharge and surface runoff

- minimum disruption to existing watersheds

- avoidance of geological features which could affect the structural integrity of the dykes and subsurface foundation materials.

From the factors listed above, two locations were identified as potential tailing disposal and management sites. These were Cirque Lake to the north of the proposed plant site and Dale Creek valley to the south.

Cirque Lake is an existing lake created by a landslide caused by a bedding plane failure on the mountain slope to the south. There is no apparent surface discharge from the lake, although the lake has an appreciable annual recharge from the surface slopes surrounding it. Consequently, discharge from the lake apparently occurs by seepage through the landslide material which initially dammed the surface runoff watercourse. Consideration was given to the possibility that tailing water might follow the same course, and thereby present possible control difficulties. Some minor dyke construction might be required in later years as solids volumes increased the water level of the lake.

Dale Creek valley is a relatively flat valley sloping gently eastward at about a 3% grade and some 300 m (1000 ft) elevation below the proposed plant site. Dale Creek is a collection of a series of small surface runoff creeks, draining a very large surface area, and accumulating up to a peak of 2500 L/s (40,000 USgpm) of runoff water. A tailing pond would be created by a modest amount of dyke construction on Dale Creek at two points at the eastern end of the valley, and encircling the pond with a diversion ditch to minimize entry of surface runoff water into the pond.

3.8.3 RECOMMENDED TAILING DISPOSAL SITE

The selection of the Dale Creek alternative appears to satisfy the design criteria and feasibility factors best, and with almost unlimited capacity for expansion beyond a mine life of 25 years. It also offers the following favourable features conducive to good tailing management practice:

- simple dam structures required for impoundment with less than 764,600 m^3 (100,000 cu.yds) of fill material required for construction, and natural valley sideslopes being used for retaining tailing water and solids
- low surface area to volume ratio which allows more efficient reclamation possibilities
- high storage volume to dam volume ratio which indicates economic efficiency.

The Dale Creek valley site is located south of the proposed plant site, with the centre of the pond about 2438 m (8000 ft) southeast of the plant site. Details of the tailing pond are shown in Figure 3-8. Construction of the initial dykes will allow a storage capacity of about 7,194,000 m^3 (5,500,000 cu. yd) to elevation 1478 m (4850 ft). Above this level, stored liquids would be discharged into the lower end of the Dale Creek system through a control structure in one of the dykes, to mix with the surface runoff water captured in the diversion ditch surrounding the pond. If necessary, the height of the dykes can be increased almost indefinitely, thereby adding to storage capacity.

The tailing line from the process plant to the pond will be a 152 mm (6 in) diameter insulated steel pipe and will require a large number of drop boxes enroute in order to dissipate energy and limit pipe erosion during the 300 m (1000 ft) drop in elevation from the plant.

3.8.4 QUALITY AND QUANTITY OF EFFLUENT

As the initial plant operation contemplates total impoundment of tailing for a period of about 3 years, there should be negligible discharge of effluent to the environment during that period. Thereafter, up to a maximum of about 31.5 L/s (400 USgpm) of clarified effluent would be discharged to Dale Creek to mix with an anticipated average flow of surface water of about 378 L/s (6000 USgpm). Without use of sodium cyanide in the process, and with adequate settlement time for solids, it is expected that effluent quality will be environmentally acceptable. Studies on dissolved solids and suspended solids anticipated at MacTung indicate that the effluent quality will be environmentally acceptable.

3.8.5 FLOOD CONTROL DESIGN

A 3660 m (12,000 ft) long diversion ditch will encircle the north, west and south sides of the tailing pond to divert Dale Creek and to capture surface runoff water from the surrounding steep slopes to the downstream side of the tailing dykes as shown in Figure 3-8. Consequently, with only straight precipitation in the pond area as an input, and which represents about 25% of the total pond influent, flooding is not considered to be a major difficulty. A concerted maintenance program for the diversion ditch will be required however, to ensure diversion of the surface waters.

3.9 WATER SUPPLY AND DISTRIBUTION

3.9.1 WATER REQUIREMENTS

Based on an operating workforce of 200 persons, domestic water consumption is estimated at 227 L (60 USgal)day/person for a total demand of 45,420 L (12,000 USgal)/day for the 900 (1000 tons) per day operations. Total daily fresh water demand is expected to be about 870,550 L (230,000 USgal), at an average rate of 10 L/s (160 USgpm).

Fire water requirements indicate the need for up to 78.8 L/s (1250 USgpm) for a 3 hour period for protection of the plant complex.

Instead of providing pumping capacity in this amount, fire water storage will be provided in tankage in the plant complex, and the fresh water supply system designed for a 31.5 L/s (500 USgpm) maximum rate of flow.

Total annual water consumption is estimated not to exceed 424,800 m^3 (15,000,000 cu. ft).

3.9.2 COMPARISON OF ALTERNATIVE SOURCES OF WATER

Water supply is available potentially from only two areas in the vicinity of the proposed plant site: Dale Creek and Cirque Creek. Surface runoff calculations in the Dale Creek valley, and some preliminary field measurements, indicate that a peak flow of nearly 1260 L/s (20,000 USgpm) exists in Dale Creek, and an annual average of about 315 L/s (5000 USgpm) is likely. Consequently, construction of a small dam across Dale Creek would readily provide freshwater sufficient to supply the project.

Cirque Lake has been formed by a rock slide across the creek which drains Cirque valley. The lake measures about 37 m (120 ft) in depth at the centre, and contains an estimated 3,900,000 m^3 (130,000,000 cu. ft) of water. The lake has no surface discharge, apparently seeping through the rockslide which initially created the lake. Without any recharge from surface run-off, the lake contains over 5 years of water at the predicted project consumption rate. It is expected that the lake level would drop substantially with the operation of MacTung, and reach a new equilibrium level such that project consumption and a decreased seepage rate would balance inflow.

3.9.3 PROPOSED WATER SOURCE

There are only two potential sites for tailing disposal and water source and Cirque Lake has been chosen as the freshwater source for the project. A pumping station will be provided on a rock-fill causeway into the lake to enable suction from below the anticipated new lake level after commencement of operations. Water will be pumped from the lake at elevation 1600 m (5250 ft) to the plant complex at about elevation 1768 m (5800 ft) using two freshwater pumps, one operating and one on standby. A diesel powered electrical generating set will also be provided to operate the pumps in the event of a power failure during a fire or emergency.

The main supply line from the pumphouse for the plant complex will be 203 mm (8 in) in diameter with 76 mm (3 in) of insulation laid on sleepers and trestles up the side of the mountain ridge. A new access road from the east up Cirque valley to the lake will be provided for construction and maintenance use. See Figure 3-8.

3.10 MINE PRODUCTS

The only commercial products that will be produced by the project will be scheelite concentrate, which will be packaged suitably for shipment and transported by truck to markets. The only other product will be mill tailing which has no commercial value and will be disposed of as described in Section 3.8.

3.11 MANPOWER REQUIREMENTS

3.11.1 CONSTRUCTION

Construction manpower is estimated to peak at about 335, twelve months after initial field work commences. An approximate breakdown of this manpower is shown in Table 3-4.

3.11.2 OPERATION

The total manpower requirements for operation of MacTung have

TABLE 3-4

CONSTRUCTION MANPOWER

Skilled labour	190
Semi-skilled labour	97
Underground	40
Management	28
Owner's Staff	13
Caterers	27
TOTAL	335

TABLE 3-5

OPERATION MANPOWER REQUIREMENTS

Mine Operators	45
Mill Operators	35
Maintenance, Surface	66
Warehouse, Administration	18
Whitehorse Staff	10
TOTAL	174

The total manpower requirements for operation of MacTung have been estimated at 174 people with accommodation being provided for a possible maximum of 350 on site at any one time. Separate accommodation will be provided for women staff and visitors.

Manpower estimates for various areas of the complex are presented in Table 3-5.

3.12 TRANSPORTATION

3.12.1 FUEL AND MATERIALS

With the proximity of the North Canol Road to the project site, it is anticipated that nearly all transportation of fuel and materials will be by truck, with only nominal amounts of strategic or emergency materials flown in to the newly built airstrip. Also during the freeze-up period late each year, it is expected that ferry service at Ross River will be interrupted and some air transport for site servicing will be required. Largely, however, site inventories will be maintained to permit interruptions of truck traffic for up to 8 weeks, until an ice bridge across the river can be built. The same strategy will apply during spring break-up of the ice bridge prior to reactivation of the ferry service.

It is expected that an average of between 2 and 3 truck loads of materials, fuel and supplies will be required daily at the site. Of these loads, an average of 1.5-2.0 will be bulk transportation fuel oil.

3.12.2 PERSONNEL

With the long distances involved from major urban centres to the site, transportation of most personnel will be by aircraft from Whitehorse to the site airstrip on a regular rotational basis. Only those employees resident in Ross River are likely to consider ground transportation to the site. The rotational cycle selected will determine the size of aircraft and frequency of flights.

3.12.3 PRODUCT

The process plant at MacTung is expected to produce about 23 t (25 tons) of concentrates per day. This amounts to slightly more than one one truck load per day, and should present an opportunity for equivalent backhaul loads for trucks transporting supplies and materials to the site. During fall freeze-up and spring break-up at Ross River, the product would be stockpiled at site for later transport.

3.13 WASTE MANAGEMENT

3.13.1 SEWAGE COLLECTION AND DISPOSAL

All sewage discharged from the plant complex (mine dry, mill dry, washrooms), and from the residential complex (kitchen and accommodations), will be collected in a holding tank and pumped directly to the first tailing line drop box for mixing with tailing and gravity disposal to the tailing pond. Since the pond represents a minimum of 3 years retention, and the sewage volume is about 5% of the total discharge, it is expected that the tailing pond will provide ample lagoon-type treatment of the sewage.

This system will form part of the initial accommodation complex required for construction forces and therefore will be part of the initial site installations. The holding tank will provide sufficient retention time to allow septic treatment of sewage before discharge to the Dale Creek valley.

3.13.2 GARBAGE DISPOSAL

All solid garbage will be collected and burned in a fuel-oil fired incinerator. Incinerator residue and unburnable garbage will be buried at a controlled landfill station as established in accordance with Land Lease requirements. Fencing of the landfill station is not contemplated as necessary at this time.

3.14 SUPPORT FACILITIES

3.14.1 ACCOMMODATION AND RECREATION

During the construction phase of the project, up to 350 people may be resident on site at any given time. Consequently, the accommodation facilities for construction will house 350 people in 3 types of units; 252 in units with communal washrooms, 66 in units with washrooms shared between two persons, and 32 in units containing private washrooms, kitchenette and sitting room. At completion of construction these units will be refurbished in sufficient number and type to accommodate the operating personnel. Central to the complex will be a kitchen/dining facility which will also house first-aid, post office, commissary and a recreational area. The latter will contain pool tables, table tennis, shuffleboard, darts and card tables. A movie and TV room will also be provided. No gymnasium or swimming pool facilities are planned initially, but re-use of some of the surplus construction buildings for this purpose may be suitable.

3.14.2 FUEL HANDLING AND STORAGE

Under normal operating conditions, fuel oil consumption at MacTung is estimated to average 11,355,000 L (3,000,000 USgal) per year, or 31,794 L (8400 USgal) per day. Maximum daily consumption during winter months is expected to be about 45,420 L (12,000 USgal). These estimates include the total fuel oil requirements for power generation, plant and residential heating, and diesel equipment operating underground and on surface.

It is intended to provide bulk storage of fuel-oil in two steel tanks measuring 12.2 m (40 ft) diameter by 12.2 m high and containing about 1,419,400 L (375,000 USgal) each for a total of 2,839,000L (750,000 USgal). This represents about 8 weeks supply at anticipated maximum consumption, and corresponds to the maximum anticipated interruption of ferry traffic across the Ross River.

In addition, a single 3.7 m (12 ft) diameter by 6.1 m (20 ft) long horizontal steel tank will be provided to contain bulk gasoline required for surface vehicles and equipment. All tanks will be contained in an earth-filled berm lined with an impermeable membrane, and provide a volume equivalent to at least one-quarter of the volume of the largest tank.

Dispensing of gasoline will be by gravity from the tank through a single local hose station. Dispensing of fuel oil will be through a common header system between the two tanks to a small, metered pumping station to supply either the day tanks for the diesel generators inside the plant complex, or a bulk fuel oil vehicle used to dispense fuel to surface and underground vehicles.

3.14.3 HEATING AND VENTILATING

Heating and ventilating of the plant complex and residential complex will vary depending on the particular area. In general, air changes will be achieved by roof or wall mounted ventilators, and fresh air will be drawn in through motorized wall louvres. In all cases, the buildings will operate under a small positive pressure.

Waste heat produced by the diesel generators will be recovered by exchanging cooling water from the engine jackets and gas stacks with a glycol-water fluid. The glycol solution will then be circulated through the individual unit heaters and make-up air units to heat circulated and fresh air respectively. The same principle applies to heat the residential complex. In the coldest winter months, the waste heat supply will be augmented as necessary by direct fuel oil fired boilers heating the glycol stream. Waste heat normally should provide sufficient energy to heat fresh air by 28°C (50° F) to allow 2 air changes per hour throughout the entire plant complex. In the summer months, diesel waste heat will be dissipated to the atmosphere through external air exchangers.

No heating of mine ventilation air is contemplated.

3.14.4 COMPRESSED AIR

Low pressure compressed air at 862 kPa (125 psig) will be provided for process flotation by two 149 kW (200 HP) air blowers at 15300 m^3/hr (9000 CFM) each. Plant air will be supplied by three 149 kW (200 HP) air compressors at 850 m^3/hr (500 CFM) each. The blowers will be installed in the plant complex.

3.14.5 ELECTRICAL POWER SUPPLY AND DISTRIBUTION

Discussions with the Northern Canada Power Commission and Yukon Electric confirmed that neither commercial power nor hydro development is available in the area. On-site generation of electric power by diesel generating units has been included in the design of the project.

It is proposed that power will be provided by four diesel engine sets rated at 1100 kW each, to generate up to 4400 kW. Normally it is expected that only three units will operate, with one undergoing routine maintenance or on standby. Power will be generated at 4160 V, 3 phase, 60

Hz, and distributed within the plant complex via armoured (Teck) cable in cable tray. Motor loads will be distributed from local Motor Control Centres at the appropriate voltage, which usually will be 600 V.

Underground power is expected to amount to less than 800 kW and will be provided by armoured cable from the powerhouse to electrical distribution centres underground.

Lighting generally will be of the high pressure sodium type with open reflectors and integral ballasts. Fluorescent lighting will be used in low ceiling areas.

3.14.6 LABORATORY

Laboratory space of about 28 m^2 (300 sq. ft) will be provided to house both an analytical and a physical metallurgy section. The laboratory will be located on the ground floor level of the plant complex.

3.14.7 EQUIPMENT MAINTENANCE SHOPS

Approximately 1860 m^2 (20,000 sq. ft) of shops area will be provided in the plant complex for maintenance of equipment. This will include electrical, instrumentation, welding, machine shops and vehicle repair bays and others necessary to sustain an efficient operation. Initially all major maintenance of underground equipment will also be done in these shops.

3.14.8 WAREHOUSING

Warehousing in a remote facility such as MacTung is vital to the success of the operation. Thus some 1210 m^2 (13,000 sq. ft) of warehouse space will be provided within the plant complex for spare parts, major components, supplies and reagents. Additional cold storage facilities will likely be provided by taking advantage of surplus construction buildings apart from the main plant complex.

Storage of explosives for underground operations will be provided in an underground facility established inside the upper level of the mine in accordance with applicable regulations.

3.14.9 PLANT FIRE PROTECTION

A single, steel raw water storage tank located in the plant complex, measuring 12.2 m (40 ft) diameter by 14.6 m (48 ft) high will contain about 1,703,250 L (450,000 USgal) of water. One-third of this tank is designated for retained fire water and will not be accessible for process use. The entire volume, however, is potentially available for fire fighting. Both electric and diesel fire water pumps, taking suction from the bottom of the tank, will be provided.

Distribution of fire water will be through header systems and sprinklers designed to provide 0.17 L/s per m^2 (0.25 USgpm/sq. ft) of floor area in the plant complex, and 0.068 L/s per m^2 (0.1 USgpm/sq. ft) in the residential complex. In both cases, auxiliary hose stations will also be provided in selected areas.

3.14.10 AIRSTRIP

In order to facilitate transportation of people and some materials, it is proposed to construct an airstrip 1981 m (6500 ft) long by 46 m (150 ft) wide to accommodate Hercules-type aircraft. The location of this strip is shown in Figure 3-1. The facilities will be provided with a Non-Directional Beacon, Microwave Landing System and a full complement of approach, threshold and runway lighting. A separate diesel generating set located centrally to the airstrip will provide power for the instrumentation and lighting. A small building located at one end of the airstrip will accommodate personnel in transit as well as an airstrip controller's office.

The airstrip location and design has been selected to minimize environmental impact and maximize the availability for aircraft. It is intended that the airstrip will meet Transport Canada criteria but will be owned and operated privately by AMAX Northwest Mining Company Limited.

3.15 HAZARDOUS MATERIAL CONTROL

3.15.1 GENERAL CONSIDERATIONS

The engineering design criteria at the MacTung site are based on current governmental guidelines and have been developed to minimize gaseous, liquid and solid emissions by the use of capture and recycle techniques wherever possible. Dust control, scrubbing, spill containment, reclaim and maximum product recovery have been incorporated into the design philosophy of the complex.

All final solid wastes, liquid effluent and sewage will be discharged to the tailing disposal area.

3.15.2 SOLID AND GASEOUS EMISSIONS

Solid emissions from equipment and transfer points in the crushing plant will be controlled by a dry dust collection system in the form of a baghouse. On the other hand, dust from the direct fired product drier will be collected and treated in a high efficiency wet scrubber system. Maintenance and service areas will be provided with an adequate ventilation system for the control of welding and diesel fumes.

In the flotation circuits, excess air used in the process will be vented to the atmosphere.

3.15.3 PROCESS CHEMICALS

Ten different chemicals will be used in various amounts in the MacTung process, almost exclusively for pH adjustment of solutions and as frothing agents for the flotation circuits. In all, it is expected that about 900 t (1000 tons) of chemicals will be used annually, and 75% of that total will comprise equal amounts of soda ash and sodium silicate. No toxic chemical usage is anticipated.

3.16 REAGENT SUPPLY AND HANDLING

The total annual reagent supply amounts to the equivalent of one truckload per week, and will consist exclusively of prepackaged bags or drums. Typically, palletized bags of reagents will be trucked to the site, off-loaded with a forklift and stored in the warehouse until required for the process. Considering the quantity, type of packaging and the nature of the reagents, handling is not considered to be hazardous.

3.17 CONSTRUCTION DETAILS

Construction activities at the MacTung site will commence with site preparation at the beginning of summer of the second year. Initial work would involve road upgrading, construction of the airstrip and cleaning of the plant site. Prefabrication and re-erection of the 350 man accommodation facilities would follow in the summer of that same year.

Plant footings, equipment foundations and steel erection would all commence by late summer with cladding and roofing to be complete by the summer of the third year.

Tailing dams construction and diversion ditches would commence in the third summer with most of the material being obtained from local borrow pits inside the pond area. Rip rap on the outside of the dams will be obtained by crushing surface rock. Ore from the pre-production development of the mine will be stockpiled until the process plant is commissioned, and then used as feed for start-up of the mill.

3.18 ENERGY CONSERVATION

In view of the remoteness of the proposed mine and process plant, the entire complex has been designed to conserve energy, thereby reducing the amount of fossil fuel to be transported to the site. Efficiency measures include the minimization of outside wall space by reducing the number of buildings; designing the camp complex to meet arctic conditions through 15 mm (6 in) walls with a high R value; and recycling waste heat from the generators to supply heat to the plant and residence complexes.

3.19 ABANDONMENT AND RECLAMATION

An overview and comparison of the surface disturbances is presented to put the project in perspective before describing the Reclamation Plan. Although the final engineering design for the project has not been carried out, the overall reclamation commitment, approach, and methods will not be significantly affected by final engineering design. Aspects of reclamation which might be subject to adjustment by final engineering are the exact locations of some facilities, steepness of slopes, and the size of specific disturbances.

3.19.1 DISTURBANCE OF SURFACE LANDS

The total disturbed surface area of the mine is not expected to exceed 228 ha. A breakdown of estimated areas of disturbance is provided in Table 2-1.

3.19.2 RECLAMATION GOALS AND PROCEDURES

Physical disturbance of land creates a situation which, without relamation, will induce additional degradation for a period of time prior to attainment of equilibrium and initiation of natural recovery. AMAX's reclamation goals are:

- to reduce the interim period of continued degradation; and
- to initiate and accelerate the process of continuous natural ecological recovery.

These goals are achieved by implementing the two major components of reclamation - regrading and revegetation.

In general, the ecosystem will be returned to a structure similar to the existing structure, and the reclaimed land will be amenable to a variety of beneficial uses by future generations as far as practicable. Reclamation will provide conditions capable of supporting uses similar to those presently existent in the project area.

Revegetation will entail the establishment of grasses, shrubs, and forbs. All areas which are amenable to revegetation will be revegetated. Finished cuts and fills will be graded to slopes appropriate to the terrain of the area and consistent with construction economy and long term stability. Slopes will be designed to insure stability, to prevent erosion and to facilitate revegetation. Cut and fill slopes will be revegetated during the construction and operations phases and will have undergone many years of growth by the time bench areas are revegetated during the final reclamation process. Successfully revegetated slopes will not be redisturbed by grading operations during final reclamation. Regrading during final reclamation will be limited to providing proper drainage and burying or covering unsalvageable materials when structures are dismantled. Excessively steep cut slopes cannot be revegetated.

Rates of vegetation recolonization are surprisingly rapid on many disturbed arctic-alpine sites. Although not mandatory for the revegetation of many sites, topsoil is the most important ingredient for reducing the time required to achieve high quality self-sustaining revegetation. However, good quality soil is not available for salvage at most of the sites slated for disturbance. The only sites which may contain sufficient quantities of salvageable soil are the toe traces of the tailing dams and perhaps the overburden in one or more of the potential borrow areas. Good quality soil at these sites will be salvaged to aid reclamation.

The soil will be stockpiled in areas adjacent to disturbed sites and seeded to provide temporary stabilization until the material is required. Soil will be redistributed only on areas which are most difficult to revegetate. Generally, eight centimeters of soil is adequate to promote rapid germination and establishment. No attempt will be made to place soil on cut or fill slopes too steep to hold the soil.

Prior to seeding, the surface will be scarified to prepare the seedbed properly. The rough conditions which exist immediately following construction of cuts and fills or ripping of platform areas are optimum for seeding. At the time of seeding, 20-20-10 fertilizer will be applied at the rate of 112 kg/ha or equivalent. Because of the rough and steep conditions, it is anticipated that all areas will be broadcast seeded. The seeding rate for broadcast seeding will be approximately 50 kg pure live seed (PLS)/ha.

The seed mix decribed in Table 3-6 will be used in all areas to be revegetated. The seed mixture is subject to change depending on commercial availability.

Shrubs such as Betula glandulosa may be added to the seed mix (if available) or may be transplanted along with Salix alaxensis which is an excellent colonizer. Where possible, seeding will take place immediately following construction. If immediate seeding is not practical, disturbed areas will be revegetated during the growing season following completion of the disturbance.

Ammonium nitrate maintenance fertilizer will be applied at a rate of 112 kg/ha as necessary to maintain moderately vigorous vegetation. It is expected that within five years after planting, the natural nitrogen cycle will be reestablished and no further nitrogen fertilization will be necessary or desirable.

3.19.3 STRUCTURE DISMANTLING

It is impossible to predict whether or not it might be beneficial to leave any of the structures associated with the project in place after mining has ceased. No structure would be left unless it provided a beneficial use. With the exception of certain flood control and water management facilities, the present plan is to remove all surface facilities and structures during final reclamation. Materials of no salvage value such as concrete will be buried.

Flood control has been integrated into the overall design of the tailing pond. At the termination of operations, the permanent flood protection facilities will be adequate and should require no maintenance to remain functional. The spillway will be designed to ensure adequate passage of all drainage water behind the earth-filled dams in the event that diversion ditches cease functioning. Essentially all tailing will be deposited underwater within the earthen dam reservoir. As such, the faces

TABLE 3-6

SEED MIX FOR MACTUNG REVEGETATION

Scientific Name	Common Name-Variety	% by Weight in Mixture
Agrostis alba	Redtop	5
Alopecurus pratensis	Meadow Foxtail	10
Bromopsis inermis	Smooth Brome - Polar	15
Deschampsia caespitosa	Tufted Hairgrass	5
Festuca ovina	Hard Fescue - Durar	10
Festuca rubra	Red Fescue - Arctared	10
Phleum pratense	Timothy - Climax	10
Poa pratensis	Kentucky Bluegrass - Nugget	5
Secale cereale	Rye - Balboa	20
Trifolium repens	White Dutch Clover	10
	TOTAL	100

of the dams will be revegetated but the tailing deposition pond surface will remain a water pool.

4.0 EXISTING ENVIRONMENT

CHAPTER FOUR

EXISTING PHYSICAL AND BIOLOGICAL ENVIRONMENT

4.1 INTRODUCTION

Meteorological studies at MacTung date back to 1968. Other environmental studies have been conducted for the MacTung project since 1973 in the following subject areas: climate, air quality, geomorphology, soils, groundwater, surface water, aquatic ecology, vegetation, large and small mammals, avifauna, and heritage resources. The overall objectives of environmmental studies have been to identify critical or important areas and to provide a sound environmental base of knowledge to be taken into consideration along with other variables during detailed mine design. The baseline data also permits forecasting of impacts of the project and will serve as a control for comparision in assessing effects on specific aspects of the environment during the life of the mine.

Environmental studies were performed by AMAX employees, various government agencies and contracted individuals and companies. Results of these studies exist in the form of 48 reports and file documents, most of which deal with a specific subject area although two environmental reports provide a relatively comprehensive summary of study results on the different environmental aspects. Since 1981 additional studies have been performed on all 13 subject areas listed above and significant effort has been expended to compile pre-existing information with recent study results into five component reports, which provide the basis for most of the information summarized in this document. The reports are entitled:

- o MacTung Meteorology and Air Quality Analysis and Assessment,
- o Geomorphology and Vegetation of the MacTung Study Area, Yukon/N.W.T.,

- o Aquatic Ecology of the MacTung Area,
- o 1981-82 MacTung Wildlife Studies, Yukon/N.W.T.,
- o Avifauna of the MacTung Project Area.

Each report contains the specific details of the various studies and is considered to be an integral element of this Initial Environmental Evaluation. Brief summaries of the studies and their results are included herein and should provide enough information to satisfy the needs of most individuals, organizations and agencies. However, for those who desire more detail, sets of the complete reports will be placed at various central locations for public review.

4.2 CLIMATE

AMAX collected extensive meteorological data from two sites in the MacTung area (Figure 4-1). Data were collected periodically at the potential mine site (elevation 1875 m) from 1968 through August 1982, and continuously at the Tsichu River Airstrip or Mile 222 of the North Canol Road (elevation 1265 m) from October 1974 through mid-August 1982. The airstrip station was maintained by AMAX under supervision of the Atmospheric Environment Service (AES) offices in Whitehorse.

The mean daily temperatures for the Tsichu River Airstrip and the Mine Site (Table 4-1) were -7.7°C and -8.5°C respectively; the extreme minimums were -54°C and -41.7°C, the extreme maximums were 30°C and 23.9°C. The mean annual precipitation at the Tsichu River Site is 489.7 mm (refer to Table 4-2) and the postulated mean annual precipitation at the Mine Site is 641.0 mm. The average annual snowfall at Tsichu River is 294.2 cm and the expected snowfall at the mine site is calculated to be approximately 393.7 cm.

TABLE 4-1

TEMPERATURES, TSICHU RIVER AIRSTRIP AND MACTUNG MINE SITE (°C)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Tsichu River Airstrip													
Mean Daily Maximum	-18.6	-14.8	-12.9	-2.0	6.0	14.9	17.0	14.3	7.3	-2.3	-11.3	-17.5	-1.7
Mean Daily Minimum	-29.5	-26.9	-26.7	-16.1	-4.9	0.9	2.9	1.0	-2.9	-12.2	-23.0	-28.2	-13.8
Mean Daily	-24.1	-20.9	-19.8	-9.1	0.6	7.9	10.0	7.7	2.2	-7.3	-17.1	-22.9	-7.7
Extreme Maximum	3.0	2.2	2.5	8.3	21.5	30.0	27.2	25.0	19.4	9.0	5.6	0.0	30.0
Extreme Minimum	-51.1	-51.0	-43.0	-41.5	-21.0	-12.0	-5.0	-10.6	-19.0	-35.6	-45.0	-54.0	-54.0
MacTung Mine Site													
Mean Daily	-19.6	-21.9	-17.3	-11.2	-2.9	2.8	4.4	2.2	-0.6	0.8	-19.2	-20.0	-8.5

NOTES:

- Tsichu River Airstrip normals calculated for 1959-1978 period by the AES (Whitehorse) and based (in part) on actual data for October 1974 to August 1982 period. Extremes are abstracted directly from AMAX data for October 1974 to August 1982.

- Mine Site data are actual values.

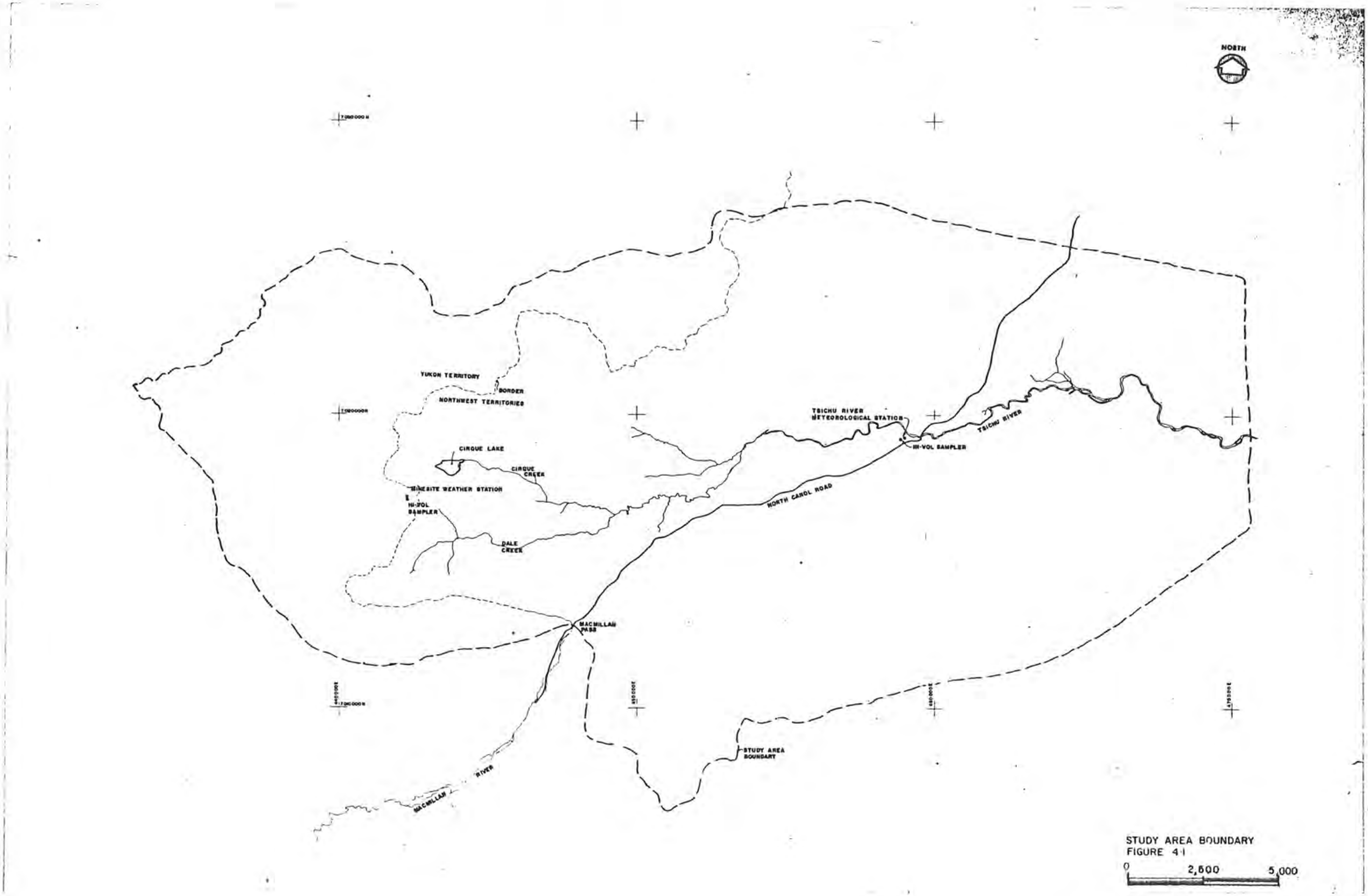
TABLE 4-2

TSICHU RIVER AIRSTRIP PRECIPITATION NORMALS CALCULATED FOR 1959-1978 PERIOD

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Mean Rainfall (mm)	Nil	0.7	0.4	Tr.	10.0	42.8	53.9	55.5	33.5	1.1	0.4	Nil	198.3
Mean Snowfall (cm)	36.0	21.1	29.3	32.0	15.0	0.9	0.9	0.8	18.7	54.6	44.6	40.3	294.2
Total Mean Precipitation (mm)	33.0	21.8	28.9	32.0	25.0	43.7	54.8	56.3	52.2	55.7	45.0	40.3	489.7
Number of Days of Measurable Precipitation	12	10	12	12	9	14	15	14	15	15	14	13	155
Mean Month End Depth of Snow on Ground (cm)	69	72	72	79	10	Nil	Nil	Nil	Nil	35	43	59	
Maximum Total Precipitation (mm)	66.8	35.1	56.7	46.0	43.6	63.8	77.7	88.3	77.0	143.0	70.0	62.5	
Year	76	81	79	77	78	81	82	80	75	78	81	74	
Minimum Total Precipitation (mm)	5.2	3.9	11.9	6.2	7.1	19.8	41.4	52.6	25.1	30.7	32.9	12.8	
Year	82	79	82	82	76	75	78	79	78	76	79	80	

NOTES:

- By the AES (Whitehorse) and based (in part) on actual data for October 1974 to August 1982 period.
- Extremes are abstracted directly from AMAX data for October 1974 to August 1982.



STUDY AREA BOUNDARY
FIGURE 4-1

Wind data at the mine site, summarized for the 16 cardinal directions, indicated that prevailing winds were strongly westerly throughout the year (17.6% of the time). Westerly winds were particularly dominant during the winter period (23.6% of the time). The average annual wind speed for the mine site was 12.1 km/h. Winds appear to be slightly stronger in winter than in other seasons; averaged seasonal wind speeds were 13.0 km/h in winter, 12.6 km/h in spring, 11.9 km/h in summer and 10.9 km/h in the fall. The maximum recorded hourly wind speed was 64.4 km/h.

Wind data at the Tsichu River Site, summarized for the eight cardinal directions, indicated an overwhelming dominance of westerly flow (50% of the time) likely reflecting a funneling effect out of the Macmillan Pass area. The mean annual wind speed at the Tsichu River Site is 7.9 km/h, with the strongest winds occurring during the summer. The maximum hourly wind speed recorded at Tsichu River was 69 km/h, however the probable maximum gust for this speed is 98 km/h.

Atmospheric stability calculations based upon the meteorological data indicate that excellent dispersion (associated with unstable atmospheric conditions including Classes A, B and C) would occur 25.9% of the time at the mine site and that good dispersion (Classes A, B, C and D) can be expected 72% of the time (Table 4-3). Very poor dispersion (calm conditions - Class F) can be expected only 3% of the time. Excellent mixing level potential, in combination with unstable wind conditions provides excellent dispersion characteristics for the mine site throughout the year.

All useable and pertinent meteorological data collected for the MacTung Project can be found in the companion report entitled "MacTung Meteorology and Air Quality Analysis and Assessment," prepared for AMAX by International Environmental Consultants, Ltd.

TABLE 4-3

SEASONAL ANNUAL FREQUENCY (PERCENT) DISTRIBUTIONS OF STABILITY CLASSES FOR THE MACTUNG MINE SITE

Stability Class	Season: Winter	Spring	Summer	Fall	Annual
A	1.4	3.3	3.9	1.9	2.8
B	3.3	6.6	7.3	4.6	5.8
C	11.7	11.5	34.2	8.6	17.3
D	51.2	49.1	40.1	46.5	46.1
E	33.0	25.6	13.0	35.5	25.0
F	5.0	3.6	1.4	2.5	3.0

NOTE:

- Period of record: 1972-1982 AMAX data base. 17,237 cases evaluated; stability classes evaluated using σ_θ method suggested by Slade, P.H., 1966. Air Resources Laboratory, Report No. 3. U.S. Department of Commerce. Washington, D.C.

4.3 AIR QUALITY

Total suspended particulates data and dustfall data[1] were collected at both the mine site and the Tsichu River Airstrip during July, August and part of September of 1982. Two Hi-Vol samplers and six dustfall stations were used to obtain the data. Data from dustfall station numbers two through six were collected in the vicinity of the mine and data from dustfall station number one were collected at the Tsichu River Airstrip which is approximately 17 km east by east-northeast of the mine site. One Hi-Vol sampler was placed at each site.

Total suspended particulate samples were generally taken over a period of 24 hours. Three samples at each site were taken during July and 13 samples were collected at each site during August. Average suspended particulates for the Tsichu River Site and the mine site were 5.3 and 5.4 ug/m^3, respectively (Table 4-4).

Dustfall measurements were made with six dust jars. Dust jars, filled with distilled water, were left at sampling stations for periods of approximately 30 days. Dust and fallout trapped in the jars were analyzed in the laboratory to determine the proportion of material in each of six categories: insoluble solids; insoluble solids ash; soluble solids; soluble solids ash; total combustible solids; and total non-combustible solids. The analysis of dustfall in these categories gives some indication of the chemical nature and source of the particles which have been deposited in the jars. For example, ash levels may reflect concentrations of mineral dusts or mineral solid particles. Total combustible solid levels reflect to a large extent the presence of organic material such as plant parts, pollen or insects which have fallen into the sampler. The effect of organic matter from natural sources is seen in the data presented in Table 4-5 where combustibles account for a large percentage of the total dustfall. The

(1) total suspended particulates and dustfall are measures of suspended and unsuspended particulates respectively.

TABLE 4-4

TOTAL SUSPENDED PARTICULATES (IN MICROGRAMS PER CUBIC METER) AT THE TSICHU RIVER AIRSTRIP AND THE MACTUNG MINE SITE FOR JULY AND AUGUST, 1982

Sample Date[1]	Tsichu River	Mine Site
July 10	5.4	6.2
July 17	2.9	8.9
July 24	4.8	10.4
August 1	3.6	10.1
August 5	14.0[2]	7.4
August 7	4.9	4.5
August 9	3.3	3.5
August 11	11.5[3]	1.8
August 13	2.2	6.0
August 15	6.3	8.5
August 17	2.8	2.2
August 19	2.3	0.8
August 21	3.1	3.2
August 23	4.1	4.9
August 25	6.9	6.0
August 27	8.4	4.2
August 29	3.4	3.3
Average	5.3	5.4

NOTES:

[1] In many cases the sample period was initiated late in the day on the date indicated.

[2] Sample is of questionable value because of damage to filter (filter paper thin and torn).

[3] Sample is of questionable value because the Hi-Vol operated for a period of only 1.5 hours rather than the desired 24 hours.

TABLE 4-5

DUSTFALL MEASUREMENTS FOR THE TSICHU RIVER AIRSTRIP
AND THE MINE SITE, 8 JULY - 5 SEPTEMBER, 1982

	Tsichu River Airstrip		Mine Site										
Parameter Measured	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6		Average
Date	10/7-9/8	9/8-5/9	8/7-9/8	9/8-5/9	8/7-9/8	9/8-5/9	8/7-9/8	9/8-5/9	8/7-9/8	9/8-5/9	8/7-9/8	9/8-5/9	
Insoluble Solids ($mg/dm^2/day$)	0.03	0.04	0.06	0.07	0.04	0.03	0.06	0.04	0.06	0.04	0.05	0.54	0.09
Insoluble Solids Ash ($mg/dm^2/day$)	0.02	0.02	0.02	0.05	0.01	Tr.	0.03	Tr.	0.02	Tr.	0.02	0.42	0.05
Soluble Solids ($mg/dm^2/day$)	0.18	Tr.	0.10	Tr.	0.04	0.02	0.05	Tr.	0.05	Tr.	0.06	0.28	0.07
Soluble Solids Ash ($mg/dm^2/day$)	0.08	Tr.	0.06	Tr.	0.01	Tr.	0.02	Tr.	0.04	Tr.	0.02	0.13	0.03
Total Combustible Solids ($mg/dm^2/day$)	0.11	0.02	0.08	0.02	0.06	0.05	0.06	0.04	0.05	0.04	0.07	0.27	0.07
Total Non-Combustible Solids ($mg/dm^2/day$)	0.10	0.02	0.08	0.05	0.02	Tr.	0.05	Tr.	0.06	Tr.	0.04	0.55	0.08
Total Dustfall ($mg/dm^2/day$)	0.21	0.04	0.16	0.07	0.08	0.05	0.11	0.04	0.11	0.04	0.11	0.82	0.15

NOTES:

- All values adjusted for sample blank.
- All sample sites had large quantities of small flies removed by 20 mesh screen - explaining why combustibles are a large component of the total contents.

estimated average total dustfall at the Tsichu River Airstrip was 0.13 $mg/dm^2/day$ and the estimated average total dustfall at the mine site was 0.16 $mg/dm^2/day$ (Table 4-5).

Both total suspended particulates and dustfall in the six categories were very low at all sites for all sample periods. These results are consistent with what one might expect for a remote site largely devoid of human settlements and sources of natural or industrial particulates.

Details of the study can be found in the companion report entitled "MacTung Meteorology and Air Quality Analysis and Assessment," prepared for AMAX by International Environmental Consultants, Ltd.

4.4 TERRAIN

A 500 km^2 area straddling the border of the Yukon and Northwest Territories was selected as the basis for terrain, vegetation and wildlife studies which are described in the component reports and summarized in this document (Figure 4-1). The drainage of a secondary tributary to the Hess River forms the western portion of the study area with the western most edge approximately 9 km west of the mine site at an elevation of 1036 m. The Tsichu River drainage forms the eastern portion of the study area with the eastern most edge approximately 28 km east of the mine site at an elevation of 1160 m. The western portion is part of the Yukon River drainage basin while the eastern portion is within the Mackenzie River drainage basin. The Continental Divide, at elevations ranging from about 1615 m to 2438 m, separates these major drainages and forms the Yukon/Northwest Territories border.

4.4.1 GEOMORPHOLOGY

Landscapes of the study area vary from flat-lying to almost vertical relief that has been sculpted, primarily by glacial erosion. The area is almost treeless east of the Divide and forest stands occur only at lower elevations in the Yukon portion of the study area. The entire area falls within the discontinuous permafrost zone; however, with a mean annual temperature range of -7.7°C to -8.5°C, the area should perhaps be described as bordering the continuous permafrost zone.

Geomorphological features of the area were categorized as: glacial landforms, (glacierets, mammaliated surfaces, ice-molded features and moraines); glacio-fluvial landforms (outwash channels, kames, eskers and outwash plains); periglacial landforms (rock glaciers, debris slopes, palsas and peat plateaus, blockslopes, gelifluction slopes and patterned ground); landforms produced by mass-wasting (landslides); fluvial landforms (mudflows, flood plains, and alluvial fans); organic landforms; and bedrock. It is recognized that these landform categories are not necessarily mutually exclusive. For example, organic deposits might also be classified as permafrost features if palsas or peat plateaus are present.

Existing glaciers in the area are only remnant forms and therefore have been classified as glacierets. Glacierets exist along the Continental Divide at elevations above 2075 m on certain north-facing slopes and evidence indicates they are presently receding. Rock glaciers, however, appear to be active. Well developed rock glaciers occur along the north facing slope of Dale Valley.

Only one major type of destructive fluvial landform occurs in the study area, that of V-shaped fluvially-incised valleys. A number of such features, 3 to 6 m deep, are present in the higher elevation valleys. Running water has had relatively little time to etch the land because high alpine areas are estimated to have been deglaciated for approximately 8000 years. Furthermore, the period during which water actually erodes at this latitute and elevation is only three to four months each year.

Alluvial fans in the study area are recognized by their uniform vegetative cover. An example of an alluvial fan in the study area is one formed by the major tributary to Cirque Creek. Where permafrost is not present, as in the Cirque Creek tributary fan, precipitation infiltrates and percolates through the ground creating a dry growth medium which supports a drought-tolerant lichen cover or a lichen-heath vegetation type. North-facing fans underlain by permafrost create and maintain a moist growth medium and may support a meadow vegetation.

A portion of the area selected for the tailing pond is apparently a lacustrine deposit, formed from fine sediment being deposited by stream action into standing water. After deglaciation, a lake approximately 1.6 km in length was apparently formed behind the drumlin at the mouth of Dale Valley. Within this lake, a layer of silts and clays was deposited, averaging at least 1.2 m (4 ft.) in thickness.

The area slated for the plant site is a good example of bedrock blockfields with thin colluvium and patterned ground. Numerous palsas exist within the study area. The most common type of palsa found in the study area is the type with a core of mineral soil (as opposed to a core of peat).

4.4.2 SOILS

The black shales of the area are slightly carbonaceous and field treatment with acid indicated some CO_2. There appears to be sufficient carbonate content in the colluvium to provide buffering stability. The carbonate is also reflected in the soil which normally ranges from neutral to slightly basic, thereby being suitable for a wide variety of plant species.

The lack of well developed profiles is one of the overriding characteristics of arctic-alpine soils. Regosols occur at high elevations in association with till deposits. Brunisols generally occur at lower elevations in well drained locations. Organosols have developed in depressions where fen and bog accumulations have produced thick peat deposits. In favourable sites where surface organic layers provide sufficient insulation, Cryosols have developed. Soils are generally absent at the highest elevations and on steeply angled slopes where geomorphological processes prevent or reduce the effectiveness of pedogenic processes. Soils are not strongly developed because of low soil temperatures and slow rates of plant production and organic matter accumulation and decomposition.

Macro-nutrient analyses were performed on soil samples which were or would be exposed during construction (Table 4-6). As would be expected, nutrient levels are low.

Additional details and a map can be found in the companion report entitled "Geomorphology and Vegetation of the MacTung Study Area, Yukon/N.W.T." prepared for AMAX by Arctic and Alpine Environmental Consulting.

4.5 HYDROLOGY

The proposed MacTung development will require water use for various purposes including:

a) Consumptive Use

Potable water supply
Fire fighting water supply
Industrial (in plant) water
Sewage water supply

b) Disposal Use

Sewage Disposal
Tailing Disposal

AMAX proposes to use Cirque Lake (and catchment) for the supply of consumptive waters and Dale Creek for liquid waste disposal purposes. Both drainages flow to the Tsichu River (Mackenzie drainage), and all surface flows lie within the Northwest Territories near the

TABLE 4-6

MACRO-NUTRIENT ANALYSIS OF SOILS IN THE MACTUNG AREA

Nutrient	Range (10 Samples)
Available Phosphorus (ppm)	<0.005-0.98
Exchangeable Potassium (me/100g)	0.049-0.24
Total Nitrogen (%)	0.009-0.98

Yukon/N.W.T. border between elevations 1525 m and 2290 m. Dominant aspect is to the east within the Hess Mountains, which are part of the Selwyn Mountains with the Mackenzie Mountains and Canyon Ranges to the east.

Base winter flows occur probably due to valley bottom groundwater outflow under ice cover in discontinuous permafrost. Peak freshet flows occur in June due to rapid snowmelt often accompanied by rainfall. During summer and the early fall storm rainfall events can produce significant peak flows.

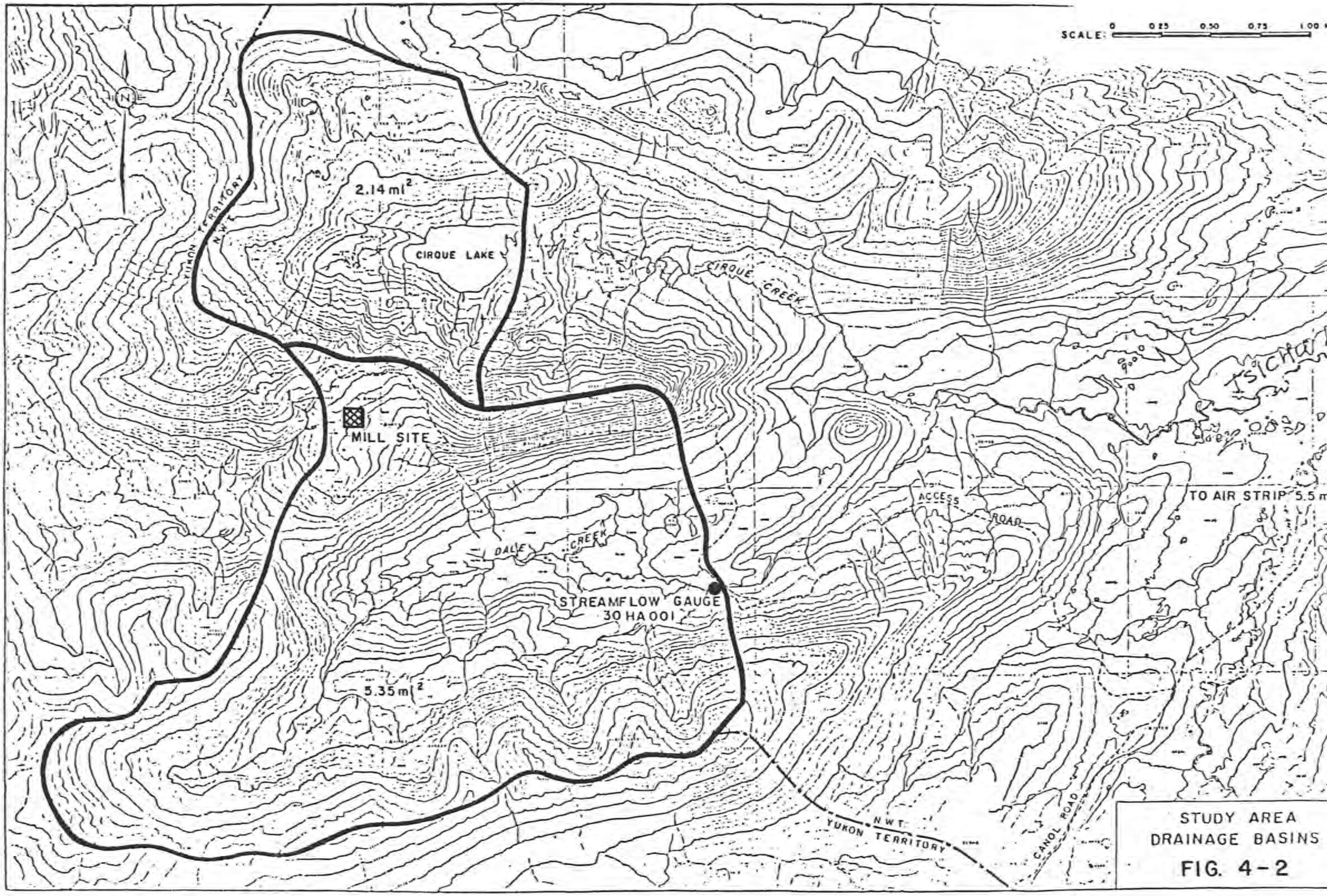
The principal drainage features in the study area are described below and shown in Figure 4-2.

4.5.1 CIRQUE CREEK

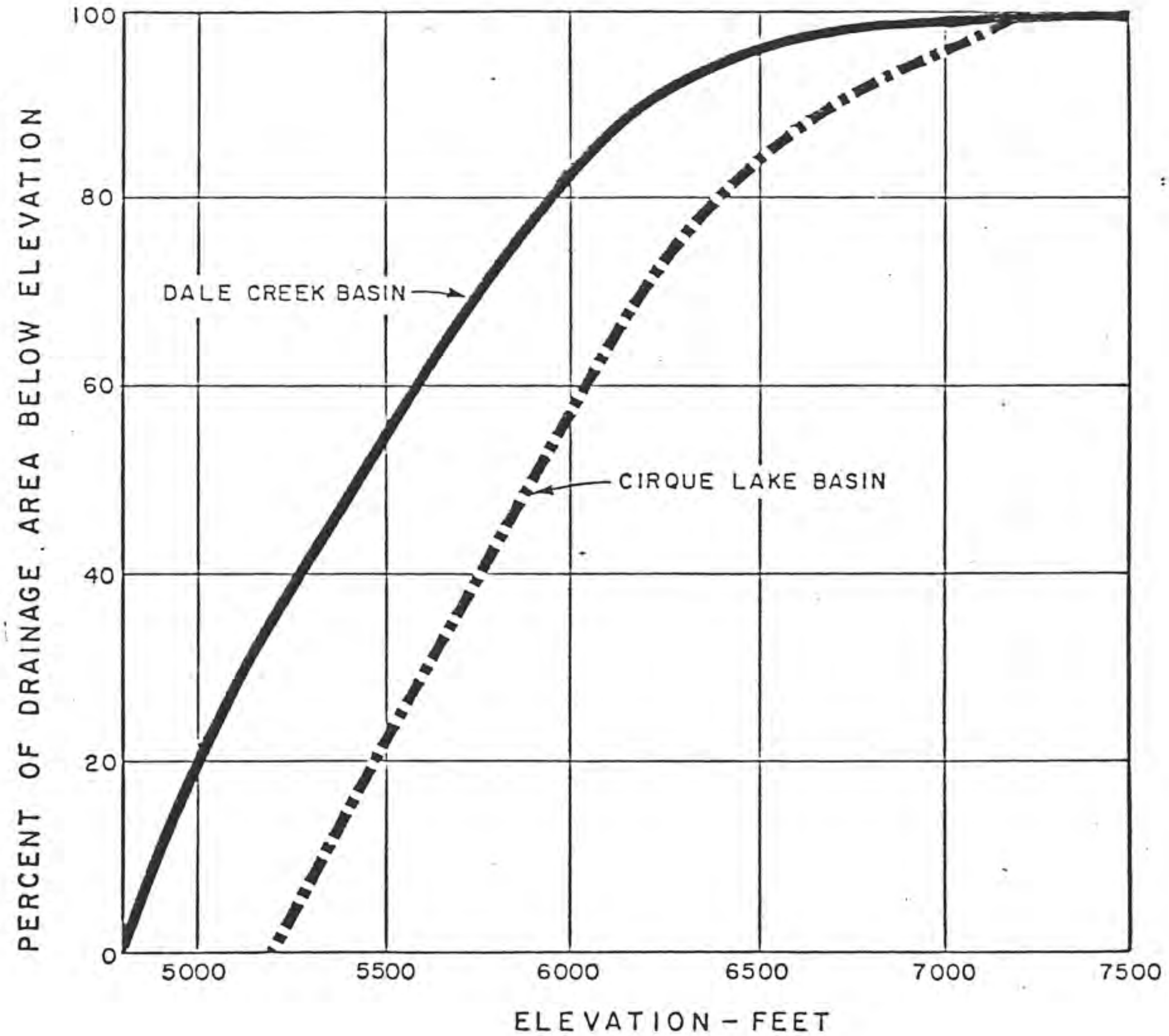
Cirque Creek headwaters lie on the Yukon/N.W.T. border at elevations ranging from 1800 m to 2200 m. The highest parts of the basin drain steeply on bedrock to Cirque Lake which at its mouth has a catchment of 5.54 km^2. The outflow from Cirque Lake only appears at the surface during high flow periods, due to a rock slide at the downstream side of the lake. All other flows seep to groundwater or filter through the slide debris and appear at the surface in Cirque Creek up to 0.5 km downstream from the lake. The stream below Cirque Lake has a mean gradient of approximately 6.7%. Cirque Creek, 3.7 km below Cirque Lake, joins Dale Creek where the gradient is much reduced being approximately 0.6% down to the old airstrip.

4.5.2 DALE CREEK

Dale Creek also originates at elevations up to 2200 m. However, the area elevation curves shown in Figure 4-3, show that Dale Creek has a larger percent of its drainage basin below equivalent areas than Cirque Creek. Other than in its remote headwaters the gradient of Dale



STUDY AREA
DRAINAGE BASINS
FIG. 4-2



DRAINAGE BASIN AREA ELEVATION CURVES

FIG. 4-3

Creek is less than Cirque Creek. From a point approximately 2.5 km above the access road crossing of Dale Creek, to the crossing, the gradient averages 1.6%; and 3.6% below the crossing to the confluence with Cirque Creek. Catchment to the access road crossing is 13.86 km^2.

The hydrologic regime of these two creeks has been reported by numerous authors using the following:

- Spot discharge mesurements by DINA (see Orecklin 1981) and project personnel working in the area between 1972 and 1978.
- Using the Water Survey of Canada gauge #10HA002 on the Tsichu River which began operations in 1975 and has a catchment of 222 km^2 (Figure 4-4 shows a typical hydrograph for 1978).
- Review of other northern streamflow data.
- Review of meteorological data.

The hydrologic analyses, however, suffer from a lack of specific data for the two streams in the study area. A synthetic hydrograph for Dale Creek and Cirque Lake is shown in Figure 4-5.

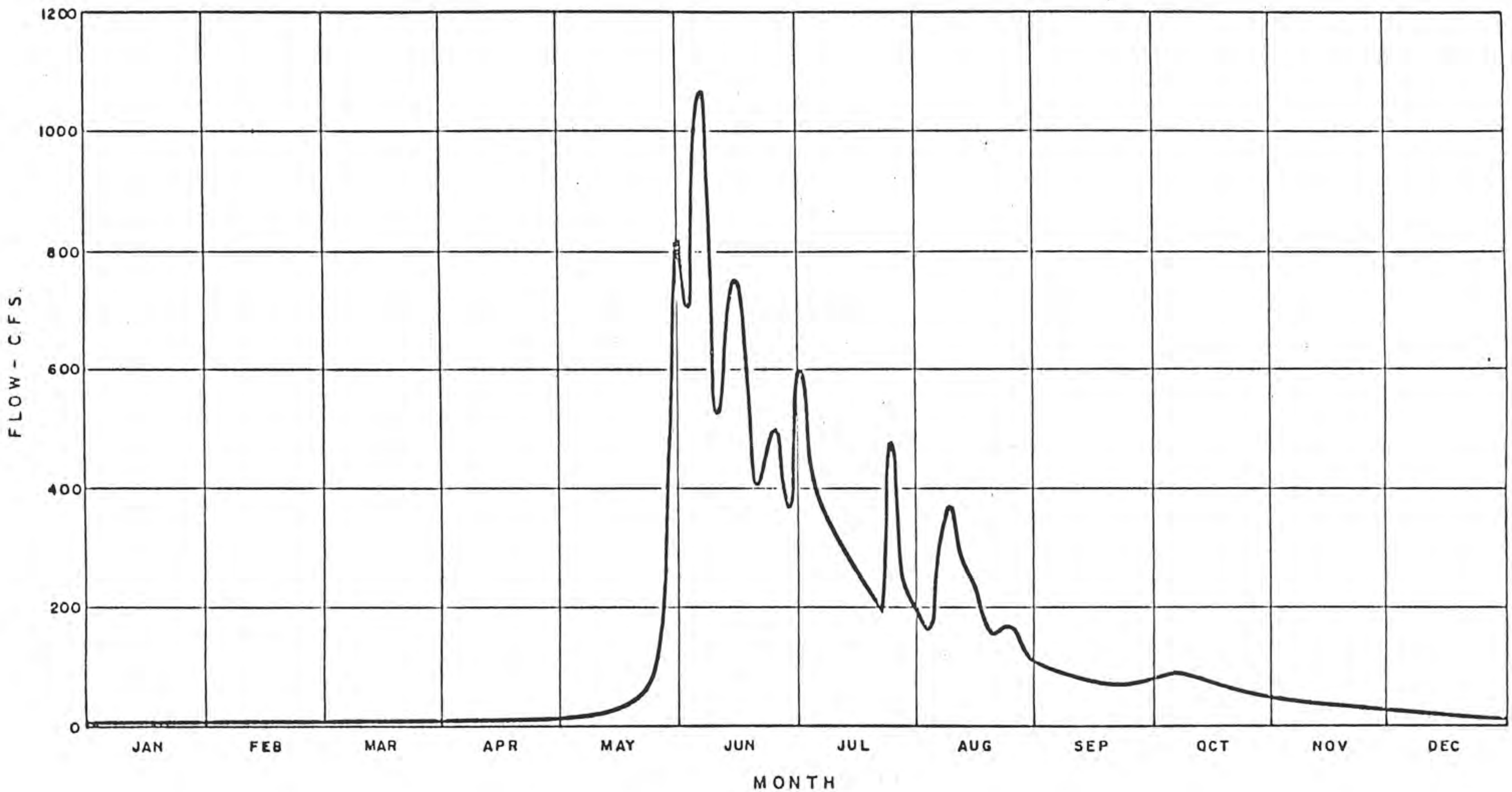
In 1982 the Department of Indian Affairs and Northern Development extended operation of its gauge #30HA001 (part of the small streams survey) on Dale Creek, at the access road crossing, to include the whole open water period.

The data indicates:

a) Dale Creek at the Access Road Crossing

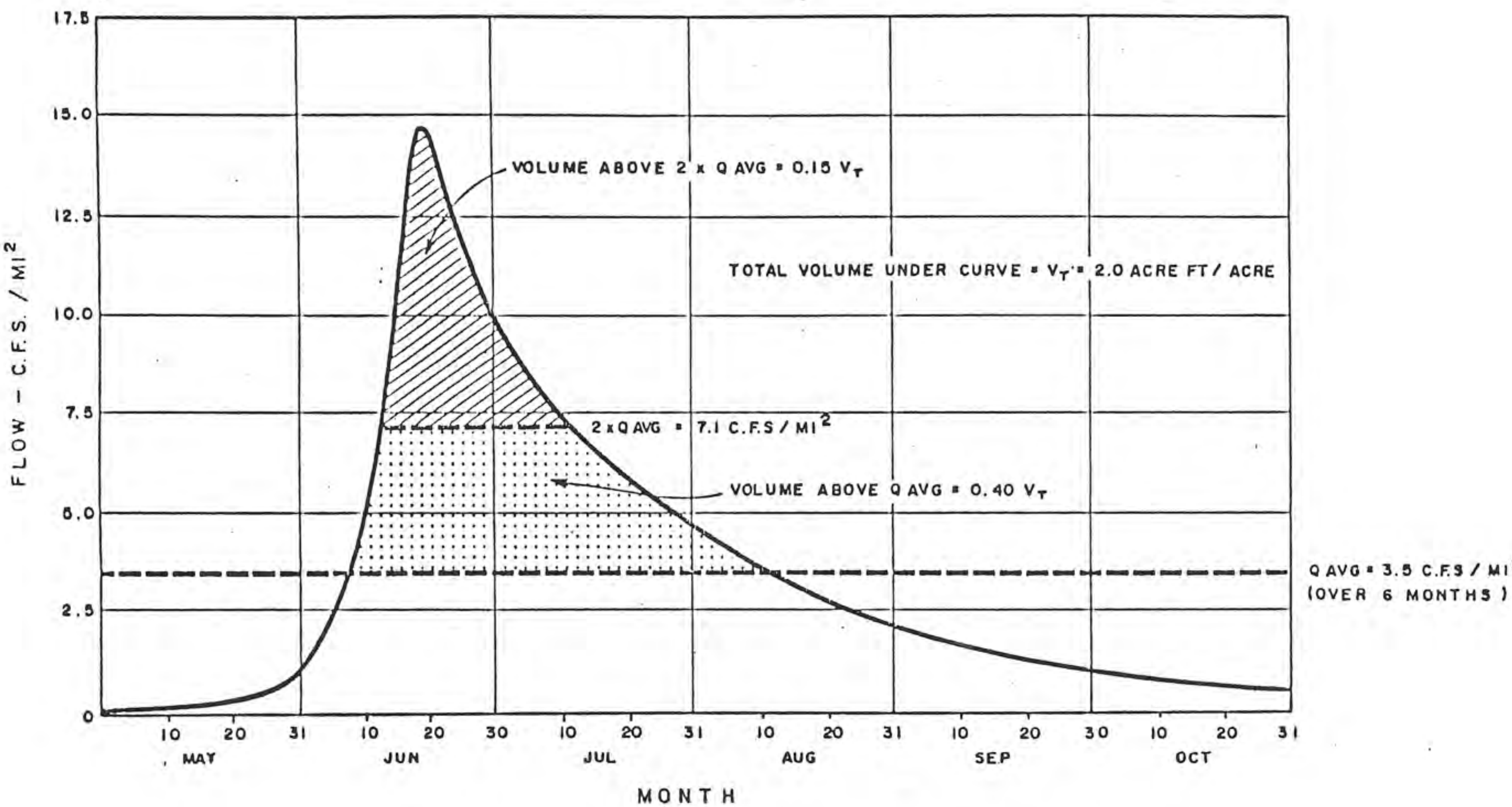
Mean Annual Runoff - Upper Limit - 82.3 cm or 0.359 m^3/s/day

- Lower Limit - 54.9 cm or 0.239 m^3/s.



ESTIMATED 1978 ANNUAL HYDROGRAPH
FOR THE TSICHU RIVER

FIG. 4-4



SYNTHETIC HYDROGRAPH FOR
DALE CREEK AND CIRQUE LAKE BASINS

FIG. 4-5

Flood Flows	- 10 yr. return period	7.57 m^3/s*
	- 25 yr. return period	10.60 m^3/s
	- 100 yr. return period	21.21 m^3/s*
	- MPF	45.45 m^3/s

*Corresponding values from Department of Indian Affairs and Northern Development are 4.70 m^3/s and 6.51 m^3/s.

b) Cirque Creek at the Mouth of Cirque Lake

Mean Annual Runoff - Upper Limit - 82.3 cm or 0.143 $m^3/s/day$

- Lower Limit - 54.9 cm or 0.096 $m^3/s/day$

Flood Flows	- 10 yr. return period	3.03 m^3/s*
	- 25 yr. return period	4.24 m^3/s
	- 100 yr. return period	8.48 m^3/s*
	- MPF	18.18 m^3/s

*Corresponding values from Department of Indian Affairs and Northern Development are 1.88 m^3/s and 2.61 m^3/s.

It should be noted that the mean annual runoff calculated to a mean annual daily flow is not the base winter flow. The base winter flow would likely be lower (note that Gill, 1974 reported for Cirque Creek a flow of 0.057 m^3/s or 2 cfs in February 1974, as compared to a lower limit for the mean annual daily flow of 0.096 m^3/s or 3.4 cfs). In addition, considerable variation on the estimated peak flows exists. In 1981 staff gauges were installed on Dale Creek above the tailing pond and on Cirque Creek. In 1982 these staff gauges were replaced with continuous flow gauges. Results from these gauges are not yet available.

4.5.3 GROUNDWATER

In 1982 a well monitoring program was undertaken in which five wells were drilled in Dale Creek valley downstream of the tailing pond (Figure 4-6), ranging in depth from 4.3 m to 21.4 m. The objective was to assess transmissivity and permeability, and to obtain samples for testing groundwater quality. The results were as follows:

Well No.	Transmissivity	Permeability
MW-1	5.57 m^2 (60 ft^2/day)	0.002 cm/s (6 ft/day)
MW-2	2.79 m^2 (30 ft^2/day)	0.001 cm/s (4 ft/day)
MW-3	83.61 m^2 (900 ft^2/day)	0.03 cm/s (75 ft/day)
MW-4	2.79 m^2 (30 ft^2/day)	0.01 cm/s (3 ft/day)
MW-5	Dry hole	

These wells have the potential to serve as future monitoring points.

Groundwater flows are poorly understood in terms of volumes, variations (spatial and temporal) and pathways. Complex geological structures, variable surficial materials, discontinuous permafrost, expected base winter flows originating from groundwater are mostly speculative. Perhaps most relevant are two important observations:

- outflow from Cirque Lake is groundwater dominated except at high flows
- the presence of base winter flows is indicative of sustained groundwater inflow to streams in the main valleys throughout the year.

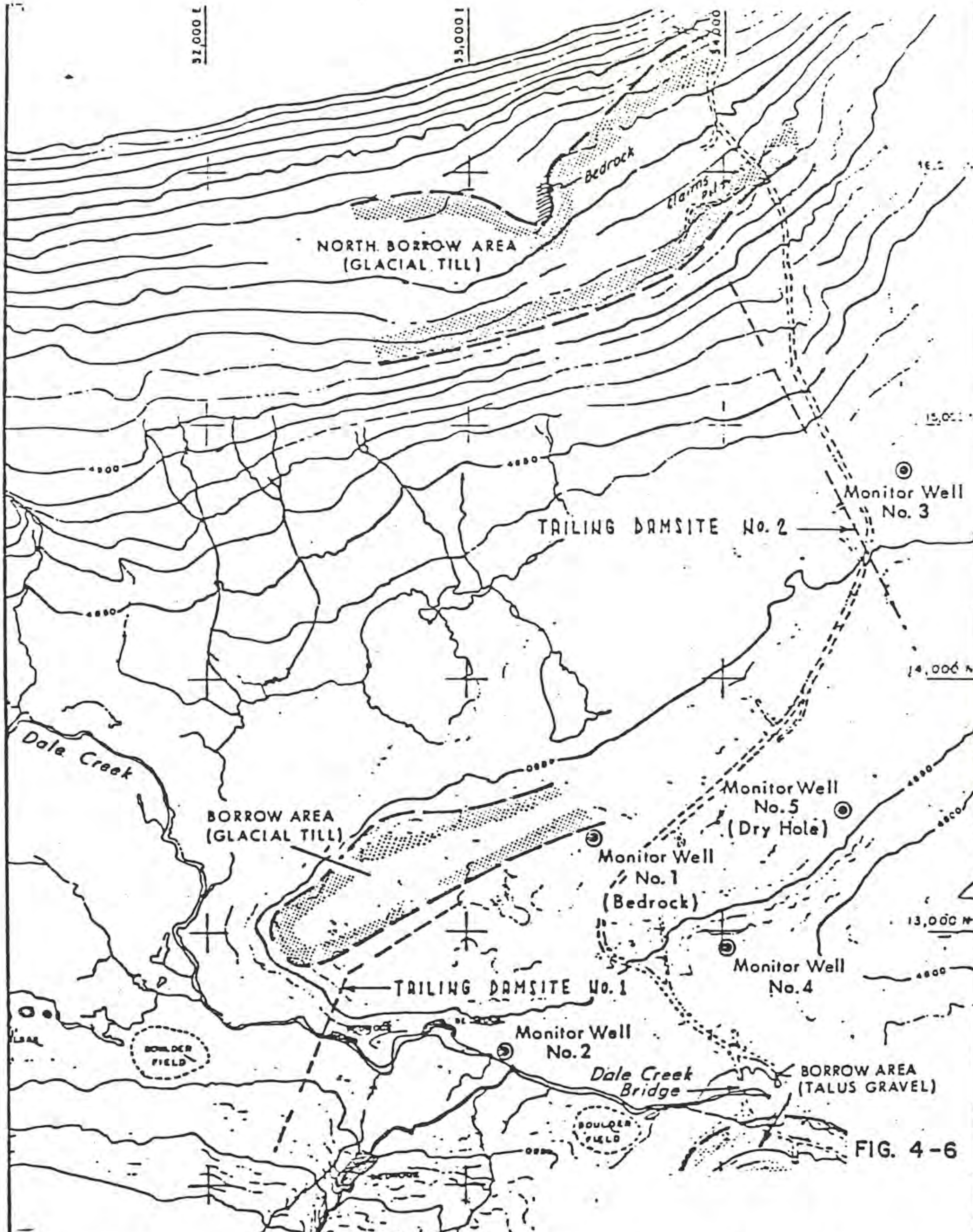


FIG. 4-6

Note: Adapted from Figure 6 in "Report to Amax Northwest Mining Company Ltd. on Geotechnical Investigations for Tailing Disposal at Mactung" by: Golder Associaltes, Feb. 1981.

LOCATION OF MACTUNG TAILING AREA MONITOR WELLS

4.6 WATER QUALITY

4.6.1 INTRODUCTION

Water chemistry analyses were performed each year from 1973 through 1981, with the exception of 1979. Sites which received major emphasis through the years were upper Dale Creek, Cirque Creek, lower Tsichu River (2 km downstream of the Dale Creek confluence), lower Tsichu River at the Bridge, upper Tsichu River at the Bridge, Cirque Lake, various branches of the Hess River tributaries, and Airstrip Pond. Stream reaches are shown in Figure 4-7 with the exception of the Hess drainage, which is the network of streams on the Yukon side of the Continental Divide. In addition, contamination of the upper Tsichu River was traced to its source and analyses were performed on stream sediments collected throughout the system. Results of these analyses are discussed and summarized in tabular form.

4.6.2 UPPER DALE CREEK

Water quality in Dale Creek was generally good. Table 4-7 shows the ranges of values and number of samples analyzed for Dale Creek and the other major streams in the system.

The pH values of Dale Creek were fairly uniformly distributed throughout the range 6.9 to 8.0 (Table 4-7). The stream was generally clear, that is, most turbidities were `1.0 J.T.U. (Jackson Turbidity Units) with the exception of 12 July, 1977 when turbidity was 7.0 J.T.U. The stream can become turbid during periods of high runoff. Conductance and dissolved solids had fairly even distribution from 42.8 to 209.0 umhos/cm and 1.5 to 172.0 mg/L, respectively. Values for suspended solids were generally below 33.0 mg/L with one exception of 53.0 mg/L. Nitrate and phosphate were somewhat higher than expected, reaching levels of 1.8 mg/L and 22.5 ug/L, respectively. Dissolved fluoride levels were low, ranging from 0.038 to 0.43 mg/L. Dissolved sulfate values were slightly higher than anticipated, with fairly even distributions ranging from 5.9 to 45.7 mg/L.

TABLE 4-7

SUMMARY OF WATER QUALITY DATA OF THE MAJOR STREAMS IN THE SYSTEM, 1973-1981. NUMBER OF SAMPLES IS SHOWN IN PARENTHESES PRECEEDING THE RANGE VALUES. (ALL VALUES IN mg/L UNLESS OTHERWISE SPECIFIED. T = TOTAL; D = DISSOLVED; E = EXTRACTABLE; P = PARTICIPATE).

Parameter	RANGE				
	Upper Dale Creek	Lower Tsichu River	Lower Tsichu Bridge	Upper Tsichu Bridge	Cirque Creek
Physical Properties					
pH	(21) 6.9-8.0	(6) 7.1-8.5	(17) 7.0-8.0	(12) 4.7-7.3	(20) 6.7-7.7
Turbidity (J.T.U.)	(22) 0.14-7.0	(9) 0.28-17.0	(19) 0.17-9.1	(16) 0.14-4.4	(20) 0.15-2.90
Color (Co - Pl units)	(19) <5.0-30.0	(9) <5.0-20.0	(19) <5.0-25.0	(14) <5.0-11.0	(19) <5.0-30.0
Conductance (umhos)	(23) 42.8-209.0	(8) 34.0-110.0	(16) 41.1-124.0	(10) 65.8-134.0	(20) 27.0-117.0
Suspended Solids	(17) Nil-53.0	--	(10) <1.0-31.2	(3) <1.0-5.0	(13) Nil-24.6
Dissolved Solids	(18) 1.5-172.0	--	(9) 5.6-87.0	(3) 93.0-99.0	(12) 18.8-92.0
Total Solids	(1) 53	--	(1) 44.0	--	(1) 25.0
Res: NF (105°C)	(4) 1.3-53.0	(1) 61.8	(5) 3.6-47.5	(3) 4.8-86.0	--
Res: NF Fixed (550°C)	(3) 1.0-3.6	(1) 52.5	(5) <1.0-37.5	(3) 2.8-42.0	--
Nutrients					
NH_3-N	(2) 0.006-0.045	--	(1) 0.008	--	(1) 0.015
Nitrate NO_3	(13) 0.03-1.8	--	(7) <0.02-0.8	(4) 0.05-0.203	(11) 0.05-2.7
Nitrates	(1) <0.01	--	(1) <0.01	--	(1) <0.01
Nitrogen - T	(2) 0.36-0.62	--	(3) 0.22-0.66	(3) 0.22-0.53	(2) 0.55-1.0
Nitrogen - P	(3) 0.006-0.011	--	(3) 0.007-0.010	(3) 0.012-0.018	(2) 0.006-0.011
NO2+NO3 as N	(9) 0.002-0.113	(1) <0.01	(9) <0.01-0.089	(5) 0.010-0.127	(9) <0.002-0.73
Dissolved Nitrogen	(3) 0.113-0.115	--	(5) 0.04-0.153	(3) 0.053-0.188	(4) 0.011-0.152
Phosphate - T (μg/L)	(9) <2.0-22.5	--	(3) <2-22.5	--	(7) <2-7.5
Phosphorus - T	(3) 0.009-0.058	--	(4) <0.01-0.048	(3) <0.002-0.101	(2) 0.01-0.048
Chemical-Inorganic					
Chloride - D	(14) 0.1-<1.0	(2) 0.3-<0.5	(15) <0.1-2.3	(7) <0.1-0.3	(12) <0.1-<1.0
Fluoride - D	(12) 0.038-0.43	(1) 0.049	(12) 0.044-0.21	(10) 0.059-0.37	(10) 0.042-0.125
Bicarbonate as CO_3	(3) 37.0-83.0	--	(3) 25.4-30.4	(4) 7.0-23.0	(3) 16.0-22.2
Reactive Silica	(3) 3.9-18.0	--	(4) 3.8-4.4	(2) 4.8-20.0	(3) 0.59-4.1
Sulphate - D	(23) 5.9-45.7	(7) 10.6-33.5	(22) 9.0-39.5	(15) 20.1-58.0	(22) 5.0-24.5
T.I.C.	(7) 4.0-16.3	--	(7) 2.4-6.8	(4) 0.7-5.4	(5) 1.4-4.7
Tot. Alk. as CaCO3	(30) 12.0-77.0	(9) 7.6-24.4	(22) 9.4-24.9	(17) 0.0-40.0	(29) 7.0-35.7
Tot. Hard. as CaCO3	(31) 16.8-117.0	(8) 17.4-49.2	(23) 19.0-64.6	(18) 18.3-63.9	(29) 18.3-53.8

TABLE 4-7 (Cont'd)

SUMMARY OF WATER QUALITY DATA OF THE MAJOR STREAMS IN THE SYSTEM, 1973-1981.
NUMBER OF SAMPLES IS SHOWN IN PARENTHESES PRECEEDING THE RANGE VALUES. (ALL VALUES IN mg/L UNLESS OTHERWISE SPECIFIED. T = TOTAL; D = DISSOLVED; E = EXTRACTABLE; P = PARTICIPATE).

	RANGE				
Parameter	Upper Dale Creek	Lower Tsichu River	Lower Tsichu Bridge	Upper Tsichu Bridge	Cirque Creek
Metals					
Arsenic - E	(11) 0.0005-<01	(3) 0.003-<0.005	(12) 0.0001-<0.01	(11) 0.0001-<0.01	(11) 0.0005-<0.01
Boron - D	(5) 0.0005-<0.005	--	(1) <0.005	(2) <0.005-<0.010	(2) <0.005-<0.01
Cadmium - E	(19) <0.0002-<0.01	(3) 0.0006-<0.001	(18) 0.0002-<0.001	(14) 0.0006-0.007	(15) <0.0002-<0.01
Calcium - D	(14) 8.2-39.0	(2) 4.3-12.5	(14) 5.3-110.0	(11) 7.0-20.0	(12) 6.9-13.0
Chromium - E	(13) 0.001-0.02	--	(13) 0.001-0.02	(10) 0.002-0.02	(8) 0.001-0.01
Cobalt - E	(14) <0.001-<0.02	(1) 0.001	(13) <0.001-<0.02	(11) <0.001-<0.02	(10) <0.001-<0.02
Copper - E	(33) <0.001-0.015	(8) 0.001-0.011	(27) <0.001-0.01	(19) <0.001-0.043	(29) <0.001-0.01
Iron - E	(29) <0.01-1.0	(8) 0.067-1.2	(22) 0.001-1.2	(17) 0.009-2.89	(29) 0.005-<1.0
Lead - E	(25) <0.001-0.010	(8) <0.001-0.005	(24) <0.001-<0.10	(19) <0.001-<0.01	(21) <0.001-<0.1
Magnesium - D	(10) 1.1-4.0	(1) 1.6	(9) 1.4-3.3	(8) 2.2-4.2	(9) 0.2-1.1
Manganese - E	(20) 0.003-0.05	(8) <0.001-0.3	(19) <0.002-0.11	(17) <0.002-0.111	(20) <0.002-0.11
Mercury (µg/L)	(14) <0.05-<0.4	(1) <0.05	(14) <0.01-<0.5	(9) <0.0001-<0.1	(10) <0.05-3.0
Molybdenum - E	(13) 0.0006-<0.3	(1) 0.0005	(22) <0.0005-<0.3	(8) <0.0005-<0.002	(9) 0.0005-<0.3
Nickel - E	(20) <0.001-<0.01	(3) <0.001-0.012	(18) <0.002-0.02	(14) 0.002-0.197	(17) <0.001-<0.02
Potassium - D	(11) 0.5-1.0	(1) 0.6	(13) 0.20-0.7	(9) 0.3-0.4	(10) 0.4-0.51
Selenium - E	(13) 0.0008-0.01	(3) 0.0003-<0.001	(13) 0.0005-<0.010	(12) 0.0005-<0.01	(12) <0.0001-<0.010
Silver - E	(12) <0.001-0.03	--	(13) <0.001-0.03	(8) <0.001-0.005	(12) <0.001-<0.03
Sodium - D	(12) <0.2-0.60	(1) 0.3	(13) 0.2-0.6	(9) 0.2-0.30	(9) <0.2-0.35
Tungsten - E	(15) <0.05-<10.0	(3) <0.016-<10.0	(14) 0.016-<10.0	(10) <0.5-<10.0	(13) <0.05-<10.0
Zinc - E	(23) 0.003-0.006	(8) 0.003-0.06	(22) 0.006-0.08	(19) 0.006-0.79	(23) 0.001-0.032
Chemical-Organic					
Carbon - P	(3) 0.037-0.12	--	(3) 0.053-0.12	(3) 0.015-0.20	(2) 0.054-0.12
Carbonate as CO_3	(2) <0.1-<0.1	--	(2) <0.1-<0.1	(2) <9,1-<0.1	(1) <0.1
C.O.D.	(4) <0.01-<10.0	--	(5) <1.0-<50.0	(3) <1.0-<10.0	(4) <1.0-<50.0
D.O.C.	(1) <1.0	--	--	--	(1) <1.0
Phenolics	(2) <0.0005-<0.002	--	(3) 0.0005-<0.0005	(2) <0.0005-<0.002	(2) 0.0005-0.002
TOC	(6) <1.0-2.2	--	(7) 1.0-4.0	(4) <1.0-1.6	(5) <1.0-3.7
Cyanide - T	(5) 0.0005-<0.005	--	(4) <0.002-<0.005	(4) <0.001-<0.005	(3) <0.002-<0.005

Figure 4-7 STREAM SURVEY MAP

SCALE: 4 cm = 1.0 km

The water was weakly buffered with total alkalinity ranging from 12.0 to 77.0 mg/L. Dale Creek was generally soft, with most hardness values falling below 70.0 mg/L and only 4 of 31 samples exceeding 100 mg/L. As expected, concentrations of major ions, hardness, alkalinity and dissolved solids fluctuated inversely to stream flow.

Levels of essentially all metals were low, often with concentrations below detection limits, and relatively constant throughout the year. According to McKee and Wolf (1974) all metals, with the possible exception of iron (which ranged up to 1.0 mg/L) were present at concentrations not considered deleterious to fish. Clarke (1974) reported that incubated spawn of Arctic Cisco (Coregonus Automnalis) were killed at concentrations of 0.52 mg/L iron, although these fish were not found in the MacTung drainage system.

4.6.3 TSICHU RIVER

Results from the three sampling stations in the Tsichu River (Table 4-7) indicate that it was a slightly turbid, soft water, and weakly buffered stream with quality which improved with distance from its headwater.

4.6.3.1 Upper Tsichu River

The water sampled at the upper Tsichu River Bridge (Figure 4-7) upstream of the Dale Creek confluence frequently was acidic, ranging between 4.7 and 7.3; of the 12 pH determinations, only 3 were 7.0 or greater. Alkalinity ranged from 0.0 to 40.0 mg/L and hardness ranged from 18.3 to 63.9 mg/L, both slightly lower values than those of Dale Creek. Dissolved sulphate concentrations were somewhat elevated, ranging from 20.1 to 58.0 mg/L. Quantities of metals such as iron (0.009 to 2.89 mg/L), copper ($<$0.001 to 0.043 mg/L), and zinc (0.006 to 0.79 mg/L) were also higher than in Dale Creek.

The headwater area of the Tsichu River contains black pyrite shale from which acid drainage is not uncommon. In such areas, red coloured, acidic water can be produced through oxidation of pyrite which in turn dissolves quantities of iron and sulphate. On contact with more alkaline water precipitation of iron in the form of siderite ($FeCo_3$) and calcium sulphate results. Siderite is visible as a red stain, while calcium sulphate is a white precipitate. Both conditions were present in the upper Tsichu River drainage, and noticeable to the extended braided channel section upstream of the lower Tsichu Bridge (Figure 4-7).

Rust Creek, a tributary to the upper Tsichu River, periodically turns red in color as a result of acid drainage from springs in its headwater area. On 31 July 1981 the pH in Rust Creek was measured at 3.85. The concomitant pH was 6.1 in the Tsichu River upstream of Rust Creek. The pH of the combined flows in the Tsichu River at the upper Tsichu River Bridge was 4.7. During this event, water samples for metal analyses were collected from Rust Creek and at the upper Tsichu River bridge. The results from Rust Creek illustrate the increased levels of metals such as copper (0.176 mg/L), nickel (0.25 mg/L), zinc (0.90 mg/L), and particularly iron (345.0 mg/L) under acidic conditions. Although metal values were lower in the sample collected at the upper Tsichu River Bridge (copper: 0.043 mg/L, nickel: 0.197 mg/L, zinc: 0.79 mg/L, iron: 2.89 mg/L), a review of Clarke (1974) indicates that the values for zinc, copper, and iron exceed reported lethal levels for several species of fish and invertebrates.

4.6.3.2 Lower Tsichu River

The two Tsichu River stations located downstream of the Dale Creek confluence had comparitively high pH's. In contrast to the upper Tsichu River, of 23 pH determinations at two sample sites in the lower Tsichu River, all were 7.0 or greater. Concentrations of iron, copper, and zinc were lower (Table 4-7), indicating that Dale Creek had a moderating effect on the poorer water quality of the upper Tsichu River.

4.6.4 CIRQUE LAKE

Water quality data of Cirque Lake at various depths and locations are summarized in Table 4-8. Cirque Lake water is of excellent quality in terms of potability and growth and survival of fish. Environment Canada's Environmental Protection Service (1976) noted that in terms of conductivity and total dissolved solids, Cirque Lake water was comparable to distilled water.

Waters are generally soft, poorly buffered (alkalinity range: 6.0 to 20.0 mg/L as $CaCO_3$), colorless, and low in conductance and dissolved solids. Field pH determinations ranged from 6.8 to 7.6 and all pH's ranged from 6.3 to 7.8 (Table 4-8). Phosphate ranged from 0.002 mg/L to 0.120 mg/L. With the exception of iron and magnesium, metals generally were below detection limits. Water transparency was 8.0 m under overcast skies.

Although a thermocline was evident between 4.5 m and 6.0 m, dissolved oxygen and conductivity did not vary significantly between the surface and 21 m. Nitrates, organic nitrogen and phosphate were appreciably greater in concentration at lower depths compared to surface water samples (Table 4-8).

4.6.5 CIRQUE CREEK

Cirque Creek water quality data is summarized in Table 4-7. Basically, the quality of the stream reflected the quality of the lake. The stream remained clear throughout the seasons with turbidities ranging from 0.15 to 2.90 J.T.U. Dissolved solids, hardness, and major iron content were all low, with no significant seasonal variation. The pH ranged from 6.7 to 7.7. Water was soft with seasonal values ranging from 18.6 to 53.8 mg/L as $CaCO_3$. Most metal concentrations were at or below their detection limits. Iron ranged in concentration from 0.005 to <1.0 mg/L.

TABLE 4-8

SUMMARY OF WATER QUALITY DATA FOR CIRQUE LAKE, 1973-1977. NUMBER OF SAMPLES IS SHOWN IN PARENTHESES PRECEEDING THE RANGE VALUES. (ALL VALUES IN mg/L UNLESS OTHERWISE SPECIFIED. T=TOTAL: D=DISSOLVED; E=EXTRACTABLE; P=PARTICULATE).

Parameter	Range		
	Surface	Mid-Depths	Bottom
Physical Properties			
pH	(25) 6.4-7.8	(16) 6.3-7.4	(15) 6.5-7.6
Temperature (°C)	(10) 8.0-9.0	(15) 4.2-8.4	(8) 3.9-8.0
Turbidity (J.T.U.)	(3) 0.25-<1.0	(2) 0.5-<1.0	
Color (Co-Pl units)	(3) 0.0-<5.0	(2) 0.0-<5.0	
Conductance (umhos)	(11) 15.0-20.0	(17) 18.0-25.4	(7) 18.8-28.0
Suspended Solids	(11) 0.2-10.4	(7) <1.0-126.4	(7) 0.2-37.8
Dissolved Solids	(14) 12.0-34.2	(6) 31.2-36.2	(7) 26.2-37.2
Total Solids	(2) 4.8-16.0	(2) 9.5-22.0	
Dissolved Oxygen	(11) 9.7-11.9	(8) 10.0-12.4	(8) 8.0-11.4
Nutrients			
Nitrates	(14) <0.01-0.56	(7) 0.01-0.4	(7) 0.1-2.7
Nitrites	(1) <0.01	(1) <0.01	
NO2+NO3-N	(2) 0.0002-<0.01	(2) 0.002-0.01	
Organic Nitrogen	(1) 0.06	(1) 0.15	(7) 5.0-15.0
Phosphate - T (μg/L)	(10) 2.0-40.0	(7) 2.5-120	
Ortho PO_4 as P	(1) 0.02	(1) 0.05	
Meta & Poly PO_4 as P	(1) <0.005	(1) 0.01	
Chemical - Inorganic			
Chloride - D	(6) Nil-4.59	(2) <1.0-4.13	
Fluoride - D	(4) <0.1		
Bicarbonate as CO_3	(6) <0.01-12.0	(1) 9.8	
Reactive Silica	(1) 1.28	(1) 1.48	
Sulphate - D	(5) 4.0-6.0	(1) 4.0	
Tot. Alk. as CaCO3	(16) 6.0-20.0	(8) 6.0-8.0	(7) 6.0-9.0
Tot. Hard. as CaCO3	(16) 9.1-16.0	(8) 3.8-16.0	(7) 8.8-13.7
Ca Hardness as $CaCo_3$	(6) 10.0-14.0	(2) 12.0-14.0	
Mag. Hardness as $CaCO_3$	(4) 0.0-5.0		
Tot. Salinity	(1) 24.2	(1) 24.0	
Metals			
Cadmium - E	(2) <0.001-<0.01	(1) <0.01	
Calcium - D	(1) 4.8	(1) 5.6	
Copper - E (μg/L)	(11) <5.0-<15.0	(7) <5.0-<15.0	(7) <5.0
Iron - E	(16) 0.002-0.25	(9) 0.03-0.06	(7) <0.05-0.15
Lead - E	(3) 0.003-<0.1	(1) <0.1	
Magnesium - D	(1) 1.0	(1) 0.5	
Manganese - E	(5) <0.010-<0.05		
Nickel - E	(2) 0.003-<0.02	(1) <0.02	
Potassium - D	(5) Nil-0.2	(1) 0.0	
Selenium - E	(1) <0.010		
Sodium - D	(4) 0.9-1.5		

TABLE 4-8 (Cont'd)

SUMMARY OF WATER QUALITY DATA FOR CIRQUE LAKE, 1973-1977. NUMBER OF SAMPLES IS SHOWN IN PARENTHESES PRECEEDING THE RANGE VALUES. (ALL VALUES IN mg/L UNLESS OTHERWISE SPECIFIED. T=TOTAL: D=DISSOLVED; E=EXTRACTABLE; P=PARTICULATE).

Parameter	Range		
	Surface	Mid-Depths	Bottom
Metals (Cont'd.)			
Tungsten - E	(1) <10.0	(1) <10.0	
Zinc - E	(2) 0.002-<0.005	(1) <0.005	
Chemical - Organic			
Carbonate as CO_3	(4) Nil		
Chlorophyll (mc^3/m^3)	(9) <0.2		

4.6.6 AIRSTRIP POND

Airstrip Pond, located adjacent to the Tsichu River Airstrip (Figure 4-7), is approximately 3 m deep, 305 m in length, and 267 m wide. Being shallow and ringed with vegetation, Airstrip Pond is somewhat richer in organics and nutrients than Cirque Lake. Conductance and hardness were also somewhat greater at 75 umhos/cm and 24 mg/L, respectively.

4.6.7 HESS RIVER TRIBUTARIES

The Hess River is on the western slope of the Continental Divide in the Yukon River drainage. A tributary to the Hess River separates the MacTung area from the Keele Peak area to the northwest. A number of water samples were taken from feeders to this tributary and from the tributary itself to assess the overall water quality of the watershed. The data is summarized in Table 4-9.

Generally, the water quality of the various tributaries parallels the quality of Dale Creek. Conductance and dissolved solids are somewhat elevated ranging from 9 to 248 umhos/cm and 9.0 to 160.0 mg/L, respectively. Alkalinity is low, ranging from 2.0 to 64.0 mg/L, and hardness ranged up to 114.0 mg/L (Table 4-9). The quality of the feeder tributaries is lower than the quality of the main tributary to the Hess River.

4.6.8 SEDIMENT CHEMISTRY

Sediment samples were collected on 25 July, 1979 from two sites in Dale Creek and one site in the lower Tsichu River, and on 31 July 1981 from four sites in Dale Creek, two sites in the lower Tsichu River, and three sites in the upper Tsichu River. The results (Table 4-10) can be discussed as three separate groups. Sediments of Station T2-Rust Creek, the

TABLE 4-9

SUMMARY OF WATER QUALITY DATA FOR HESS DRAINAGE, 1973-1978. (ALL VALUES IN mg/L UNLESS OTHERWISE SPECIFIED. T=TOTAL; D=DISSOLVED; E=EXTRACTABLE; P=PARTICULATE).

Parameter	Number of Samples	Range
Physical Properties		
pH	18	5.7-7.9
Temperature (°C)	16	4.0-21.1
Turbidity (J.T.U.)	17	0.14-27.0
Color (Co - Pl units)	17	<5.0-25.0
Conductance (umhos)	18	9.0-248.0
Suspended Solids	5	<1.0
Dissolved Solids	3	9.0-160.0
Total Solids	2	7-74
Residue: NF (105°C)	5	10.0-36.0
Residue: NF Fixed (550°C)	5	3.0-33.0
Dissolved Oxygen	4	<0.01-0.04
Nutrients		
Nitrates	2	<0.01
Nitrates	2	<0.01
Nitrogen - P	2	0.006
Nitrogen - D	2	0.041-0.063
Nitrogen - T	1	0.57
NO2+NO3 as N	1	<0.01
Phosphate - T	1	<0.01
Phosphorus - T	2	0.007-0.019
Chemical - Inorganic		
Chloride - D	5	<0.2-<1.0
Fluoride - D	3	0.145-0.248
Sulphate - D	15	3.0-52.5
T.I.C.	2	5.5-15.2
Tot. Alk. as CaCO3	17	2.0-64.0
Tot. Hard. as CaCO3	17	5.0-114.0
Ca Hardness	2	4-54
Metals		
Arsenic - D (μg/L)	1	6.0
Arsenic - E (μg/L)	8	<5.0-15.0
Cadmium - E (μg/L)	9	0.6-<14.0
Calcium - D	8	0.59-41.4
Calcium - E	1	42.0
Chromium - E (μg/L)	3	1.3-<8.0
Cobalt - E (μg/L)	3	<1.0-1.0
Copper - E (μg/L)	19	<1.0-<15.0
Iron - E	17	0.011-2.1
Lead - E (μg/L)	19	<1.0-<100.0

TABLE 4-9 (Cont'd)

SUMMARY OF WATER QUALITY DATA FOR HESS DRAINAGE, 1973-1978. (ALL VALUES IN mg/L UNLESS OTHERWISE SPECIFIED. T=TOTAL; D=DISSOLVED; E=EXTRACTABLE; P=PARTICULATE).

Parameter	Number of Samples	Range
Metals (Cont'd.)		
Magnesium - D	2	2.6-4.3
Magnesium - E	1	2.0
Manganese - E	15	<0.002-0.04
Mercury - E (μg/L)	6	<0.05-<0.4
Molybdenum - E	4	0.007-<0.3
Nickel - E	9	<0.001-0.02
Potassium - D	1	1.0
Selenium - D (μg/L)	2	1.5-2.6
Selenium - E (μg/L)	3	<1.0
Silver - E (μg/L)	5	<3.0-<30.0
Sodium - D	1	3.7
Sodium - E	1	3.6
Tungsten - E	7	<0.016-<10.0
Zinc - E (μg/L)	19	<1.0-110.0
Chemical - Organic		
Carbon: P	2	0.060-0.061
Bicarbonate as CO_3	1	78.1
Carbonate as CO_3	1	<0.1
C.O.D.	3	2.0-<50.0
T.O.C.	2	1.5-1.7
Cyanide - T	2	<0.002-<0.002

TABLE 4-10

CHEMICAL CHARACTERISTICS OF SEDIMENTS COLLECTED FROM DALE CREEK AND THE TSICHU RIVER. LOCATION OF SAMPLING STATIONS IS PRESENTED IN FIGURE 4-7. (ALL VALUES IN mg/L)

Station #	24		28	29		67	68		70	T1	T2	T4
Stream	Dale		Dale	Dale		Dale	L.Tsichu		L.Tsichu	U.Tsichu	Rust	U.Tsichu
Date	25JUL79	31JUL81	31JUL81	25JUL79	31JUL81	31JUL81	25JUL79	31JUL81	31JUL81	31JUL81	31JUL81	31JUL81
Parameter												
Aluminum	46,123			56,703			59,168					
Arsenic	46.7			26.5			24.8					
Barium	3,344			3,768			2,951					
Beryllium	<1.0			<1.0			<1.0					
Boron	254			1,111			1,389					
Cadmium	7.52	11	13	6.66	6	10	3.87	7	4	6	<1	3
Calcium	11,638			11,102			6,797					
Chromium	84.4	18	17	84.3	16	16	77.4	13	11	12	12	9
Cobalt	45.1	47	50	31.4	32	38	91.4	81	48	115	7	105
Copper	112.0	139	118	80.0	100	87	225	224	83	370	88	425
Iron	32,237	24,000	25,000	34,398	27,500	29,500	50,363	47,500	48,250	76,250	122,500	51,500
Lead	182	40	32	163	25	25	7.01	20	23	35	5	27
Lithium	105			103			111					
Magnesium	17,481			13,012			8,139					
Manganese	695			642			1,077					
Mercury	1.4	0.4	0.38	1.9	0.25	<0.2	2.6	<0.2	<0.2	<0.2	<0.2	<0.2
Molybdenum	36.9			21.7			32.9					
Nickel	199	230	210	122	145	155	205	190	114	178	30	99
Phosphorus - Total	2,552			2,814			2,312					
Potassium	19,090			24,710			18,512					
Selenium	.2			4.76			.2					
Silver	<1.0			<1.0			<1.0					
Sodium	4,330			5,010			4,458					
Strontium	137			124			108					
Tellurium	<1.0			<1.0			<1.0					
Titanium	2,392			2,678			2,181					
Tungsten	<2.0			<2.0			<2.0					
Vanadium	855			506			437					
Zinc	845	1,100	960	503	800	800	943	1,000	670	900	160	660

source of contamination to the upper Tsichu River, were significantly different from sediments of the other stations in the Tsichu River (68, 70, T1 and T4) which, in turn, appeared to be significantly different from the sediments in Dale Creek. With the exception of iron, metals in the sediments of Rust Creek were lower than metals values of the other Tsichu River sites and the Dale Creek sites. These results demonstrate the effect of the highly acidic nature of Rust Creek under which the soluabilities of most metals are greater. After mixing with more normal waters, a higher pH results and the metals precipitate out.

Comparing the two remaining groups, Dale Creek sediments appeared to have higher concentrations of cadmium, lead, mercury, and nickel than the Tsichu River; while the Tsichu River appeared to have higher concentrations of iron, cobalt and copper (Table 4-10). Dale Creek sediments had the lowest concentrations of iron (24,000 to 32,237 ppm), followed by the Tsichu River (47,500 to 76,250 ppm), with Rust Creek having the highest concentration (122,500 ppm).

Although discussed in more detail later, it is worth noting here that benthic macroinvertebrate communities were reduced at Stations T1, T2, T3, T4, 68 and, to a lesser degree, at 70, relative to Dale Creek stations. Iron precipitates and other sediments were deposited in the substrate interstitial spaces, producing a more compact and solidified substrate. Hence, micro-habitat diversity was often reduced in these areas. Areas characterized by moderate to high levels of sedimentation were limited to the Tsichu River upstream of the braided channel section (Figure 4-7). The reduced levels of iron, nickel, cobalt, zinc, and copper in sediments below the braided channel indicates that the expanded, braided channel area may function as a sediment trap.

The highest level of copper occurred in the sediment of upper Tsichu River station T4 (425 ppm), with progressively lesser amounts at the two downstream stations 68 (224 ppm) and 70 (83 ppm).

In the Tsichu River, cobalt decreased progressively downstream (115 ppm at station T1 to 48 ppm at station 70). However, zinc, cadmium, nickel, and chromium concentrations were greater in sediments at station 68 relative to upstream station T4, perhaps reflecting metal precipitation as a result of mixing with the higher pH of Dale Creek water.

More detailed information on water quality can be found in the companion report entitled "Aquatic Ecology of the MacTung Area, 1973-1982".

4.7 AQUATICS

4.7.1 INTRODUCTION

Preliminary aquatics and water quality information was collected at MacTung as early as 1973 (Cody and Acton 1973). AMAX commissioned Shultz International to perform additional investigations during 1974 and 1975. Also in 1975, the Environmental Protection Service of Environmental Canada conducted a study. Additional information was collected during 1975 and 1976 and a pre-study investigation was performed in 1977 in an effort to determine the benthic sampling technique best suited to arctic streams. Thereafter, extensive benthic data were collected each year from 1978 through 1981. The fishery was evaluated through the years culminating in 1981 with a trapping and tagging program. Habitat physical parameters were also determined.

The primary area of interest was the watershed directly downstream of the MacTung Project, i.e., Dale Creek and that portion of the Tsichu River from the Dale Creek confluence to the lower Tsichu Bridge (Figure 4-7). Dale Creek was divided into three broad habitat zones: upper, middle, and lower. Upper Dale Creek is the section from the headwaters to the mine access road crossing; middle Dale Creek is the section from the mine access road crossing to the confluence with Cirque

Creek; and lower Dale Creek is the section from the Dale Creek/Cirque Creek confluence to the confluence with the Tsichu River.

The Tsichu River was divided into two broad habitat zones: upper and lower. The upper Tsichu River is the section from the headwaters to the confluence with Dale Creek and the lower Tsichu River is the section from the Dale Creek confluence to the lower Tsichu Bridge.

The entire system was surveyed and prominent features of the streams were assigned numerical designations numbering 1 through 70 from upper Dale Creek to the lower Tsichu River Bridge, and T1 through T4 on the upper Tsichu River (Figure 4-7).

The upper Tsichu River was of secondary interest because it was tributary to the area directly downstream of the project. Other tributary features studied included Cirque Lake, Cirque Creek, Rust Creek, Culvert Creek, Airstrip Creek, and Airstrip Pond (Figure 4-7).

4.7.2 PHYSICAL CHARACTERISTICS

Dale Creek and the Tsichu River are headwater streams located in mountainous terrain. Dale Creek is approximately 14 km in length and is a tributary stream to the Tsichu River (Figure 4-7). The Tsichu River flows eastwards approximately 65 km, where it intersects the Keele River. The Keele River enters the Mackenzie River south of Fort Norman, N.W.T.

Dale Creek and the Tsichu River are characterized by high and irregular flow rates. Runoff in these streams is strongly controlled by snowmelt, storm patterns, and the nature of the substrate. Because of the large extent of exposed rock at higher elevations and thin soils over much of the lower valleys, spring runoff is rapid. Although the lower elevations are not underlain by permafrost, soils generally are frozen during snowmelt, thus limiting infiltration. Stream substrates are scoured by suspended and saltating sediments, thereby minimizing colonization by aquatic plants.

The major sources of water to Dale Creek include a snow field, springs, melt water from (presumed) ice cores in the rock glaciers, and precipitation. Major sources of water to the Tsichu River include a glacier, springs, and precipitation.

4.7.2.1 Dale Creek

Upper Dale Creek descends rapidly from its headwaters (mean gradient of 61 m/km) through a narrow gorge and subsequent stretch of predominantly boulder subtrate (mean gradient of 32 m/km). In the upper Dale Creek valley bottom, the stream begins to meander through an alpine meadow (mean gradient of 9.5 m/km).

The meandering stream section from sites 6 through 24 (Figure 4-7) is characterized by alternating stretches of riffle, run, and pool habitats. Downstream of site 24, a single linear channel descends to the mine access road crossing. This reach provided only feeding habitat.

Middle Dale Creek is predominantly white water, descending rapidly through a narrow gorge (mean gradient of 49 m/km). In the gorge, the stream channel is bordered by bedrock outcrops with slopes generally exceeding 45 degrees. The series of velocity chutes in the narrow gorge probably presents a significant velocity barrier to fish passage. Hence, middle Dale Creek provides very limited potential spawning, resting, rearing, and overwintering habitat.

With a riffle:run:pool ratio 49:35:16, lower Dale Creek provides the best physical habitat in Dale Creek system. The meandering channel, modified by beaver activity, provides suitable spawning, rearing, feeding, and resting areas. As indicated on Figure 4-7, open water was observed below site 67 at the Dale Creek/Tsichu River confluence during February 1982 indicating potential fish overwintering habitat.

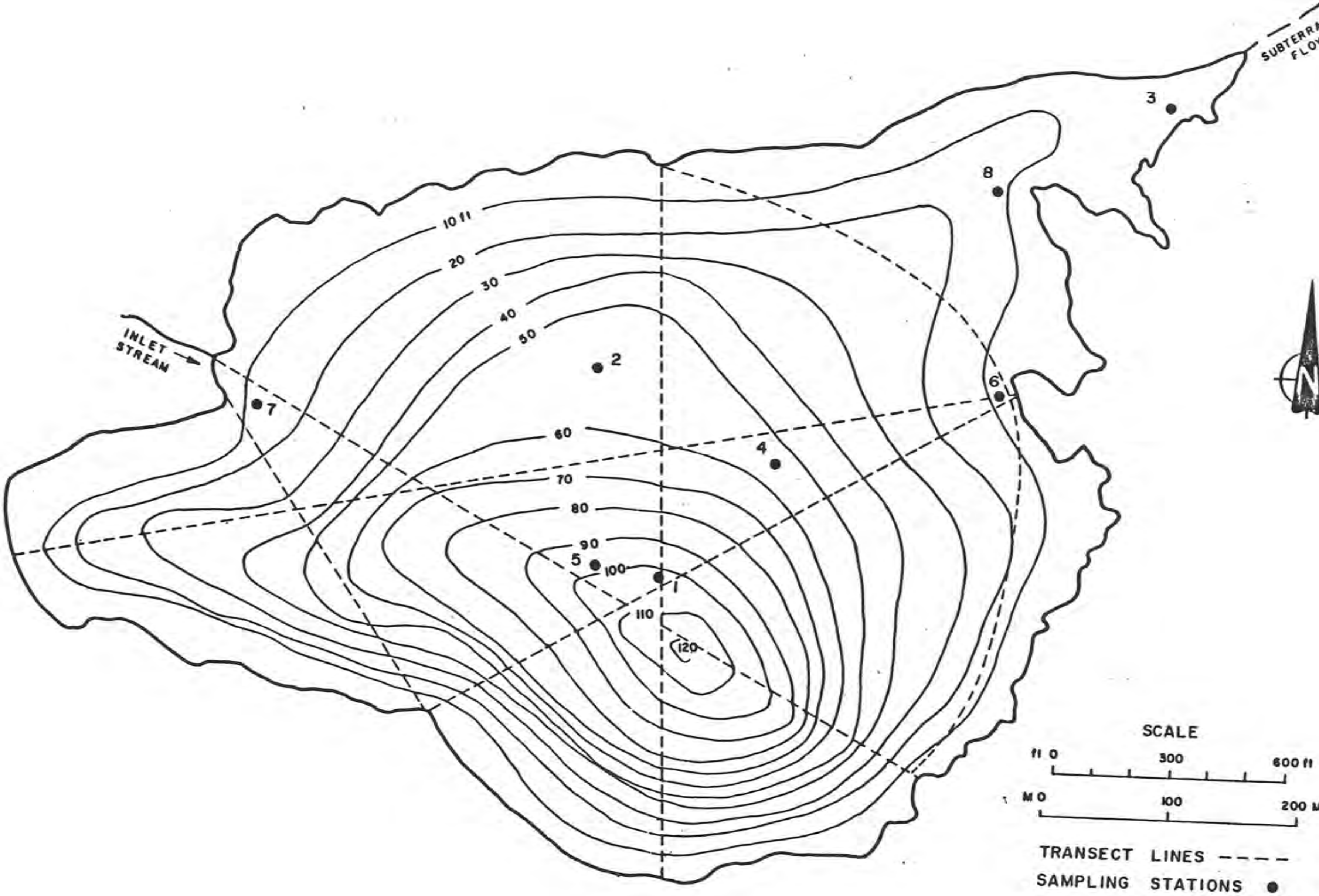
4.7.2.2 Tsichu River

Physical characteristics of the lower Tsichu River (downstream of the Dale Creek/Tsichu River confluence) are similar to those of lower Dale Creek. A segment of the lower Tsichu River referred to as the "braided channel section" commences about 0.5 km downstream of station 69 and continues for approximately 3.5 km. Patches of open water were observed at the lower end of the braided channel and at the lower Tsichu River Bridge during February 1982 indicating the potential for fish overwintering habitat.

All but the uppermost reaches of the upper Tsichu River are a meandering stream with physical characteristics similar to those of lower Dale Creek. The degraded chemical characteristics of upper Tsichu (discussed earlier) were, however, significantly different from Dale Creek. The impact of the degraded quality of upper Tsichu River carries over to the lower Tsichu River.

4.7.2.3 Cirque Lake

Cirque Lake (Figure 4-8) was previously thought to be a typical glacier-created lake, occupying a well developed cirque or tarn. The name "Cirque Lake" is probably not technically appropriate because more recent examination indicates the lake was created by a slump block. The lake is 1070 m long and 520 m wide, with a maximum depth of 38 m. The surface area and volume were calculated at 354,890 m^2 and 3.9×10^6 m^3 respectively (Environment Canada 1976). Cirque Lake is fed by glacial melt water and bedrock springs. Water from Cirque Lake discharges through a subterranean network and emerges via springs to form Cirque Creek approximately 600 m east of the lake. Annual variation in water level was reported to be 1.5 m.



CIRQUE LAKE - BATHYMETRY

FIG. 4-8

4.7.2.4 Cirque Creek

After surfacing as a subterranean discharge of Cirque Lake, Cirque Creek flows approximately 3 km before joining Dale Creek. Cirque Creek is a steep, narrow cascading stream with a mean gradient of 61 m/km. Potential fish habitat is marginal in all but the lowest 600m prior to joining Dale Creek where a gorge may prohibit migration further upstream.

4.7.2.5 Airstrip Pond

Airstrip Pond, located north of the Canol Road and east of the Tsichu River Airstrip at the AMAX Meteorological Station (Figure 4-7), is approximately 3 m deep, 305 m long, and 267 m wide. Physical characteristics of the pond are conducive to fish spawning and rearing.

4.7.3 BENTHIC MACROINVERTEBRATES

4.7.3.1 Overview of Streams - 1977 Through 1981

The benthic macroinvertebrate sampling schedule is presented in Table 4-11 and the locations are shown in Figure 4-7. During the five year study, 59 taxa were identified (Table 4-12). Of these, 10 taxa were mayflies (Emphemeroptera), 15 taxa were stoneflies (Plecoptera), 19 taxa were true flies (Diptera), and 11 taxa were caddisflies (Trichoptera). Other taxa included Oligochaeta, Hydracarina, Collembola, and Nemata.

Diptera was the dominant group in terms of total abundance of organisms, followed by Plecoptera, Emphemeroptera and Trichoptera.

In terms of overall community composition, Orthocladiinae was the most abundant taxon representing 31% of the individuals collected in the 86 samples, 1977 - 81. *Alloperla sp.* closely representing 30%. Other taxa in decending order of abundance were Diamesine (14%) *Cinygmula sp.* (6%), and *Ameletus sp.* (4%).

Seasonal phenology and habitat quality both affect the distribution and abundance of organisms. For example, *Ameletus sp.* was not present in the upper Tsichu River (Table 4-12). *Alloperla sp.* was present during all phases of the summer in all major stream segments comprising greater percentages of composition (PC) as the season progressed in all but

TABLE 4-11

SCHEDULE OF BENTHIC MACROINVERTEBRATE SAMPLING THROUGH THE 1977-81 PROGRAM

LOCATION	STATION	1977 MID	1978 LATE	1979 MID	1979 LATE	1980 EARLY	1980 MID	1980 LATE	1981 EARLY	1981 MID	1981 LATE
Upper Dale Creek	23S*	x	x								
Upper Dale Creek	23F*	x	x								
Upper Dale Creek	24S		x	x	x						
Upper Dale Creek	24F		x	x	x	x	x	x	x	x	x
Middle Dale Creek	28			x	x	x	x	x	x	x	
Lower Dale Creek	29S		x	x	x						x
Lower Dale Creek	29F		x	x	x	x	x	x	x	x	x
Lower Dale Creek	31S		x								
Lower Dale Creek	31F		x								
Lower Dale Creek	67S	x	x								
Lower Dale Creek	67F	x	x	x	x	x	x	x	x	x	x
Lower Tsichu River	68S		x	x	x						
Lower Tsichu River	68F		x	x	x	x	x	x	x	x	x
Lower Tsichu River	69S		x								
Lower Tsichu River	69F		x								
Lower Tsichu River	70S		x								
Lower Tsichu River	70F		x	x	x	x	x	x	x	x	x
Upper Tsichu River	T1								x	x	x
Rust Creek	T2								x	x	x
Upper Tsichu River	T3								x	x	x
Upper Tsichu River	T4								x	x	x

*S denotes pool habitat, F denotes riffle habitat.

Table 4-12 Percent Occurrence (PO) and Percent Composition (PC) of Benthic Macroinvertebrate Taxa Over All Samples (n=86) at all Stations, by Phase of Summer Season, 1977-81 (Page 1 of 3 Pages)

	Dale Creek						Lower Tsichu River						Upper Tsichu River					
	Early N=8		Mid N=18		Late N=24		Early N=4		Mid N=7		Late N=13		Early N=4		Mid N=4		Late N=4	
	PO	PC	PO	PC	PO	PC	PO	PC	PO	PC	PO	PC	PO	PC	PO	PC	PO	PC
EPHEMEROPTERA																		
Ameletus																		
spp.	50.0	0.5	77.8	0.5	87.5	7.3			28.6	0.3	38.5	1.2						
Baetis																		
foemina	87.5	5.2	66.7	1.7	41.7	1.1	50.0	0.8	57.1	2.2	7.7	0.2						
spp.	37.5	2.0	44.4	1.3	45.8	0.3	50.0	6.8	28.6	1.0	30.8	2.7						
Cinygmula																		
spp.	100.0	9.5	94.4	7.1	100.0	3.4	100.0	12.8	100.0	8.9	76.9	5.9			50.0	6.7		
Ephemerella																		
doddsi	25.0	0.2	5.6	0.1	16.7	0.1	50.0	0.8	57.1	0.4	15.4	0.7						
flavilinea-colorad	12.5	0.2	22.2	0.2	4.2	0.1	25.0	0.3	42.9	0.4	23.1	0.5						
Iron																		
spp.	75.0	2.4	66.7	2.9	79.2	1.5	100.0	2.2	85.7	7.4	53.8	1.7						
Ironopsis																		
spp.	12.5	0.1			20.8	0.1					15.4	0.5						
Rithrogena																		
spp.	62.5	1.5	77.8	0.8	83.3	1.6	75.0	1.4	14.3	0.1	38.5	0.7						
Unidentified																		
sp. 1					16.7						7.7							
PLECOPTERA																		
Alloperla																		
spp.	100.0	13.4	94.4	23.0	100.0	38.5	100.0	3.9	100.0	21.9	100.0	45.3	75.0	18.2	50.0	20.0	75.0	8.3
Arcynopteryx																		
spp.			5.6		20.8													
Brachyptera																		
spp.					20.8	0.1					7.7							
Capnia																		
spp.	12.5	0.1					25.0	0.1										
Capniidae																		
spp.					33.3	0.2					30.8	0.4						
Eucapnosis																		
spp.											7.7	0.1						
Hastaperla																		
spp.									14.3	0.1								
Isogenus																		
spp.	12.5								14.3	0.1	7.7						25.0	1.2
Isoperla																		
spp.	12.5		16.7				25.0	0.1	14.3	0.1	7.7	0.2						
Megaleuctra																		
spp.									14.3	0.1								

Table 4-12 Percent Occurrence (PO) and Percent Composition (PC) of Benthic Macroinvertebrate Taxa Over All Samples (n=86) at all Stations, by Phase of Summer Season, 1977-81 (Page 2 of 3 Pages)

	Dale Creek						Lower Tsichu River						Upper Tsichu River					
	Early N=8		Mid N=18		Late N=24		Early N=4		Mid N=7		Late N=13		Early N=4		Mid N=4		Late N=4	
	PO	PC	PO	PC	PO	PC	PO	PC	PO	PC	PO	PC	PO	PC	PO	PC	PO	PC
PLECOPTERA																		
Megarcys spp.	37.5	0.1	33.3	0.1	45.8	0.3	25.0	0.1			7.7							
Nemoura (subg.)Podnosta																	25.0	13.1
Nemoura subg. Zapada	87.5	1.2	72.2	0.9	87.5	1.4	75.0	3.8	100.0	11.3	76.9	6.2	75.0	22.7	25.0	3.3	100.0	8.3
Taseniionema spp.					8.3	0.3			14.3	0.3	7.7							
Unidentified sp. 1			5.6		12.5													
TRICHOPTERA																		
Arctopsyche spp.					8.3		25.0	0.1										
Dicosomyia spp.					4.2													
Ecclisomyia spp.			44.4	0.3	75.0	1.1					30.8	0.5						
Glossosoma spp.	12.5		11.1		50.0	0.4					46.2	0.4						
Imania spp.					4.2													
Limnephilidae spp.											7.7							
Manophylax annulatus	12.5																	
Parapsyche spp.			5.6								7.7							
Rhyacophila spp.			5.6		4.2						7.7							
Unidentified sp. 1					4.2													
pupae			5.6															
DIPTERA																		
Ceratopogonidae spp.	12.5				4.2				14.3	0.7								
Chironomidae chironomini					8.3				14.3	0.1								
diamesinae	100.0	19.4	100.0	15.7	100.0	12.1	100.0	18.4	100.0	11.3	84.6	7.2	50.0	9.1	75.0	20.0	50.0	14.3
orthocladiinae	100.0	39.4	100.0	39.4	100.0	25.3	100.0	44.2	100.0	27.2	100.0	18.1	75.0	45.5	75.0	33.3	100.0	39.3
tanypodinae	50.0	1.3	27.8	0.7	20.8	0.1	50.0	1.2	42.9	0.7	15.4	0.1						

Table 4-12 Percent Occurrence (PO) and Percent Composition (PC) of Benthic Macroinvertebrate Taxa Over All Samples (n=86) at all Stations, by Phase of Summer Season, 1977-81 (Page 3 of 3 Pages)

	Dale Creek						Lower Tsichu River						Upper Tsichu River					
	Early N=8		Mid N=18		Late N=24		Early N=4		Mid N=7		Late N=13		Early N=4		Mid N=4		Late N=4	
	PO	PC	PO	PC	PO	PC	PO	PC	PO	PC	PO	PC	PO	PC	PO	PC	PO	PC
DIPTERA																		
Chironomidae																		
tanytarsini	12.5	0.1	22.2	1.0	20.8	0.1												
pupae			22.2	0.4														
Empididae																		
spp.	62.5	1.3	77.8	1.1	62.5	1.9	50.0	0.7	100.0	3.3	69.2	1.1			50.0	6.7	25.0	1.2
Simuliidae																		
prosimulium fulvum	62.5	0.3	77.8	0.9	25.0	0.2	50.0	1.6	71.4	1.0	15.4	0.1						
Tipulidae																		
dicranota	12.5	0.1	44.4	0.3	95.8	0.8	50.0	0.3	42.9	0.3	76.9	2.9	25.0	4.5	25.0	6.7	50.0	11.9
dixa	12.5																	
hexatoma											7.7							
ormosia					8.3													
pedicia			5.6		29.2	0.1					7.7	0.4						
rhabdomastix					4.2													
tipula	12.5	0.1	5.6						28.6	0.2	23.1	0.8						
sp. 1											23.1	0.1					25.0	2.4
Molophilus																		
spp.			5.6		4.2													
Unidentified																		
spp.			5.6															
NEMATA																		
spp.					4.2													
COLLEMBOLA																		
spp.	12.5		5.6		4.2						7.7				25.0	3.3		
OLIGOCHAETA																		
spp.	62.5	1.3	77.8	1.4	79.2	1.5	50.0	0.3	42.9	1.0	61.5	1.6						
HYDRACARINA																		
spp.			16.7		4.2						7.7	0.1						
		100.0		100.0		100.0		100.0		100.0		100.0		100.0		100.0		100.0

the upper Tsichu River (Table 4-12). Diamesinae and Orthocladiinae were also present during all phases of the summer in all stream segments, however, comprising lower PC's as the seasons progressed, again with the exception of the upper Tsichu River.

Each stream segment stands by itself. Greatest numbers of both taxa and organisms are present in Dale Creek. The upper Tsichu River has few taxa and organisms, while the lower Tsichu River distinctly falls between the other two (Figures 4-9 and 4-10). Lesser abundance in the upper Tsichu River is probably due to siltation and the degraded physical and chemical nature of the substrate in the upper Tsichu River. Figure 4-9 illustrates the greater abundance of individuals and more varied fauna in Dale Creek (Stations 24F, 28, 29F, 67F) compared to stations in the lower Tsichu River (68F and 70F). However, the lower Tsichu River supported greater abundance and diversity than the upper Tsichu River (Stations T1, T2, T3, and T4, Figure 4-10).

Two measures were used to delineate benthic community homogeneity or similarity at stations within and among various habitat zones: the coefficient of community (CC), and the proportional similarity of community (PSC). Samples were stratified according to sampling period and the average within sample CC and PSC indicated a high degree of uniformity among samples collected during the same month (albeit one year apart).

The criteria used to differentiate similarity or affinity association was adopted in part from Johnson and Brinkhurst (1971). Values that determine high affinity are based on the average of within sample means for each sampling month. High affinity is defined as values greater than the average within sample mean, while values equivalent to 50% of the within sample mean are used to differentiate between stations with low or intermediate affinities.

Comparisons of 282 such CC and PSC values were made between stations sampled during the four main years of the program. Overall, the results revealed that most of the comparisons were in the high or intermediate affinity ranges for both CC and PSC. Few of the CC and PSC were in the low affinity range.

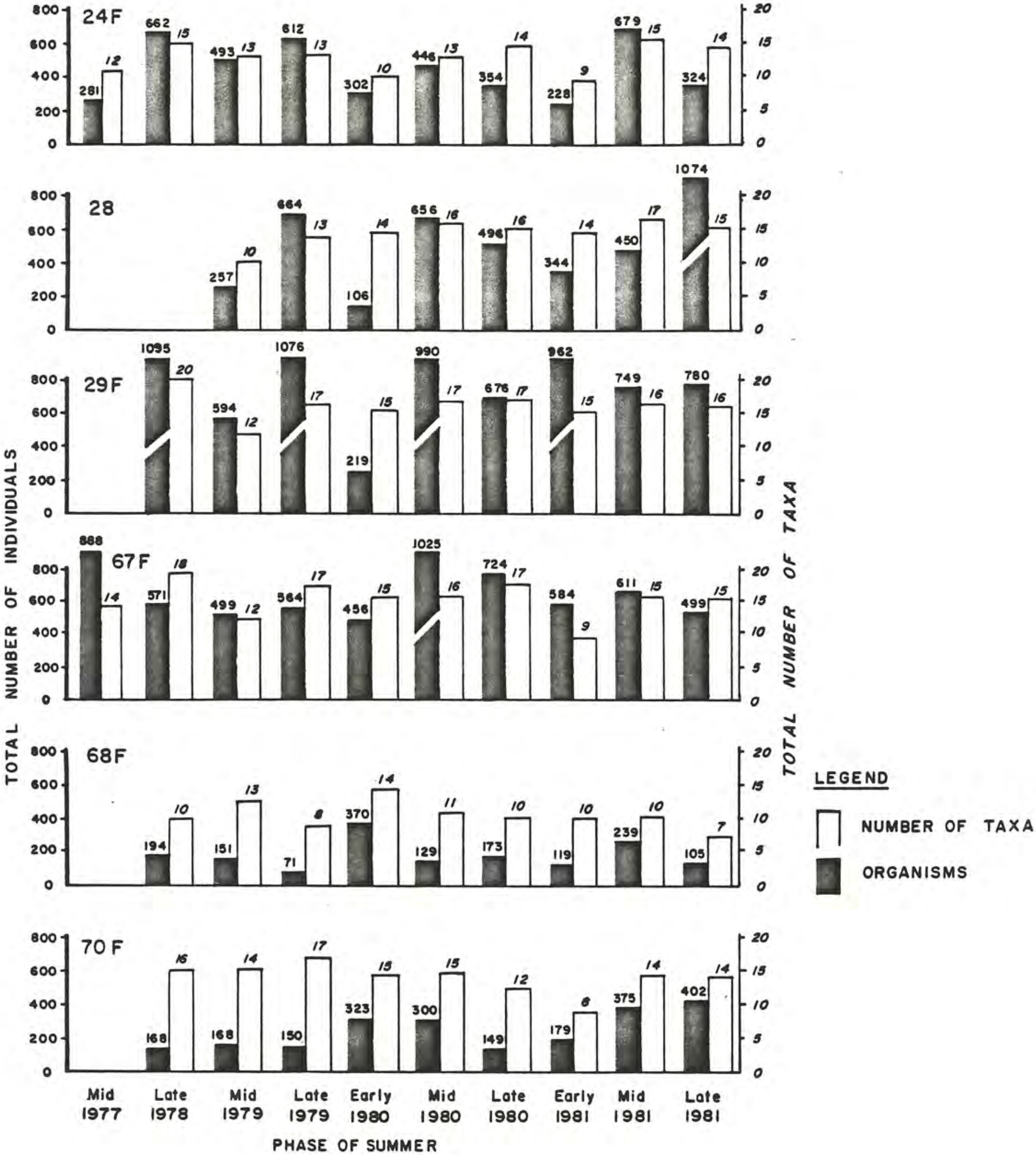


Figure 4-9 TOTAL NUMBER OF INDIVIDUALS AND TAXA CONTAINED IN BENTHIC MACROINVERTEBRATE COLLECTIONS FROM DALE CREEK AND LOWER TSICHU RIVER, 1977-1981

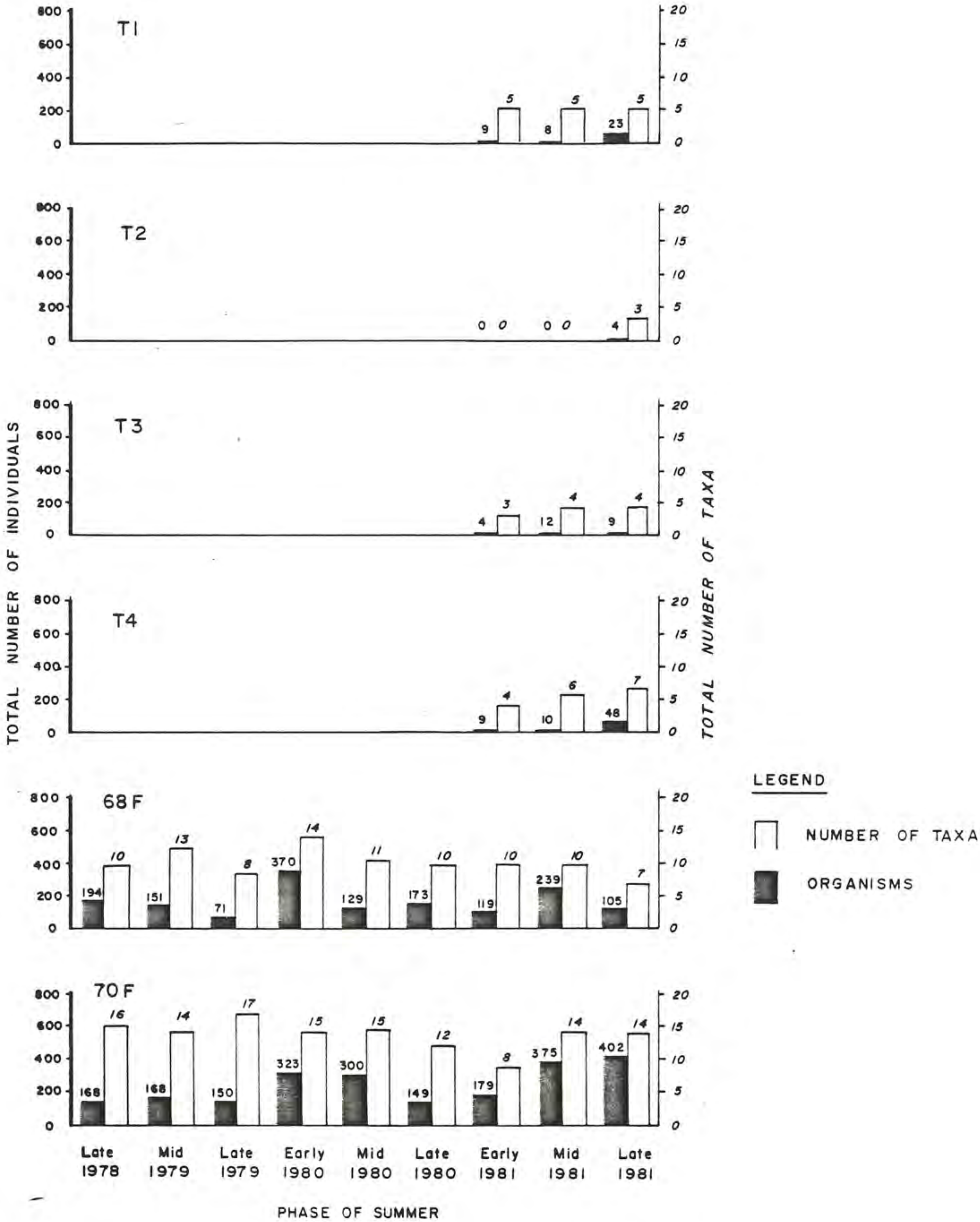


Figure 4-10 TOTAL NUMBER OF INDIVIDUALS AND TAXA CONTAINED IN BENTHIC MACROINVERTEBRATE COLLECTIONS FROM TSICHU RIVER, 1978 - 1981.

Variation between the mid and late 1979 sampling periods can be grouped into three observations. First, the number of taxa and number of organisms increased at stations in Dale Creek. Second, the number of taxa and organisms decreased substantially at Station 68F in the lower Tsichu River during this period; a condition likely due to increased sedimentation as a result of lower flows during the autumn period. The third occurred at Station 70F in the lower Tsichu River. Although the number of organisms decreased slightly, the number of taxa increased. Sedimentation is generally not as severe at this station as compared to upstream Tsichu River stations. Consequently, Station 70F appears to be in a zone of recovery from sedimentation effects.

The increase in organisms from early to late summer 1979 in Dale Creek was in the orders Ephemeroptera, Plecoptera, and Trichoptera. The decrease in organisms in the heavily silted reach of the Tsichu River mainly was due to lower numbers of Ephemeroptera and Diptera. Diptera generally increase in numbers subsequent to siltation, but the species in this system are classified as clingers and/or sprawlers (Merritt and Cummins 1978); i.e. organisms clinging to the upper surfaces of rocks as opposed to burrowing in the substrate.

During the initial stages of the program, contiguous pool and riffle stations were sampled. In 1979, an overall assessment of community composition between pool and riffle habitats indicated that the benthic community was generally more varied in riffle habitats, and that pool habitat sampling tends to be redundant when compared to contiguous riffle stations. Thus, all pool habitats were deleted from the sampling network following the 1979 program.

In order to further assess temporal variation, samples were collected during three periods beginning in 1980: early, mid, and late summer. As depicted in Figure 4-9, the three general observations noted in 1979 were not identical to those observed in 1980. In Dale Creek numbers of organisms increased dramatically between the early and the mid summer samplings, then declined in late summer. This is in contrast to Station 68F in the lower Tsichu River where numbers of organisms decreased between early and mid summer then increased in late summer. Station 70F was stable between early and mid summer, but numbers of organisms and taxa both then decreased in late summer. Dale Creek stations showed a slight increase in number of taxa between early and mid summer, then either stabilized or increased slightly during late summer. Station 68F in the Tsichu River contained three less taxa between early and mid summer, and decreased one more in late summer.

The trend in Dale Creek was mainly in response to increased numbers of Plecopterans, Ephemeropterans, and Dipterans between early and mid season. The decrease in late summer was due primarily to an emergence of Dipterans in Dale Creek. The decline in organisms between early and mid summer at Tsichu River Station 68F was the result of fewer Ephemeroptera and Diptera (in contrast to Dale Creek stations). However, evidence of increased siltation was observed at 68F between the two samplings. The decline in numbers of organisms at 70F between mid and late summer was mainly due to an emergence of Diptera paralleling similar events in Dale Creek.

During 1981, the three general observations discussed for 1979 and 1980 were not as apparent (Figure 4-9). Only at Stations 24F, 67F, and 68F did the number of organisms increase between early and mid summer with a subsequent decline in late summer. During 1980, organisms at 68F decreased substantially between early and mid season. However, in 1981, the number of organisms almost doubled at 68F during the same period.

Although occasionally station comparisons were dissimilar on a particular sampling date, no dissimilarity occurred when each station was compared with itself one or more years apart. Cluster analysis of benthic macroinvertebrate samples during each phase of the summer season reflects a high degree of stability within the respective communities at each station. This stability and similarity indicates that a solid baseline of benthic macroinvertebrate data has been established.

4.7.3.2 Cirque Lake

Only three benthic organisms were collected in a shallow (0.7 m) dredge and two in a deep (30 m) dredge. In a 17 m dredge, a total of 71 organisms were collected. Chironomid larvae (mostly Tanytarsini and Tanypodinae) were dominant, with fingernail clams (Pelecypoda) represented. In an earlier investigation by Environment Canada (1976), trichopterans, oligochaets and chironomids were also observed in benthic grab samples from Cirque Lake.

At the time of sampling, the zooplankton crustacean community was simple. Two species were observed, *Daphnia pulicaria* and *Cyclops scitifer*, the latter species being dominant. Large numbers of *Daphnia ephippa* were observed in vertical hauls and dredge samples; therefore *Daphnia spp*. are likely more abundant at other times. Although phytoplankton samples were not specifically collected, the taxa were observed and their relative abundance was recorded.

4.7.3.3 Airstrip Pond

The distribution of organisms among taxa in Airstrip Pond was very low in July 1977. Only eight taxa were collected with molluscs (snails and clams) dominating. August 1978 collections provided five benthic samples from depths of 1.0 m, 2.75 m, and 3 m. Generally, the 3 m stations yielded the most organisms as well as taxa. Sixteen taxa were represented in the 3 m collections, while only 7 taxa were present in the 1 m collection. Again, molluscs dominated, with Valvata sincere helicoidea being the dominant and Pisidium the sub-dominant organisms. Among the Diptera, the major organisms were Chironomus, Psectrocladius, Phaenospectra, and Procladius.

Three crustacean zooplankton species were present during July 1977, while four species were documented in samples collected during August 1978. During July 1977, the calanoid copepod (Diaptomus probilofensis) was the most abundant form. The colonial rotifer Conochilus unicornis was also relatively abundant.

Copepoda were the most abundant organisms collected during the August 1978 survey and were dominated by Cycolopoida with Diaptomus probilofensis (Calanoida) subdominant. The weed dwelling Cladocera species Simocephalus vetulas was six times more numerous than the planktonic species Chydorus sphaerious. The larger species of planktonic Cladocera are prey for young or planktivorous fish, more so than stronger swimming copepods which can avoid predation to some extent. The presence of a small population of Cladocera in Airstrip Pond (only the small sized planktonic species [C.sphaericus] or the weed dwelling species [S. vetulus] which can avoid predation) tends to suggest that the Cladocera are heavily preyed upon by young fish. Further circumstantial evidence concerning predation is the lack of Daphnia in the pond during both the 1977 and 1978 sampling period. Daphnia species are relatively large and slow, and are generally the first organisms to be reduced greatly in numbers, size, range, or even eliminated from a lake or pond when there is heavy zooplankton predation by fish (Brooks and Dodson 1965).

4.7.4 FISH

4.7.4.1 Introduction and Overview

The MacTung fishery program was initiated during the summer of 1977. The objectives of the program were:

1. To determine presence, relative abundance, and distribution of fish species in Dale Creek, the Tsichu River and, to a lesser degree, in Cirque Creek;

2. To compile information on age, growth, and life histories; and

3. To evaluate habitat in the three streams.

Assessment of habitat was discussed in detail in previous sections.

The majority (80%) of the fishery data was collected during the summer of 1981 from specimens captured in a fish trap placed in lower Dale Creek at site 67 (Figure 4-7). The trap was installed on 10 June 1981. Early season fish movements were monitored until 8 July. Late season movements were monitored from 3 September through 30 September when removal of the trap became necessary because of ice formation. Trapping data were supplemented with information obtained from captures by seine, dip-nets, and angling in 1977 and 1978.

A total of 552 individuals of six fish species were captured by various methods in the general MacTung area during the summers of 1977, 1978, and 1981 (Table 4-13). The six species included Arctic Grayling, Dolly Varden, Mountain Whitefish, Slimy Sculpin, Lake Trout, and Burbot. The primary portion of the fisheries program occurred from June through September 1981 when 393 fish were captured. A tagging program during 1981 accounted for 258 tagged and released fish of which 66 (26%) were recaptured in 1981, and 4 (2%) were recaptured in 1982 (by one angler).

Arctic Grayling was the most abundant species in the general area, comprising 78% of all captures. Dolly Varden and Mountain Whitefish

Table 4-13 Capture and composition data for six fish species captured in the Tsichu River System, N.W.T. 1977-1981

Species	Total cap.	%SC[1]	Total Tsichu	%SC	Total Dale	%SC	Total Other	%SC	Total Tagged	Recaps 1981	Recaps 1982
Arctic Grayling	433	78	87	68	285	82	61	79	220	49	4
Dolly Varden	59	11	19	15	34	10	6	8	13	8	0
Mountain Whitefish	37	8	10	8	27	8	0	0	24	9	0
Slimy Sculpin	12	2	12	9	0	0	0	0	0	0	0
Lake Trout	10	2	0	0	0	0	10	13	1	0	0
Burbot	1	-	0	0	1	-	0	0	0	0	0
Total	552		128		347		77		258	66	4

[1]Percent Species Composition

followed with 11% and 8% of the species composition, respectively. The remaining 4% of the captures was composed of Lake Trout, Slimy Sculpin, and one Burbot. Lake trout were captured only in Gill Lake (the headquarters of Gill Creek, Figure 4-7) and in Lost Guide Lake (15 km east of the lower Tsichu River Bridge), and not in the river or drainages of the immediate MacTung Project area. Figure 4-11 illustrates the locations of the three principal species within the study area.

4.7.4.2 Dale Creek

Dale Creek joins the Tsichu River approximately 9 km upstream of the lower Tsichu River Bridge (Figure 4-7). Lower Dale Creek (from the Cirque Creek to the Tsichu River confluence) supports good populations of Arctic Grayling, Dolly Varden, and Mountain Whitefish. Slimy Sculpins are present, and occasionally Burbot may be found. Based on 347 total captures in Dale Creek, Arctic Grayling comprised 82% of the population, followed by Dolly Varden (10%), and Mountain Whitefish (8%).

Mature and immature males and females of Arctic Grayling and Dolly Varden were captured at the fish trap in lower Dale Creek, indicating that spawning and rearing occurred in that reach. Arctic Grayling were captured in the upstream trap in lower Dale Creek throughout the June-to-September 1981 period. Although no distinct "peak" in upstream movement into Dale Creek can be determined, 52% of upstream captures occurred between 14 June and 25 June. Major downstream movement of Arctic Grayling out of lower Dale Creek began in mid-September, with 80% of downstream captures occurring between 21 September and 30 September 1981.

Dolly Varden and Mountain Whitefish, both recognized as fall-early winter spawners, utilized lower Dale Creek to a lesser degree than Grayling. Dolly Varden were captured moving into and out of Dale Creek throughout the trapping period in no discernible pattern. However, mature, immature, and young-of-the-year fish were collected, indicating that Dolly Varden spawning occurs in lower Dale Creek.

Figure 4-11 FISH DISTRIBUTION IN THE STUDY AREA

SCALE: 4 cm = 1.0 km

Mountain Whitefish were captured only moving upstream into lower Dale Creek. Trapped Whitefish were large, mature fish. In all likelihood, a small number of Mountain Whitefish also spawn in lower Dale Creek beginning in late September or early October.

It is unknown whether overwintering occurs in lower Dale Creek. No open water areas have been documented during the January-to-March period except at the Dale Creek-Tsichu River confluence. However, several large pools associated with beaver activity (sites 39 to 62) and the large pool just upstream of the trap site (67) appeared to be of sufficient depth and extent to overwinter fish.

No fish were captured or observed in middle Dale Creek. Only Dolly Varden adults and juveniles were collected and/or observed in upper Dale Creek. Fewer than a dozen Dolly Varden juveniles (age: 1+) were observed during 1981 in runs and at the bottom end of pools between sites 19 and 24 in the area of the proposed tailing pond, indicating that some spawning may occur in this area. However, no fry or young-of-the-year have been collected in upper Dale Creek. The appearance of anchor ice in late September in riffle areas suggests that any successful recruitment by the fall spawning Dolly Varden was restricted to pool and run areas in which the water depth was greater than 0.3 m. The absence of Arctic Grayling in upper Dale Creek is probably a function of physical and velocity barriers in middle Dale Creek as well as the rapid runoff during the spring period.

4.7.4.3 Tsichu River

Arctic Grayling, Dolly Varden, Mountain Whitefish, and Slimy Sculpins are common inhabitants of the Tsichu River from the Keele River to the confluence with Dale Creek. Based on 128 total recorded captures in the Tsichu River, species compositions are 68%, 15%, 8%, and 19% respectively, for the four species. An additional species, the Round Whitefish, although never reported from the study area, was documented in the Tsichu River 22.5 km east of the Lower Tsichu River Bridge.

Arctic Grayling and Dolly Varden are known to spawn in Airstrip Creek and Culvert Creek. Grayling fry also were observed in the mainstem of the Tsichu in pool areas located among the islands upstream of the lower bridge during each year of the study. Although the entire river contains clean substrate gravels suitable for spawning by both species, the reaches east (downstream) of the lower Tsichu Bridge contain more pools in excess of 1 m deep in association with larger expanses of gravel and thus, better reproduction habitat. Three seasons of angling records comparing the river 15 km to 22 km east of the lower bridge to segments west (upstream) of the lower bridge indicate that catch per unit effort usually was two to three times greater in the lower stretch than above the bridge. In addition, more mature fish of larger (¨400 mm) size were captured in the downstream reaches.

The upper Tsichu River (from the confluence with Dale Creek upstream) appears devoid of fishlife (Figure 4-11). No fish have ever been observed or reported to occur in this segment. Although the physical habitat appears excellent, this reach is apparently uninhabitable because of lower ambient water quality and the associated severely reduced benthic macroinvertebrate community discussed earlier in this report.

The input of water from Dale Creek apparently ameliorates the lower quality of the upper Tsichu River, as Arctic Grayling, Dolly Varden, Mountain Whitefish, and Slimy Sculpins can be found downstream from the confluence. However, the impact of the upper Tsichu River carries downstream to just east of the confluence with Gill Creek as evidenced by the fact that few fish are resident in this stretch. Below Gill Creek, Arctic Grayling and, to a lesser extent, Dolly Varden and Mountain Whitefish may be found in the deeper pools. Mature and immature slimy Sculpins (a forage species preyed upon by Dolly Varden) are particularly common in the braided channel areas between Gill Creek and the lower Tsichu Bridge.

4.7.4.4 Cirque Lake

No fish captures have been reported from Cirque Lake. During 1975, Environment Canada placed three gill net sets consisting of 3.81 cm to 12.7 cm mesh at Station 6 for 6 hours and at Station 7 for 17 hours (Environment Canada 1976). In 1977, AMAX consultants test netted Cirque Lake for 72 hours. The net set was placed between Stations 8 and 2 from 9 July to 11 July (48 hours), and between Stations 7 and 5 from 11 July to 12 July (24 hours). In the main, nets were set in relatively shallow water (3-6 m) since Lake trout and Dolly Varden were readily angled from shore at other lakes in the region.

In addition to gill netting, approximately 100 m of shoreline between Stations 3 and 8 were seined with a 1.8 m x 9.1 m seine net. No evidence of fish habitation was observed. Presumably, the lake is fish free because of the lack of a surface channel connecting the lake to another body of water. As previously discussed, discharge from Cirque Lake is subterranean.

4.7.4.5 Cirque Creek

The origin of Cirque Creek is the subterranean flow from Cirque Lake. Cirque Creek meets Dale Creek approximately 2.5 km east (downstream) of the present minesite access road crossing. Only the lower 300 m of Cirque Creek were surveyed for fish use during the 1981 program. On 28 September 1981, two Arctic Grayling, which had been tagged in the fish trap on lower Dale Creek, were located in lower Cirque Creek. Surveying and angling of the remainder of Cirque Creek during 1982 failed to detect any fish.

The upper portion of Cirque Creek is unlikely fish habitat because of the gradient and because of a gorge located about 600m up from the confluence with Dale Creek which may serve as a barrier to migration.

4.7.4.6 Airstrip Pond Complex and Wader Pond

Other water bodies within the MacTung Project area which were found to support fish during the 1977-1981 program included Airstrip Creek, Airstrip Pond, Culvert Creek, and Wader Pond (Figure 4-7). Airstrip Creek flows from Airstrip Pond into a deep pool in the Tsichu River approximately 0.75 km upstream of the lower Tsichu Bridge. Culvert Creek (approximately 2 km in length) flows from the south through a culvert under the Canol Road near the west end of the Tsichu River airstrip and joins Airstrip Creek just below Airstrip Pond. Wader Pond is a small pond contiguous to the Tsichu River approximately 1.25 km east of the Dale Creek confluence. This pond is connected to the river by a channel 50 m in length and less than 1 m deep. Past activities by beaver have raised the water level in this pond.

The Airstrip Creek complex (including Airstrip Pond and Culvert Creek) is a documented spawning and rearing area for Arctic Grayling. In 1977, a gill net set in the central portion of Airstrip Pond produced two female Dolly Varden and three Arctic Grayling. One Dolly Varden (aged 4 years) was sexually immature, while the other (6 years) was mature and developing. All three Arctic Grayling were sexually immature. A 30 m seine haul produced three juvenile Arctic Grayling and 20 fry. In addition, angling yielded two Arctic Grayling (aged 3 years).

A gill net set in 1978 produced two Arctic Grayling, each 2 years of age. A 30 m seine haul produced four Arctic Grayling fry. In addition, Arctic Grayling spawning activity was observed in the pond's outlet channel in the spring of 1978.

Although no young-of-the-year Dolly Varden were recorded in the Airstrip Creek complex, two mature individuals (a male and a female) were captured in Airstrip Pond. Spawning habitat in lower Airstrip Creek is suitable for Dolly Varden, and the large pool at the mouth of the creek in the Tsichu River generally contains several individuals during the June to October period. Thus, it seems likely that Dolly Varden spawning occurs in the Airstrip Creek complex.

Several mature Arctic Grayling were captured in Wader Pond in 1977 and 1978, and others were observed. Observations also were recorded in 1982. However, neither spawning activities nor young-of-the-year fish have been documented for the Wader Pond area. Wader Pond appears to be draining and slowly drying. In July 1982, the water level was considerably lower, and more aquatic vegetation growth was present than in 1977 and 1978.

4.7.4.7 Miscellaneous Water Bodies

In addition to the water bodies in the study area, three adjacent lakes were sampled: (1) Gill Lake - headwater lake to Gill Creek, located 6 km (air) north and east of Cirque Lake; (2) Lost Guide Lake - located 18 km (air) downstream of the lower Tsichu Bridge; and (3) an un-named lake or expansion of a tributary stream to the Tsichu River - located 7 km (air) downstream of the lower Tsichu Bridge. The morphometry of these three lakes are unlike Cirque Lake in that they are not as steep and have somewhat more littoral area.

4.7.4.8 Life History Information

As discussed, Arctic Grayling and Dolly Varden are the two species most common to the MacTung Project area. Grayling comprised 78% of all captures, and Dolly Varden comprised 11%. For this reason, the discussion of life history information will be limited to these two species.

a) Arctic Grayling

Arctic Grayling generally spawn in small streams in early spring, migrating toward these tributaries at ice break-up (Jessop et al. 1974). Spawning occurs at a temperature range of 7°C to 10°C (Scott and Crossman 1973). Eggs are adhesive and are broadcast over gravel or rocky substrates.

Incubation periods generally are in the range of 16-18 days at 9°C.

Age and Growth. The oldest specimen recorded during the program was 9 years old, measured 430 mm (fork length) and weighed 940 g. The longest individual was 473 mm, weighed 575 g, and was 8 years old, while the heaviest Grayling was of unknown age and weighed 1,000 g. Growth (length) was relatively uniform between years 1 and 5. However, in age classes 5 through 9, variability in growth rates was high.

The average 6 year old Grayling (n = 50) was 365 mm long and weighed 540 g. In comparison, lengths of 6 year old Grayling from Great Bear Lake and Great Slave Lake were 356 mm and 405 mm, respectively (McPhail and Lindsey 1970). The "average" Arctic Grayling in the Tsichu River system (recognizing a great degree of variability) was 5.7 years old, 336 mm long, and weighed 390 g (n = 433).

Food Habits. Stomach contents of 53 Arctic Grayling were analyzed to determine general food habits. Grayling were feeding entirely on insects and primarily on aquatic macroinvertebrates. Chironomids (small midges), Ecclisomyna spp. (caddisfly), and two stonefly (Plecoptera) genera (Nemoura spp. and Alloperla spp.) were the most prevalent foods consumed. Terrestrial beetles and mayflies (Ephemeroptera) also were major diet constituents.

b) Dolly Varden

Dolly Varden spawn primarily in streams during the period August to October. Eggs are deposited in redds and covered with gravel; they develop over winter and usually hatch in the spring. Young remain in relatively shallow areas of streams and rivers for 2 to 3 years before venturing into deeper water or into larger riverine systems. Dolly Varden can travel considerable distances in a relatively short period. The species also has abilities comparable to some species of Pacific salmon in overcoming physical and velocity barriers.

Age and Growth. This char species generally is faster growing and of larger size per age class than the Arctic Grayling. The "average" Dolly Varden in the Tsichu River system was 5.1 years old, 350 mm long, and weighed 482 g (n=59). The oldest individual captured was 9 years old. This fish, trapped in Dale Creek, also was the longest (625 mm) and heaviest (1940 g).

Food Habits. Dolly Varden are voracious predators with food habits which are considerably different from those of Arctic Grayling. Of 20 Dolly Varden stomachs examined during the program, 50% contained mammalian remains (Tundra Voles and Water Shrews), 10% contained Slimy Sculpins, and 5% contained duckling feet. Some aquatic macroinvertebrates, particularly mayflies and chironomids, also were consumed.

More detailed information on aquatics can be found in the companion report entitled "Aquatic Ecology of the MacTung Area, 1973-1982".

4.8 VEGETATION

The same 500 km^2 study area described in Section 4.4 for terrain was examined (Refer to Figure 4-1). As can be expected over such a large area the vegetation varies greatly with elevation, drainage and substrate. Plant cover ranges from epilithic lichen tundra at high elevations to forested stands in the valley bottoms. Most of the MacTung area however, lies above timberline and can be classified as arctic/alpine tundra since both elevation and latitude are important parameters determining its ecological characteristics. Treed areas can be classified as subarctic forest. These generally are dominated by alpine fir (Abies lasiocarpa) but range from krummholz outliers well above the present-day treeline to mature stands of white spruce (Picea glauca) at lower elevations.

The fine-grained nature of tundra plant communities makes it difficult to delineate distinct communities without a high density of sample sites and sophisticated statistical techniques; intead, vegetation has been mapped on the basis of physiognomically defined plant community complexes. Consequently, reference is made to vegetation types, community complexes and habitat types rather than to specific plant communities.

Seventeen plant community complexes have been identified within the study area, 12 of which are found in tundra and 5 at or below timberline. They are:

Tundra Plant Community Complexes

- epilithic lichen
- cushion plant
- alpine meadow
- alpine lichen - grass
- lichen-heath
- birch-lichen
- birch-moss
- willow-forb
- riparian willow
- sedge meadow
- forb meadow

- lowland lichen-grass

Subarctic Forest Community Complexes

- krummholz
- fir-lichen
- fir-moss
- lowland white spruce
- birch-spruce

These communities are described below and referred to in the wildlife section of the report (Section 4.9) because of their importance as habitat. Although they are not mapped in this report, they have been delineated and included in the component report entitled "Geomorphology and Vegetation of The MacTung Study Area, Yukon/N.W.T."

4.8.1 TUNDRA PLANT COMMUNITY COMPLEXES

Epilithic lichen tundra is often found at or near mountain tops on slopes of all aspects. Topography is convex and the highly permeable substrates are excessively drained and xeric with extreme wind exposure. No plant growth exceeds 10 cm in height. Lichen species have colonized exposed mineral substrates and cover more than 10% of the surface. A total of 26 lichen species and 4 moss species were identified from this habitat. Vascular plant species are essentially absent from epilithic lichen sites. (Refer to Appendix I for a complete listing of identified plant species in each vegetation complex.)

Cushion plant tundra is generally found on flat to gently sloping surfaces at relatively high elevations. Internal drainage is free to excessive and consequently soil moisture ranges from semiarid to xeric. Wind exposure is extreme. In these communities, shrub species form small mats or cushions surrounded by exposed, frost riven, mineral surfaces.

Vascular plants generally dominate. Dwarf shrubs, graminoid species and mosses are characteristic of this vegetation type and no plants reach heights of over 30 cm.

Alpine meadows are found in relatively moist areas at high elevations. All are uniformly sloping with strong wind exposure. Soils are freely drained and the soil climate is humid. The site of the proposed plant/residences complex is alpine meadow. These lush alpine communities are dominated by vascular plant species. In some areas, shrubs such as Salix barrattiana are an important component of the community and grow to over 30 cm in height. Dwarf shrubs (e.g. Salix arctica, S. reticulata and Dryas integrifolia) have high cover values and are especially important on less sheltered sites.

Alpine lichen-grass tundra is generally found on drier sites at elevations similar to or slightly higher than those of the alpine meadows. Wind exposure ranges from strong to extreme. All soils are freely drained and soil climate ranges from perhumid to semiarid. Graminoid species are visually dominant when viewing an area from ground level but the important lichen component becomes obvious when these sites are observed from above in the course of aerial surveys or air photo interpretation.

Lichen-heath tundra is found on flat to gently sloping sites at moderate to high elevations. The sites occupy a wide variety of aspects and all are convex or uniformly sloping and freely to excessively drained. Soil climate ranges from subhumid to subarid and wind exposure is moderately strong to extreme. Lichens generally cover over 50% of the surface. Although 45 lichen species were recorded from sites in this type of vegetation, Cladonia mitis and Cetraria nivalis are most dominant, with an average combined cover of 40%. Of the 37 vascular plant species recorded from this habitat type Cassiope tetragona is dominant and the only one with a mean cover of greater than 2%.

Birch-lichen tundra also covers large parts of the major valleys of the study area. Local topography in sample sites ranges from convex to complex with moderate to strong wind exposure. All sites are freely drained with humid to subhumid soils. Although Betula glandulosa dominates visually, lichens are the major component of the understory having a mean cover value of 72% in the first stratum, with Cladonia mitis accounting for over one half of this value.

Birch-moss tundra is generally found on relatively moist, gently sloping sites in the major valleys. Site aspects range from north to southwest. All sample areas are on relatively uniform slopes with slight to moderate wind exposure. Drainage is impeded and soil moisture is classified as perhumid. The transition from birch-lichen to birch-moss tundra with increasing soil moisture is generally rapid. The two complexes are differentiated on the basis of the lichen/moss cover ratio. When moss species dominate the understory, the vegetation is classified as birch-moss tundra. Average total plant cover in this habitat type is 95%. Dominant moss species vary greatly from one site to the next. Hylocomnium splendens covers 60% of the ground surface in some sites but is found only occasionally in others. Similarly, cover by Polytrichum commune ranges from less than 1% to 35%.

Willow-forb tundra is found on moist sites and several of those sampled have small pools of standing water. Topography is concave, complex or neutral and internal drainage ranges from impeded to seasonally wet. Soil climate is peraquic to subaquic. The south-facing slope of Dale Valley occupied by the present access road is an example of willow-forb tundra. This complex is by far the most diverse habitat type. The shrub canopy is often dense and three or more Salix species often are found within each strata. Bryophyte cover is generally high, with a mean value of 35%; lichens are found only occasionally on raised sites. A total of 186 taxa were recorded from willow-forb tundra and many of these are important components of the community (i.e. have cover values of 1% or greater).

Riparian willow tundra is generally found on the annual floodplain along major rivers or large tributaries. Although these surfaces are flat and freely drained, most are flooded annually and the water table remains close to the surface throughout the year. Vascular plants dominate the vegetation of these sites with a mean cover of 55%. Salix alaxensis is always the dominant shrub, however, Salix planifolia is also important.

Many meadows can be found on moist sites in the MacTung study area. Two major vegetation types were defined in this complex on the basis of field checking. On wetter sites where the ground water table is at or near the surface, Carex aquatilis dominates and communities are referred to as sedge meadow. On seasonally wet to moist sites, a variety of broad-leafed species such as Rumex arcticus, Mertensia paniculata, Artemisia arctica, Petasites frigidus and Senecio triangularis also become major components and vegetation is referred to as forb meadow. Much of the Dale Valley bottom is comprised of sedge meadow and forb meadow.

Lowland lichen-grass tundra is found on well-drained sites in major river valley bottoms. This type of vegetation covers extensive areas in the Upper Tsichu River valley but is also found commonly as narrow bands interspersed in birch-lichen tundra. Site topography varies from flat to convex with moderate to strong wind exposure. All soils are freely drained and the soil climate is subhumid. This vegetation type is dominated by lichens with a few scattered vascular plants and mosses.

4.8.2 SUBARCTIC FOREST PLANT COMMUNITY COMPLEXES

The krummholz community is found at several scattered locations just above treeline in the Hess River tributary drainage basin and well above the valley bottom of the Upper Tsichu River. All sites sampled were uniformly sloping with slight to strong wind exposure. Soils are freely drained and soil climate is humid. Abies lasiocarpa dominates these stands. Tree growth is very dense and most other vascular plants are found in the more open areas between clumps of trees.

Fir-lichen communities are found on well-drained slopes in the Hess River drainage basin. Most of these sites are north-facing but similar communities exist on south-facing slopes across the valley. Topography is uniformly sloping and wind exposure is generally slight to moderate; soils are freely drained and soil climate is perhumid. Fir-lichen stands are generally open. Abies lasiocarpa is the dominant vascular plant in this community although trees are often stunted on exposed sites. Lichens dominate the understory with a scattering of shrubs such as Betula glandulosa, Cassiope tetragona, Vaccinium uliginosum and Vaccinium vitis-idaea plus mosses such as Hylocomnium splendens and Polytrichum species.

Fir-moss communities are found on moist slopes in the Hess tributary drainage where topography is uniformly sloping and wind exposure is generally slight to moderate. Soils are freely drained and soil climate is perhumid. Many seeps and small streams are found on these slopes. Tree growth (Abies lasiocarpa) is generally very dense in this vegetation type and often impedes movement through these sites. The vascular plant diversity of these sites is generally low and of the 10 species recorded, only Abies lasiocarpa had a mean cover value of 1% or greater. Bryophytes covered 72% of the ground surface with Hylocomnium splendens and Sphagnum species accounting for over 80% of this value.

A few localized areas of relatively mature spruce forest (lowland white spruce community) were found in sheltered locations at low elevations in the Hess tributary basin. Topography of these sites is flat or concave with almost no wind exposure. Drainage is often impeded and soil climate is subaquic. Picea glauca dominates these communities with trees reaching heights of over 25 m and a canopy cover of 15%, 2%, 15% and 22% in the second, third, fourth and fifth strata, respectively. Ground cover is visually dominated by vascular plants; most notably by the Equisetum species. However, bryophytes cover approximately 60% of the ground surface and Hylocomnium splendens accounts for over 95% of this value.

Extensive areas of Betula glandulosa with a few scattered coniferous trees (usually Picea mariana or P. glauca) comprise the birch-spruce community, found in the broad valley bottoms of the Hess River Tributary drainage basin. Sites in this vegetation type are flat with slight to moderate wind exposure. Soil drainage is impeded. Although soils are coarse in texture, the water table remains relatively close to the surface throughout the year.

4.8.3 PLANT RANGES

No lists of rare non-vascular plants of the Yukon/N.W.T. are available. However, Douglas et al. (1981) produced a list of the rare vascular plants of the Yukon and in 1979, Cody published a list of vascular plants of restricted range in the N.W.T.

Forty-nine of the species included in Cody's list are found in the study area. However, none of these are rare endemics and 36 are common to widespread in the Yukon Territory. Nine appear also to have limited distributions in the Yukon but are not considered rare in the Yukon (Douglas et al. 1981). Four species are considered rare in both the Yukon and the Northwest Territories.

None of the species were discovered in areas slated for construction disturbance. In addition, none of the species are endemic to northwestern North America, let alone the MacTung Study Area. In general, all four of these species are essentially on the fringes of broad distributions.

Appendix I presents the mean cumulative plant cover by species in each habitat type in the MacTung study area. More detailed vegetation information and mapping is available in the companion report entitled "Geomorphology and Vegetation of the MacTung Study Area, Yukon/N.W.T." produced for AMAX by Arctic and Alpine Environmental Consulting.

4.9 WILDLIFE

Various wildlife surveys have been conducted through the years and caretakers at the AMAX Tsichu River Meteorological station (operated from October 1974 to August 1982 at Mile 222 of the Canol Road) were asked to record wildlife sightings. A comprehensive wildlife study was done by Dr. Don Gill and published in 1978 as a booklet entitled "Large Mammals of the Macmillan Pass Area". The area studied by Dr. Gill was a rough circle with a diameter of approximately 15 km centered on the mine site. In 1981, a systematic and seasonal study was initiated and the study area was expanded to 500 km^2 to include the entire Tsichu River Basin to approximately 11 km east of the Tsichu River Airstrip. The expanded large mammal study area is identical to the terrain and vegetation study areas discussed in this report (Figure 4-1).

Aerial surveys on 10 established transects, 2 km apart, were flown at low speeds and heights for three consecutive days, during different periods of the day, in each of four seasons: summer - fly season, fall - rut, mid-winter, and spring - calving season. The study encompasses a two year period which commenced in June 1981. The second year of study will be completed in June 1983 and thus only the results of the first year of study are presented in this report.

In addition to the large mammal studies, the productivity and species diversity of various small mammal habitats were assessed by a trapping program during 1981 and 1982. As with large mammals the results of the first year's study only will be discussed herein.

Summer and winter wildlife habitat utilization studies were also conducted, incorporating, where applicable, information gathered in the geomorphology, vegetation, and climatological studies.

Finally, various avifauna studies were also conducted through the years. A comprehensive study was completed during 1982. All avifauna data have been compiled and are summarized in Section 4.9.4 of this report.

4.9.1 LARGE MAMMALS

In 1982 caribou calved near the eastern border of the study area approximately 25 km east of the mine site, and moved to higher slopes and snow patches during the fly season (Table 4-14). Snow conditions during 1982 were relatively heavy and it is possible that calving would occur within 18-19 km of the mine site during a more open spring. Approximately one third of the cows and calves observed during the spring calving survey were in shrub communities but during the summer only a few solitary animals were sighted in this habitat. In several communities light use consisting primarily of travel through these habitats was noted.

Alpine meadow and birch-moss tundra were the only communities in which caribou were sighted on three of the four surveys but cushion plant tundra appeared to be used fairly heavily during both spring and summer. The number of caribou in the study area varied somewhat from spring to summer with maximum single flight observations of 210 and 212 animals, and densities of 42.0 and 53.0 animals/100 km^2, respectively. However, by late September few remained and during the winter no caribou were found in this area. In the 1981/1982 study, calves accounted for approximately 40% of the herd during the spring calving season and 32% of the herd during the summer fly season. Actual post-calving values may have been somewhat higher than those recorded, as calving was ongoing at the time of the June 1982 survey. Observations at a mineral lick on the western edge of the study area (the Hess River tributary lick) indicated that caribou, moose and Dall's sheep are frequent visitors of this mineral spring.

Moose, the second most abundant large mammal in the study area, are year-round residents. Riparian willow communities are used throughout the year and birch-moss tundra is also heavily used during the

TABLE 4-14

SUMMARY OF LARGE MAMMAL SIGHTINGS DURING THE 1981-82 AERIAL SURVEYS IN THE STUDY AREA

	Moose	Caribou	Dall's Sheep	Wolves	Grizzly Bear
Summer - Fly Season					
Total sightings during 3 day survey	17	305	0	0	0
Maximum sighted in 1 flight (8 Aug 82)	7	212	-	-	-
Fall - Rut Season					
Total sightings during 3 day survey	79	33	0	4	2
Maximum sighted in 1 flight (19 Sep 81)	37				
(20 Sep 81)		19	-	4	2
Winter Season					
Total sightings during 3 day survey	14	0	0	0	0
Maximum sighted in 1 flight (21 Feb 82)	6	-	-	-	-
Spring - Calving					
Total sightings during 3 day survey	21	325	6	1	2
Maximum sighted in 1 flight (2 Jun 82)	12				
(1 Jun 82)		210	3	1	1

spring, summer and fall (Figure 4-12). Moose were generally observed at low elevations and in relatively wet habitats, although a few animals were sighted on higher slopes in krummholz and birch-lichen communities during the fall survey. The presence of willow appears to be the major factor determining moose distribution. Although birch is considered highly palatable for moose, evidence of its use within the study area was rare. Aerial survey results of moose within the pre-1981 study area boundary were 3, 1 and 1 sightings on separate days in 1974; 2 and 1 in 1975; 3 and 3 in 1976; 5, 4, 7, 2, 1 and 3 in 1977; and 9 in one day in 1978. On 19 September 1981, 11 moose were sighted within that portion of the present study area which represented the old study area.

Maximum numbers of moose observed in a single flight were relatively constant at 7, 6 and 12 during the summer, winter and spring of 1981-1982 respectively, but in the fall during the rut, the population was 37 animals (Table 4-14). Calves comprised a relatively constant proportion of the population throughout the year, suggesting low calf mortality in this area. Reproductive rates were high as the 6 cows identified in the spring survey were accompanied by a total of 8 young (5 calves and 3 yearlings). A set of twins sighted in the fall was the first recorded from the MacTung areas and the spring survey identified a further two sets.

Hunting during the fall removed more moose from the study area than were found to overwinter there, probably making hunting the major mortality factor in the study area. Macmillan Pass has long been recognized as good moose habitat (DIAND 1974) but hunting has been limited by its inaccessability to N.W.T. residents. However, hunting pressure appears to have intensified (recently).

The resident band of 20-25 Dall's sheep observed in the study area during 1975 through 1978 appears to have declined severely. (Actual sightings during the period ranged from 1 to 23 animals per aerial survey). In 1979 and 1980 no aerial surveys were carried out and by 1981 only one group of three sheep was located in the study area. These animals were sighted by Nette (Department of Renewable Resources, Yukon Territorial

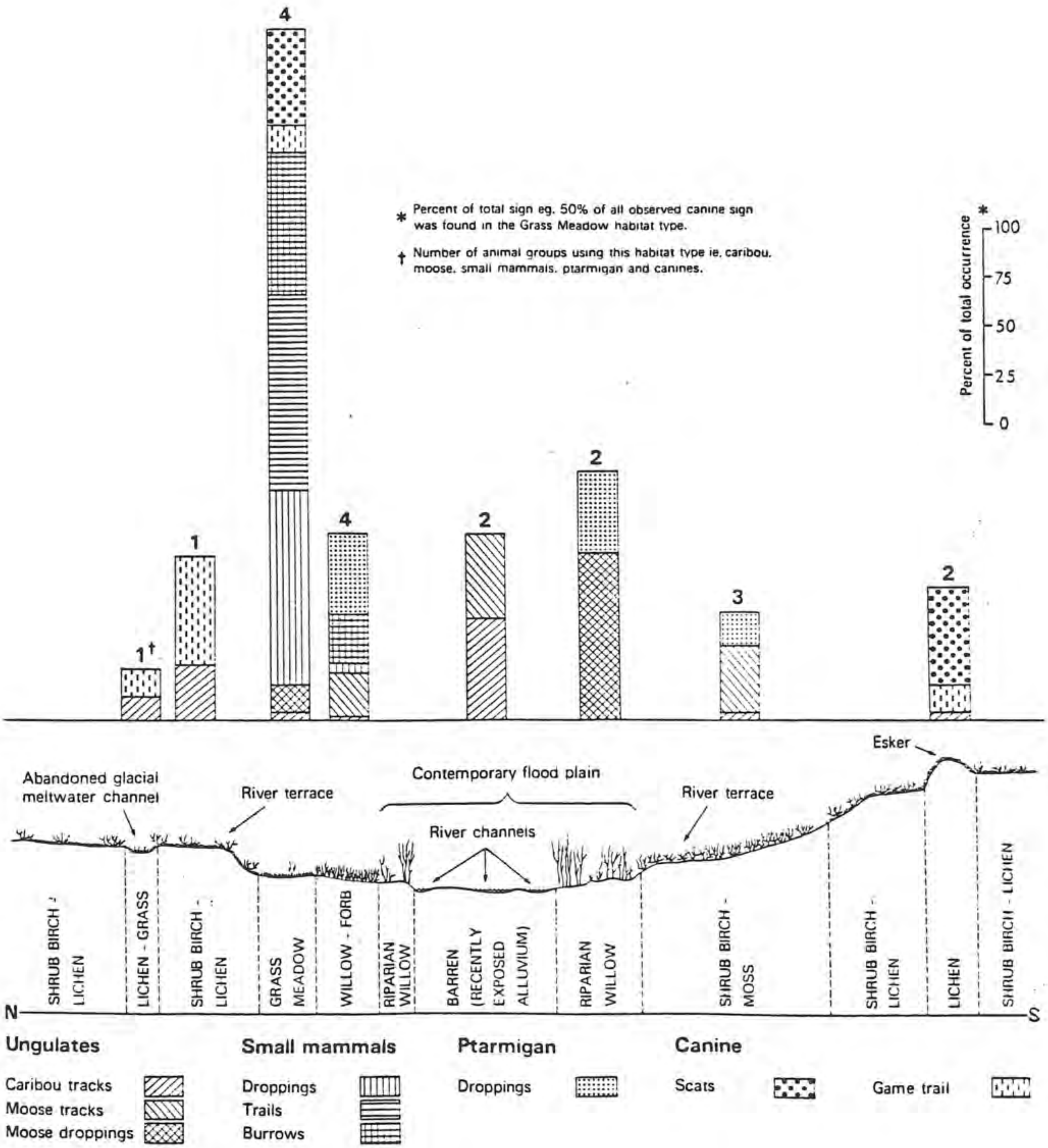


Figure 4 - 12

Habitat selection by wildlife at lower elevations in the Tsichu River Valley, MacTung study area

Government) in September 1981 and by AMAX in the June 1982 survey (Table 4-14). Both sightings were made at approximately the same location. In June, Dall's sheep were observed in an alpine meadow, below the winter range of the 1975-1978 band. Previously, bands had been seen primarily on north-facing slopes and seldom at elevations below 1800 m. In June 1982, the three ewes appeared to be staying at approximately 1500 m on south-facing slopes. The reduction in numbers could have been the result of a population crash or of migration out of the area.

Winter weather is considered the major factor influencing thinhorn sheep numbers and severe winters may cause drastic population crashes. The climatic conditions most commonly associated with population declines are wet snow or thaw followed by refreezing. This decreases the effectiveness with which wind removes snow, thereby reducing the availability of forage and inhibiting movement and cratering. A review of the climatic data indicates that thawing and freezing occurred in the spring of 1979 and may have caused the major declines in numbers of sheep. The precipitation in March of 1979 (56.7 cm) was the highest recorded for that month over the eight year period and was accompanied by the highest March maximum temperature. Temperatures plunged from the monthly maximum of +2.5°C on 22 March 1979 to the monthly minimum of -39.5°C on 31 March 1979 which would doubtless have resulted in the creation of a thick, hard crust on the snow. These warm, wet conditions followed an extremely cold February which had temperatures ranging from a high of -22°C on 1 February 1979 to a low of -51°C on both 8 and 13 February 1979. Dall's sheep in the study area are probably in a weakened physiological state during the winter and might have difficulty dealing with the added stress of these extreme weather conditions.

Earlier surveys established the presence of one sow grizzly that appeared to be producing two cubs every 3 to 4 years and occupying part of the study area on a year-round basis. Other bears were also seen but these were believed to be transients, probably boars, passing through in the spring and again the fall. Miller et al. (1981) found that mature female grizzly bears in a nearby section of the Mackenzie Mountains had an average minimum range of 265 km^2. Therefore, at least two females could have mutually exclusive ranges extending into the MacTung study area. However, no sows with cubs were sighted in the 1981-1982 surveys. Two solitary bears were seen during the course of a single flight in the fall (1981) survey and one sighting was made on each of 2 of the 3 flights in the spring (1982) survey, suggesting a transient population. Too few sightings were made in the 1981-1982 surveys to suggest areas of preferred habitat. Many potentially suitable denning sites are present in the Tsichu River area but no dens have been found. A moratorium on bear hunting in the Mackenzie Mountains was established by the N.W.T. Game Branch in 1982.

Wolves were seen in the study area during the fall and spring survey and on the day following completion of the summer fly season survey (1981). Four animals were observed on a moose kill north of the study area in the winter. Wolves range over large areas in search of prey. In the snow-free season they subsist on small game. However, in winter they form packs and take larger animals. The remains of one bull caribou and a moose were noted in the study area during the fall survey. Indications were that they had died the previous fall or winter (i.e. the racks were present). The cause of the deaths is unknown but wolves (and bears) had fed on the carcasses.

Large numbers of wolves (e.g. up to 27 in one day) have been noted in the study area in the snow-free season by AMAX personnel. However, the systematic aerial surveys have not recorded such concentrations. This may be due, in part, to the animals' small size and tendency to seek cover with the approach of aircraft.

4.9.2 SMALL MAMMALS

Eleven small mammal - trapping sites were sampled from 10 plant communities during the summer of 1981. One hundred and twenty-nine trap-nights were completed at each site for a survey total of 1419 trap-nights (Table 4-15). At total of 355 trap-nights were lost due to

TABLE 4-15

RESULTS OF SMALL MAMMAL TRAPPING SURVEY IN THE MACTUNG AREA: 11-14 AUGUST 1981

Plant Community	Red-Backed Vole #	Sex	Weight[1]	Brown Lemming #	Sex	Weight	Least Chipmunk #	Sex	Weight	Shrew #	Sex	Weight	All Species #	Weight	% of Total Biomass Sampled	# of Trap-Nights Lost	Success/100 Trap-nights Uncorrected	Correct
Alpine Lichen-Grass													0	0	0	83	0	0
Alpine Meadow	1	F	48										2	70	8	109	1.55	7.41
	1	J	22															
Forb Meadow	5	M	177							1	M	17	13	374	43	35	5.04	5.83
	3	F	103															
	4	J	77															
Sedge Meadow	1	F	E39	2	M	140							3	179	21	5	2.33	2.42
Lichen Heath													0	0	0	9	0	0
Lowland Lichen-Grass													0	0	0	24	0	0
Riparian Willow	1	F	40										1	40	4	91	0.78	2.63
Willow-Forb										1	J	11	1	11	1	3	0.78	0.79
Birch-Moss	1	M	23															
	1	F	E48										4	113	13	2	3.10	3.15
	2	J	42															
Birch-Lichen	1	M	31				1	J	40				3	86	10	1	2.33	2.34
	1	J	15															
All Communities	22		665	2		140	1		40	2		28	27	873	100	355	1.90	2.54

M = Male F = Female J = Juvenile E = Estimated

NOTES:
1 Weight indicated for all specimens
2 Of the total 1,419 trap-nights, 355 were lost due to ground squirrel activity leaving a total of 1,064 effective trap-nights. Corrected values are calculated following the subtraction of these lost trap-nights.

ground squirrel (Spermophylus parryii) activity. These animals were too large to be taken by the traps and sprung them in order to rob the bait.

Twenty-seven animals representing four species were trapped, including 22 red-backed voles (Clethrionomys rutilus), 2 brown lemmings (Lemnus sibiricus), 1 least chipmunk (Eutamus minimus), and 2 shrews (Sorex sp.). Trapping success was highest in the alpine meadow tundra where it reached 7.41 animals/100 trap-nights. Alpine lichen-grass, lichen-heath and lowland lichen-grass tundras produced no animals. However, a significant ground squirrel problem hampered trapping in two of these plant communities (Table 4-15). Two species were taken from forb meadow, sedge meadow and birch-lichen tundra, representing the only plant communities in which more than one species was observed. The larger number of species may reflect a greater habitat diversity in these plant communities. Forb meadow tundra and birch-moss tundra had the largest small mammal populations and were the only communities in which male, female and juvenile voles were taken. These plant communities therefore offer habitats suitable for animals at all stages of their life cycle.

Field biomass (undried) of small mammals in forb meadow tundra was twice that of the sedge meadow tundra, the community with the most similar level of production. Small mammal numbers should have been near their peak during the sampling period, as summer litters were part of the populations. Numbers generally decline after this period as a result of predation and over-winter fatalities. The numbers recorded during this survey represent the summer carrying capacity of these plant communities. Even in years of low numbers, summer population levels should still be the highest of the year. Animals taken in forb meadow, sedge meadow, birch-moss, birch-lichen, alpine meadow and riparian willow communities represented 99% of the biomass and 85% of the small mammals sampled.

4.9.3 WILDLIFE HABITAT STUDIES

In 1980, pellet and track counts were made along transects in eight plant communities within a valley-bottom study area. Results indicate that caribou range over much of this area while moose confine their activity to areas near the rivers (Figure 4-12).

During the February 1982 survey, snow-pack characteristics were determined in key overwintering areas utilized by resident wildlife. In the course reconnaissance surveys throughout the study area it was determined that the riparian willow and willow-forb plant communities were heavily used by all species and that other habitat types were utlized only lightly (Figure 4-13). Moose, snowshoe (varying) hare and Rock and Willow Ptarmigan confine their activities almost entirely to the river bottom and gully systems supporting these plant communities.

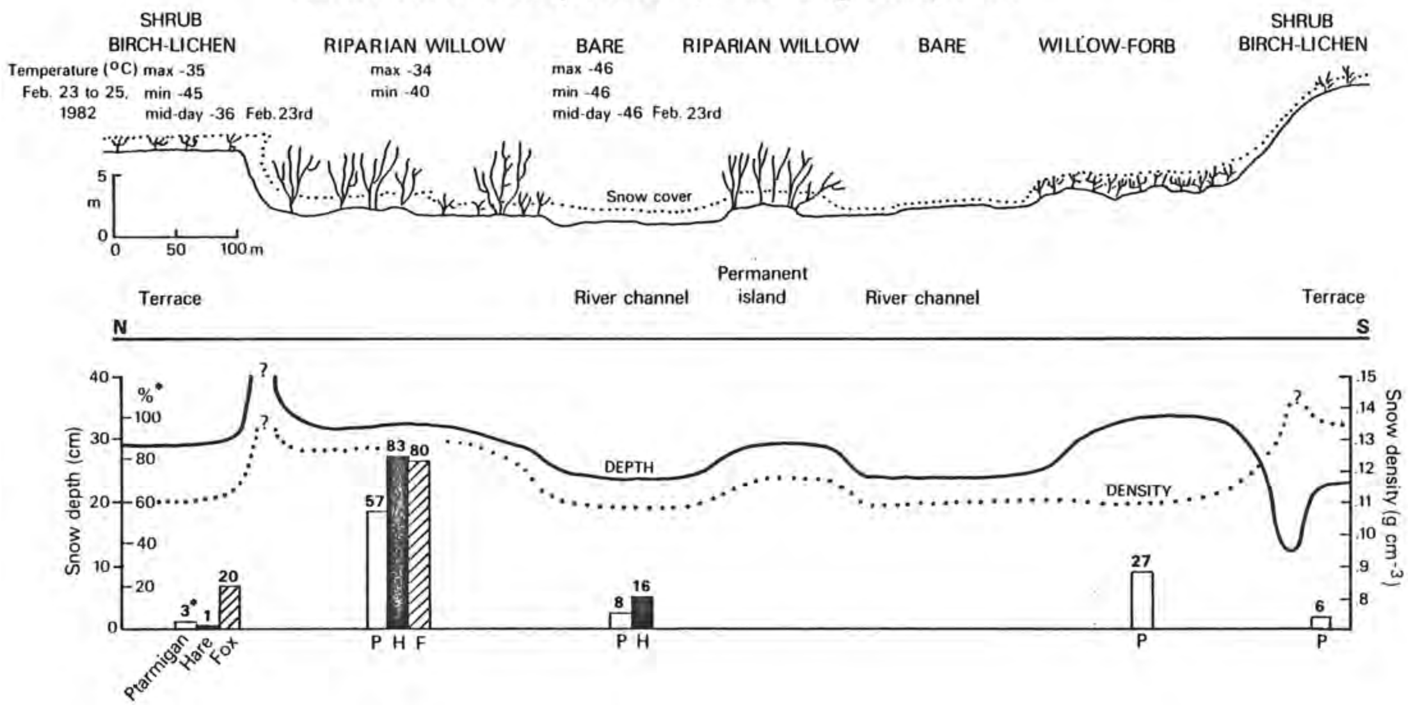
Areas used by moose had average snow depths of 31 cm with densities of 0.10 g/cm^3. The selection of these areas was the combined result of greater availability of forage (Salix alaxensis and Salix planifolia) and greater shelter from winds. Also, the dense willow stands with their dark color had lower albedos (i.e. less incoming radiation was reflected from these areas) and temperatures were consequently warmer. For example, the maximum temperatures measured in these stands were all at least 1°C warmer and the minimums were at least 5°C warmer than those of other areas. During the survey, valley bottom temperatures at mid-day on the river ice were -46°C while on the first terrace, 5 m above the river, they were -36°C. Despite this cold air drainage, the availability of food, the warmer microclimate of the willow stands and the lack of wind kept moose in the area (Figure 4-13).

Hare were sighted (in abundance) for the first time in the study area during the fall survey (September 1981) and large numbers of hare were seen throughout the riparian willow and willow-forb communities during the 1982 winter survey.

Ptarmigan flocks of at least 100 birds also frequent valley bottom locations during the winter. At this time of year, ptarmigan feed on

Figure 4-13

Winter habitat selection by over-wintering wildlife, Tsichu River Valley bottom, MacTung study area



* Percent of total track sign eg. 20% of all Fox sign was found in the Shrub Birch Lichen habitat

the buds and small twigs of shrubs that protrude above the snow. Such shrubs were most common in river and gully systems and ptarmigan use was concentrated in these areas. Roosts consisting of hollows in the snow were also common in the valley bottoms. Both types were used at night, and in very cold periods, during the day. Roost densities of 0.5 to $2.0/m^2$ were common in riparian willow and willow forb communities. None were found in other plant communities. Foxes hunt hare and ptarmigan and were frequently seen surveying the river bottom from the lower river terrace. They commonly moved along the hard snow drifts and windswept slopes found on either side of the river.

4.9.4 AVIFAUNA

Seven specific sample sites within the study areas were surveyed during the 1982 breeding season; i.e. late June and early July. Sites were selected because of their high potential as avian habitat and their importance and proximity to proposed operational areas of the mine.

Since 1972, 71 bird species have been documented within the MacTung study area. The species list along with evidence of breeding and respective habitats is prevented in Appendix II. Fifty species were recorded during a comprehensive survey conducted in 1982. The Canada Goose was the only species noted in 1982 which was not previously documented. Fringillid species (finches and sparrows) are the largest group of avifauna in the area and comprise 42% of the total species composition. Of this group, Tree Sparrows and Savannah Sparrows are the most ubiquitous. Shorebirds are the next largest group at 15% of species composition, followed by grouse at 11%. Willow Ptarmigan make up 96% of the latter group.

Fourteen species of waterfowl, eleven species of shorebirds (including the Dipper), and four species of gulls and terns (including the Parasitic Jaeger) have been recorded one or more times within wetland and riparian habitats of the area. However, five species of waterfowl have been recorded only once, and two other species are not known to breed on the site. In addition, two species of shorebird have been recorded only once, and only the Mew Gull breeds in the area.

Green-winged Teal, Lesser Scaup, and the Harlequin Duck are the most prevalent waterfowl species using the site. Green-winged Teal, at maximum, probably produce no more than six broods a year in the entire project area. Harlequin Ducks have produced at least three broods per year and may produce up to five broods in some years. Although Lesser Scaup are known to breed on the site, broods have yet to be documented. Waterfowl usage of the site appears restricted to the pond/sedge meadow/willow-forb wetlands and the Tsichu River riparian system in the eastern two-thirds of the area.

The most common shorebird species in the area are the Northern Phalarope (particularly in the upper Dale Creek wetlands), Least Sandpiper, and Lesser Yellowlegs. Other shorebird species are relatively common and also breed in the area. Shorebirds are fairly evenly distributed throughout the project area where pond/sedge meadow wetlands exist. The upper Dale Creek and the Airstrip Pond area at the eastern edge of the site are the best shorebird areas followed closely by the wetlands along the upper Tsichu River.

The Mew Gull is the only species of gull or tern which is common to the area. This species concentrates along the lower Tsichu River where it nests and utilizes the braided channel segment just north of the Tsichu River Airstrip. Individuals also frequent Cirque Lake after ice-out.

As a general conclusion, the MacTung project area cannot be considered a good waterfowl production area, especially if compared to the central prairie provinces and known waterfowl production regions to the north and east (Linduska 1964). Although the pond/sedge meadow/willow-forb wetlands provide fair to good habitat from a structural perspective, they are limited in areal extent. However, the project area can be considered fair to good for shorebird use and production. Diverse shorebird populations were recorded throughout the area.

Gyrfalcons and Golden Eagles are known to nest in the high tundra areas in the vicinity of the MacTung mine site. A pair of adults of each species was observed in the upper end of the Tsichu River - Dale Creek valleys in 1982, but no nest sites could be located. Known eyries apparently are located on the Yukon side of the project area. A Gyrfalcon eyrie is located 1 km from the mine site. However, according to Hayes and Mossop (1981) the nearest productive nest site of either species was 6 km from the mine site. The MacTung area lies outside of the most productive zones of either species.

Although none were recorded in 1982, Short-eared Owls are a common nester in the area. Snowy Owls and Marsh Hawks nest in the area less frequently.

Observations and species data indicate that the habitats of most importance to the project area avifauna are those of the upper Tsichu River which contain ponds, sedge meadows, willow-forb areas, and the braided channel segments of the lower Tsichu River. In particular, Airstrip Pond and its environs, the pond-wetlands area adjacent to the upper Tsichu River, and the Tsichu River braided channel north of the Tsichu River Airstrip appeared to support the most diverse and abundant avian populations. The pond-wetland area which included the Airstrip Pond had the highest Shannon-Weaver diversity index (H'=2.48), followed closely by the upper Tsichu River wetlands (H'=2.45), and the lower Tsichu River braided channel-riparian willow area (H'=2.20). The lowest diversity index in the area was lower Dale Creek (H'=1.30), which also contained the least avian activity. The wetland areas in upper Dale Creek (the proposed tailing pond site), at first appearance, would seem to support a diverse avain population. However, the data do not support that impression. Although 13 species were recorded for this site, the diversity index was second lowest (H'=1.62). The reason for the relatively low value was that the majority (76%) of the individuals recorded were distributed among only 4 of the 13 species. Therefore, although upper Dale Creek supports abundant populations of Tree Sparrows, Savannah Sparrows, Northern Phalaropes and Willow Ptarmigan, it does not contain a diverse avifauna relative to other project site wetland-riparian habitats.

Appendix II presents all avian species recorded at the MacTung Project Area and their habitats, and indicates whether or not evidence of breeding exists. More details on the wildlife studies are available in the companion reports entitled "1981-1982 MacTung Wildlife Studies, Yukon/N.W.T." prepared for AMAX by Arctic and Alpine Environmental Consulting, and "Avifauna of the MacTung Project Area" prepared by AMAX Environmental Services, Inc.

4.10 HERITAGE RESOURCES

An overview report has been prepared on the heritage resources of the study area (Lifeways of Canada Limited, 1982). The report is based on a literature search (including findings from as yet unpublished enquires), discussions with knowledgeable specialists and air photo interpretation. There was no field reconnaissance. The purpose of the study was two-fold: to acquire information bearing on the relative heritage value of project area lands; and to define areas which would merit predevelopment field examination. Recourse to information sources suggests a reasonable expectation that prehistoric and traditional native sites exist in the project area. The potential for sites varies between different parts of the MacTung area. The absence of unusually favourable conditions such as the presence of major caribou migration routes, greatly restricts overall archaeological potential. Known historic features and areas are primarily related to the construction of the Canol pipeline. In all there seems to have been a long term, but minor, utilization of the region wherein the project lies. Field studies would be required to locate traditional and prehistoric sites that may be extant in the project area.

Sites within the project area may have been occupied and/or utilized by highly mobile bands of hunters and gatherers for well over 10,000 years. Dene myths and legends suggest that the Mackenzie Mountains were a critical link in the ebb and flow of people across the northern interior. Recent archaeological discoveries in northern Canada and interpretation of evidence suggest the possibility of human occupation in these northern lands extending back to the initial peopling of the New World at least 55,000 years ago. Throughout the period basic patterns of utilization remained similar, only the forms and styles of technology employed changing with time. Prehistoric sites containing evidence of a weapons shift from microblade inserts to bow and arrow occur throughout the Yukon and Northwest Territories.

Of the six periods used to simplify the prehistory and history of northern North America, i.e. Paleo-Asiatic, Neo-Asiatic, Paleo-American, Neo-American, native contact - traditional and European, the Post-Pleistocene portion of the Neo-Asiatic (22,000 to 10,000 years ago) is represented in the Yukon wherever archaeological digs have been made and studies have been performed in depth. It is known to be present in the Macmillan region as a result of a recent archaeological survey south of the MacTung area. The project area was occupied traditionally by the Athapaskan speaking "Mountain Indians". These were amongst the last nomadic groups on the continent to be contacted by explorers. The Mountain Indians lived in and utilized much of the watershed between the Mackenzie River and the upper tributaries of the Yukon River (and likely frequented the MacTung area). Little is known of their prehistoric annual cycle, but probably their use of the mountain habitat was highly specialized and based on the hunting of caribou, sheep and moose.

Changes wrought by the introduction of the fur trade resulted in modification of these patterns. The establishment of fur trade posts along the Mackenzie River, on the Pelly River and in the central Yukon served to introduce the mercantile system to the nomadic hunters. Unable to produce high yields of fur bearers, the Mountain Indians interacted with the fur trade economy through the hunting and processing of large game for the provisioning of the posts. This pattern persisted until the late 1950's. The circumstances of the historical period served to reduce usage of the mountain habitat. The Mountain Indians were, more and more, attracted to centres of nucleation such as Fort Good Hope, Fort Simpson, Fort Norman, the Ross River Post, Pelly Post, Frances Lake Post, and Fort McPherson. The most distant locations from these posts, for example, the MacTung area, were utilized with less and less frequency.

EuroCanadian use of the mountains has been sporadic. In the late 1800's the Mackenzie Mountains were used as a route to the gold fields of the Yukon by perhaps 100 prospectors. And during World War II the Canadian Oil Pipeline, "Canol", was constructed through Macmillan Pass. A tote road for this project was initiated in January, 1943; the pipeline was completed on February 16, 1944. In March 13, 1945 the pipeline was closed down.

What, then, may be expected in the way of heritage remains, recognizing that the potential of prehistoric and historic use was low and few prehistoric sites may be present? Prehistoric sites would consist of manufacturing debitage, formed tools in low frequencies, fire broken rock associated with hearths, and other activity - specific types of prehistoric or traditional native materials. Known historic sites are limited to the remains of the construction and brief operation of the Canol pipeline. These include the Canol road track and Fish Lake camp at Mile 222.

In the vicinity of the MacTung project sites the distribution of favoured game species and the facility with which temporary camps could be established serve as archaeological determinants of prehistoric resources. The quality of the fisheries is low compared to the lower reaches of the Keele River. Ungulate potential, in contrast, may have been sufficient to provide a short-term attraction. An aerial photographic evaluation has been prepared of the airfield at Mile 222, the North Canol Road Between Miles 222 and 229, the existing MacTung access road (kilometer 0 to kilometer 11), the tailing pond, water supply, tailing line and return line, orebody and plant site.

4.11 SPECIAL USE LANDS

Special use lands comprise those sites and concerns which do not necessarily belong to one of the categories previously discussed in Chapter 4.0, yet should be brought up in order to complete this IEE. These special uses include surrounding potential Environmentally Significant Areas, Yukon Ecological Land Survey studies, potential heritage resource status of Canol Road features, possible recreational facilities and Indian Land Claims.

Cirque Lake has been identified as an area suitable for inclusion in the International Biological Programme (IBP) and formal application for ecological site status has been presented to the Minister of Indian and Northern Affairs. This application and other sources (La Roi et al. 1976, Theberge et al. 1980) outline special features of the site as described in the following list. Information has been summarized for brevity with the exception of point a) which is particularly relevant to the proposed mining activity.

a) The proposed Cirque Lake Ecological Site is an area which is relatively undisturbed by human influence. For this reason the collection of baseline data prior to the opening of a mining area and continued monitoring during the mining operation would provide information on the effects of such a development on the wildlife, vegetation and landforms.

b) Cirque Lake exhibits glacial features and is an exceptionally oligotrophic lake.

c) Selwyn valley lowlands provide year-round habitat for moose.

d) Woodland caribou utilize the area.

e) Mineral licks in the Hess River/Hess Mountain area are part of critical habitat for Dall's sheep, moose and woodland caribou.

f) A considerable extension to the known breeding range of hoary marmots is represented.

g) Several plant species are at or near the limits of their distribution and rare plants have been recorded.

h) The area is of geologic and pedologic interest (Anonymous, 1975).

Subsequent identification of Environmentally Significant Areas in the Yukon by Theberge et al. (1980) included the Macmillan Pass and suggested two extensions of the original boundaries of the Cirque Lake IBP site. These are the northern extension (Keele Peak area: critical habitat for moose) and southern extension (Itsi Range: numerous woodland caribou, thinhorn sheep, and mountain goats).

The Keele Peak area has also been classified as a Natural Area of Canadian Significance (N.A.C.S.) and is proposed as a Yukon Territorial Park (Inter-disciplinary Systems Ltd. 1980, cited in Kershaw and Kershaw 1982). Although no formal status has been granted to the Macmillan Pass area either as an IBP site or an Environmentally Significant Area, the potential for special land use through research programs or similar enquiries as suggested above must be acknowledged.

At the present time additional studies are proceeding for the Ecological Land Survey of the Macmillan Pass area. The Yukon Government is examining surficial geology, soils, vegetation and aquatics (hydrological classification of water bodies, water channel classification and fish analysis) at a scale of 1:100,000. Work has taken place at the ecosection level on map sheet S1/2-105O in Yukon, with the intent being to proceed on to 105P. Reports will be published on this work in 1982-1983. The Geological Survey of Canada has been undertaking reconnaissance mapping of surficial geology at the 1:100,000 scale in the Macmillan Pass region (RCPL 1982:60).

Another special use relates to the presence of the Canol Road. There are several known historic sites that remain from Canol pipeline construction and short-lived operation (see Section 4.10) which may be of interest and value as a setting for interpretive development (Lifeways of Canada Limited 1982). From an historic perspective Finni (1945; cited in Lifeways of Canada Limited 1982) recalls the Macmillan Pass as the location of the "Golden Weld" ceremony which celebrated the final linking of the pipeline. Such interpretation might increase visitation to the area, although to justify development a certain level of visitation would already have to exist. As a result the timing and effects on land use are difficult to predict.

An increase in the recreational use of the Macmillan Pass area may be anticipated reflecting both increased members of workers in the region and, more importantly, the improvement of access if the Canol Road is upgraded. Present recreational activity level is low and opportunities in the Itsi Range are mainly alpine-oriented, including glacier viewing, camping and canoeing (Theberge et al. 1980). Access is mainly by float plane. Increased use will likely bring a response from the territorial governments through provision of facilities and perhaps from the private sector which may build more lodges, camps and similar facilities. Locations of these projects is unknown at present; however, the Hess River has been identified as having potential for canoeing and campsites (DIAND 1974).

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5.0 ENVIRONMENTAL IMPACTS

CHAPTER FIVE

ENVIRONMENTAL IMPACTS

5.1 INTRODUCTION

Varying degrees of primary and secondary environmental impacts will result from development and operation of the project and all impacts will not necessarily be negative. Good engineering design and careful construction will serve to minimize adverse impacts and accentuate positive impacts. Primary impacts are those attributed directly to the operation of the project such as habitat loss/alteration, noise, etc. Secondary impacts are those resulting from ancillary activities such as increased road traffic and increased human presence and activity in the area in general.

Primary impacts to habitats and populations will be greatest during construction. Perhaps as much as 75% of the primary impact will occur during the relatively short term construction phase. The remaining 25% of the primary impact would occur throughout the operating life of the mine.

Secondary impacts, i.e. mainly human presence, would be distributed more evenly throughout the construction and operating phases. Secondary impacts will be somewhat proportional to numbers of people present, the amount of time available to those people to pursue recreation, and their ability and desire to utilize the surrounding area. For example, it is anticipated that the number of people will be greatest during the construction phase. However, those people may be working longer shifts and may or may not have transportation available to enter the surrounding countryside during off work hours.

It is estimated the project will directly disturb a total of approximately 228 ha. The largest single areal disturbance will be the

70 ha tailing pond and dams (plus approximately 20 ha of peripheral disturbance), followed by 38 ha of access roads (plus approximately 10 ha of borrow areas), the 25 ha plant/residence complex (plus approximately 10 ha of peripheral disturbance), the 15 ha airstrip and associated facilities, 20 ha for obtaining mine backfill rock, and approximately 20 ha for miscellaneous installations such as pipelines, pump stations, etc.

5.2 AIR QUALITY

Detailed design of a facility is required before an accurate estimate of air emissions can be evaluated. The MacTung Project has not yet reached the detailed design phase. However, a facility of this type and size can be expected to produce air emissions that are minimal.

Sources of emissions will include mine ventilation, crushing, mill ventilation (reagents, assay laboratory, maintenance shop, change rooms), diesel generators and the kitchen. As stated in Section 3, emissions from equipment and transfer points in the crushing plant and the dryer will be controlled by dust collection systems. No roasting or smelting operations are planned.

Fugitive dust from the tailing pond should be non-existent during the initial stages because tailing will be deposited into the water pool created by the tailing dams. When tailing beaches do build up, the potential for fugitive dust remains negligible because of the long winters and wet summers. Fugitive dust from roads is not expected to be a significant problem for similar reasons.

Based on the projected production rate of 900 t (1000 tons)/day and the excellent dispersion characteristics of the mine site area, the impact of the project on local and regional air quality is expected to be minimal.

5.3 TERRAIN

Construction has the potential of inducing thermal degradation in permafrost areas. However, most of the areas slated for construction of the various facilities and roads are free of permafrost. Some of the primary impacts on the terrain have already occurred in the form of existing access road, campsite, test pits, etc. Some alteration to the permafrost regime might be displayed through increased soil active layer.

A new access road will be constructed utilizing the present access roadbed as much as practicable. The new access road, from where it branches from the Canol Road, will cross patterned ground, pass at the base of debris slopes and a small rock glacier on the north facing slope of Dale Valley, cross Dale Creek and the drumlin in Dale Valley, cross some organic material on the north side of the valley, and climb toward the mine site on the north side of Dale Valley crossing some gelifluction slopes and bedrock outcrops. The Cirque Lake access road will cross similar terrain to the landslide which created the lake. The plant/residences complex will be located on a bedrock blockslope terrace. Terrain within the tailing area is composed of moraine, organic material, some palsas, patterned ground, gelifluction slope and a portion of an alluvial fan. The source of rock for mine backfilling would be the blockslope on the south face of Mt. Allan. The potential airstrip would be located on a coarse-grained outwash feature generally lacking permafrost.

Most of the development construction should pose few problems with respect to impact on the terrain. Where appropriate, problematic terrain will be avoided or construction techniques will be such that potential problems will be minimized. Deposition of tailing over the palsas within the basin will probably result in their degradation but would in no way threaten the integrity of the tailing dams.

5.4 HYDROLOGY

The assessment of hydrologic effects is important to project design and to the assessment of other biophysically related impacts. The following list of effects should be noted:

a) Water Supply

- withdrawal of up to an average of 2.0 million m^3 per year at the rate of 63 L/s (1000 US gpm) from Cirque Lake (for mill and campsite) with a possible drawdown of 15 m (50 ft.)

- disposal of spent waters to Dale Creek

- reduced flow in Cirque Creek below Cirque Lake

b) Tailing

- monthly average input of 85,000 m^3 of tailing to tailing pond on Dale Creek

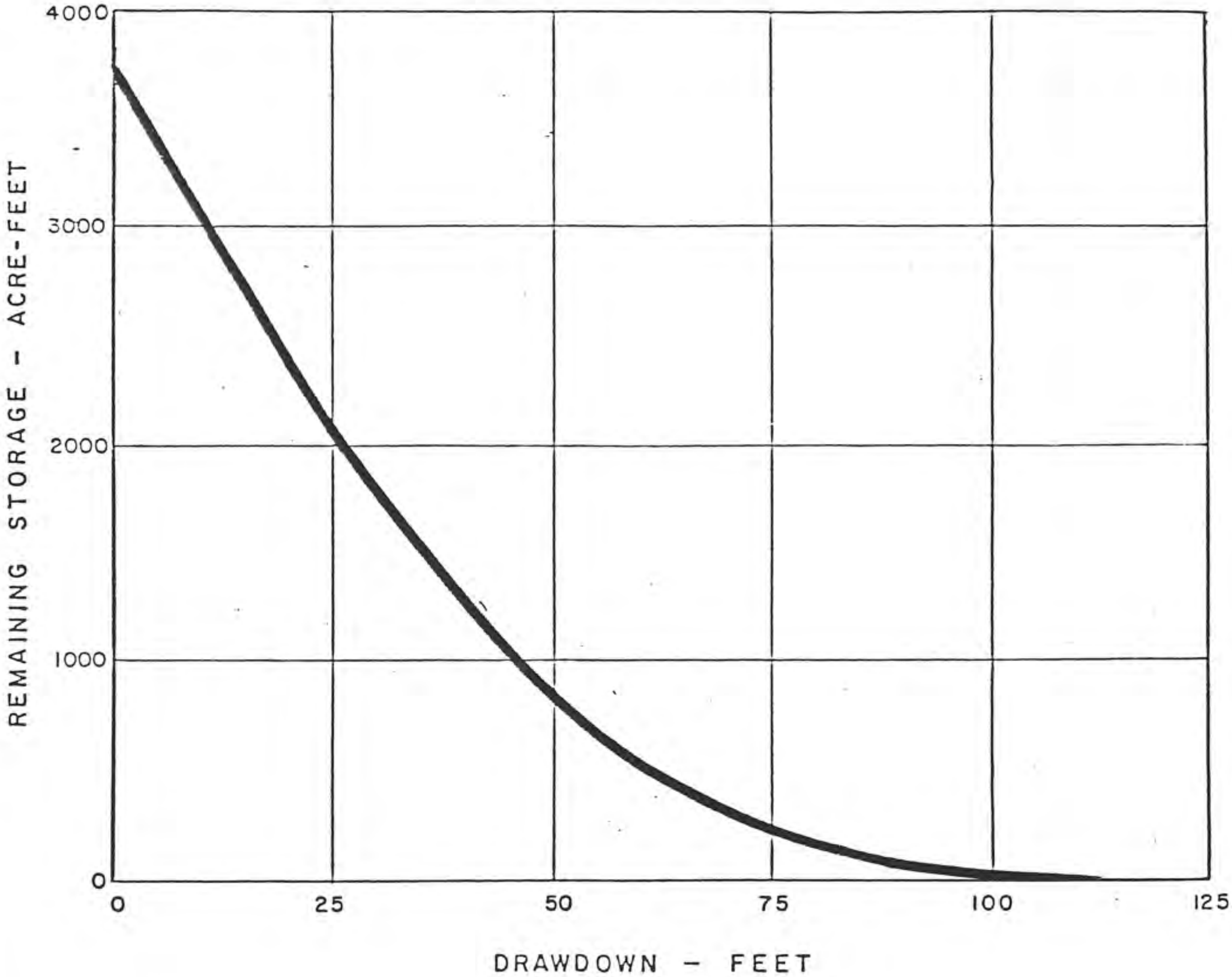
- increased summer flows on either the Cirque Creek tributary below dam No.2 or Dale Creek below Dam No.1, depending on the location of the spillway

5.4.1 CIRQUE CREEK

While not all groundwater flow from Cirque Lake would be prevented (amount unknown), flows in Cirque Creek would be reduced in order to provide full supply level by late summer/early fall in Cirque Lake. This would likely result in loss to Cirque Creek of winter base flow contribution from catchment; and loss of much of the higher open water period flow depending upon how quickly low late winter water levels are replenished to full supply level. Refer to Figure 5-1.

5.4.2 DALE CREEK

The tailing pond would be formed by two dams; No.1 across Dale Creek and No.2 a low saddle dam to the north of No.1 dam (Figure 3-8).



MAXIMUM AVAILABLE STORAGE 3800 ACRE-FEET
MAXIMUM DEPTH 112 FEET

CIRQUE LAKE

STORAGE DRAWDOWN CURVE

FIG. 5-1

The decant could be at No. 2 dam, with a spillway in the rock ridge between dams No.1 and No.2. Decant water from the ponds would be discharged in the summer months. A diversion ditch would encircle the tailing pond to minimize inflow of upstream water thereby maximizing retention time in the pond. This ditch would discharge to Dale Creek below dam No.1 (inflow from the west and south) and below dam No.2 (from the north).

The tailing pond is considered to have an initial storage capacity of 4.2 million m^3, with an average monthly inflow of approximately 85,000 m^3 of tailing; plus precipitation, less evaporation; for a total mean annual input of approximately 1.4 million m^3. Hence, it appears that the initial tailing pond could contain all input for the initial 2 to 3 years of operation.

5.4.3 DOWNSTREAM IMPACTS

The effects downstream are difficult to quantify without more specific hydrologic regime data. The volumes of water are small and will probably not impact hydrology except during natural low flow periods. The diversion ditch design will consider icing problems to minimize the potential of ditch over bank flow during the freshet which could reach the tailing pond.

Peak flows from Cirque Creek would be reduced and lower winter base flows are expected, however the effect on the Tsichu River below Dale Creek is considered negligible in terms of mean flow conditions.

5.5 WATER QUALITY

5.5.1 INTRODUCTION

Potential effects of the MacTung project on water quality in the study area would arise from three primary sources:

- ground surface disturbances during project construction with associated erosion and short term increased sediment loads to surface waters.
- changes in flow regime due to withdrawal and diversion of surface waters with possible effects on temperature, sedimentation and biological productivity.
- discharge of mine, mill and sewage wastes to the tailing pond with resultant potential chemical and physical changes to receiving waters and possibly groundwater.

Other potential effects of the mill facilities on water quality such as acidification of waste rock piles, atmospheric fall-out of contaminants from dryer off-gases and accidental spills of chemicals or fuels on the project site are judged to be minimal at the MacTung site. Acid run-off from waste rock is not anticipated due to the presence of neutralizing calcite in the rock and the low ambient temperatures in the study area (Colorado School of Mines Research Institute 1978; 1979). The project design has incorporated measures to mitigate against water quality degradation due to contaminating spills or airborn emissions (see Section 6.4).

5.5.2 IMPACTS

Ground surface disturbances which would occur during the construction phase are associated with construction of the tailing pond dkye, the diversion of Dale Creek around the tailing pond and preparation of the development site including access roads and airstrip. Effects of these activities on water quality comprise short term increased suspended sediment loads until fines are flushed from disturbed areas and the diversion channels stablize. This effect would be greatest during high flow/run-off events at a time when natural suspended sediment loads would be elevated.

Water withdrawals from Cirque Lake will cause fluctuations in water level with attendant reduction in spring peak flows and late summer and potential elimination of winter flows in Cirque Creek. The expected drop in water levels of Cirque Lake may result in a slight increase in water temperatures during the late summer period and incur a reduction in littoral productivity. Lower flows in Cirque Creek may also result in higher temperatures and reduced sedimentation while the reduction and potential seasonal absence of flows in the creek would cause a corresponding reduction in benthic productivity. Depending on final location of the decant structure (i.e. into Cirque Creek tributary or into Dale Creek) flows could vary. Potential increased flows below the Cirque Creek tributary, which could receive tailing pond decant flows (0.22 m^3/s) and 10% of the Dale Creek basin surface runoff (approximately 0.03 m^3/s), would be characterized by higher temperatures and increased suspended sediments (until the stream channel adjusted to the higher flows). Flows in Dale Creek, below the tailing pond, would be reduced by 10% with possible slight increases in water temperature and reduced sedimentation in lower Dale Creek. There would be little net change in Dale Creek flows below Cirque Creek.

The physical and chemical effects of waste water disposal on surface and ground water quality in the project area will depend on the composition of tailing pond waters. Studies are presently underway to determine the quality of the tailing effluent. Acceptable effluent levels (monthly arithmetic mean) for "controlled parameters" as stipulated by the federal regulations are as follows:

pH	6.0 (minimum)
Total Suspended Matter	25 mg/L
Total Lead	0.2 mg/L
Total Copper	0.3 mg/L
Total Arsenic	0.5 mg/L
Total Nickel	0.5 mg/L
Total Zinc	0.5 mg/L
Acute Lethality	Not less than 50% survival in a 96 hr. lethality test.

A predicted decant fluid pH of 9.5 to 10.5 would enhance precipitation of heavy metals in the tailing pond. Alkalinity and total dissolved solids in the decant water may be as much as an order of magnitude greater than those of surrounding surface waters. Major ions contributing to total dissolved solids would include sulphate (e.g. 85 mg/L*), chloride (e.g. 90 mg/L*) and sodium (e.g. 200 mg/L*). Iron concentrations (e.g. 4 mg/L*) may also be raised relative to surface waters whereas calcium would be lower (e.g. 5 mg/L*). The use of cyanide in processing is not anticipated.

Sewage effluent would also be discharged to the tailing pond; however, it is not expected to have a negative influence on water quality due to the high dilution factor and long retention period provided by the tailing pond.

If tailing pond decant flows are discharged via Dam No.2 the receiving tributary of Cirque Creek and lower Cirque Creek would provide a dilution factor of less than 1:1 on the basis of estimated average annual flows. If decant occurred to Dale Creek greater dilution would be achieved by mixing with 90% of the diverted runoff flows from Dale Creek basin. Below the confluence of Cirque and Dale Creek decant flows would be diluted on average by an additional factor of approximately 1:2. Flow measurements in the lower Tsichu River indicate an average dilution factor of 1:50 during the summer flow period.

The tailing pond decant would cause an increase in total dissolved solids in lower Cirque and Dale Creeks and potential increases in metals such as iron and copper. This cahnge in water quality would induce changes in the biotic communities of these streams with a possible reduction in productivity. Effects of the decant flows on water quality further downstream would be substantially reduced by the low pH waters of the upper Tsichu River. The decant waters are expected to cause a neutralization of

*Estimates of major ion concentrations based on chemical analyses of CanTung tailing decant waters.

the Tsichu River pH along with an elevation of alkalinity, conductivity, sodium and chloride values. Ambient levels of iron and sulphate in the Tsichu River are already within the range of concentrations anticipated in the decant waters. Although the decant waters may cause a slight increase of some metal concentrations, existing natural inflows (e.g. Rust Creek) exhibit metal concentrations which approach or exceed metal mines effluent criteria. The magnitude of effects on water quality would vary seasonally according to the decant operating schedule. Assuming decant during the summer months, potential water quality impacts on the lower Tsichu River are expected to be minimal.

On the basis of initial ground water monitoring, highest transmissivity rates were observed downstream of the Dam No.2 (0.03 cm/sec) while lowest rates occurred below the dyke on Dale Creek (0.001 cm/sec). (Refer to Figure 4-6 for well locations.) A well in bedrock adjacent to the pond had an intermediate rate of 0.002 cm/sec. Effects of the potential seepage from the tailing pond on ground water quality is expected to be comparable to the effects on surface waters although existing concentrations of major ions (sulphate, calcium and sodium) in the bedrock ground water were elevated relative to surface water concentrations. The magnitude and extent of the effect on ground water is unknown at present; however, it would be expected to vary seasonally in relation to natural ground water flows and corresponding dilution factors.

5.6 AQUATIC ECOLOGY

5.6.1 INTRODUCTION

The key aquatic biological resources in the study area include the fishes in the Dale Creek and Tsichu River system, the invertebrate animals, both planktonic and benthic, in the water bodies of the area, and both planktonic and periphytic algae in the streams and ponds. For present purposes, only the major taxa within these groups will be used for the assessment. This assessment is based on presently available estimates of future effluent quality.

5.6.2 IMPACTS

Each of the kinds of effects that the MacTung project might have on the local aquatic ecology is discussed briefly below.

5.6.2.1 Habitat Displacement

The most significant primary impact that the MacTung development will have on aquatic resources is the loss of habitat of much of upper Dale Creek in the proposed tailing area. Construction will remove that habitat from the system and eliminate the small seasonal population of Dolly Varden char that uses upper Dale Creek. However, this will not constitute a significant loss in overall fisheries productivity in the Tsichu River system.

5.6.2.2 Sedimentation

Construction of the tailing area will likely introduce some sediment to Dale Creek. Sedimentation control techniques will be implemented during construction. However, some fine grained sediments will likely reach lower Dale Creek and even the Tsichu River. The most sensitive periods for this kind of disturbance are spring and fall fish spawning times. Lower Dale Creek provides marginal spawning habitat, although both spring (grayling) and fall (char and whitefish) spawners are present in lower Dale Creek. The effects of increased sediment loads to Dale Creek would be greatest during those periods.

5.6.2.3 Migration Barriers

The access road crossing of Dale Creek is the only proposed stream crossing to be constructed for the MacTung project. The tailing dam located just upstream of the road crossing will present a barrier to the migration of fish into upper Dale Creek.

5.6.2.4 Water Withdrawals

Water for operations will be pumped from Cirque Lake. This is expected to result in a drawdown of some 15 m in the lake. Some reduction in primary (algae) and secondary (invertebrate) productivity can be expected in Cirque Lake as a result of this change. However, there are no fish in Cirque Lake and the overall direct biological impact of water withdrawal from the lake should be negligible.

Water withdrawals from Cirque Lake will likely reduce flows in Cirque Creek and possibly reduce available habitat in the lower creek. However, if the decant from the MacTung tailing area were to be sent to Cirque Creek most of the water that was withdrawn from the lake upstream would be restored. The total water balance to Dale Creek below Cirque Creek will be very much as it is now.

5.6.2.5 Fuel Spills

Fuel storage tanks will be located in areas dyked specifically to contain any spills of petroleum products. No impacts on aquatic systems from fuel spills are expected during MacTung construction of operations.

5.6.2.6 Tailing Effluent

For approximately the first three years of operations, there will be no decant from the tailing pond. Once decants begin they will consist primarily of supernatant tailing water. Concentrations of chemical elements within the tailing decant will be at or below the levels specified in the liquid effluent regulations for metal mines. It is likely that there will nevertheless be some minor changes in primary and secondary productivity downstream of the decant outfall in the receiving waters. Biological changes resulting from the discharge should be limited to small shifts in the distributions or abundances of algae and invertebrates downstream and are not expected to change the overall fisheries productivity of the area.

5.6.2.7 Sewage

Sewage effluents from the MacTung camp will be directed to the tailing containment area. There will thus be no direct discharge of high nutrient sewage effluent to the local surface waters. In the tailing area the sewage will help to precipitate heavy metals and balance the pH. The tailing decant will not likely show significantly elevated nutrient levels compared to ambient surface water conditions. If the concentrations of phosphates and nitrates in the final decant liquid are slightly elevated they will tend to increase biological productivity downstream.

Overall, given that the decant is required to meet effluent regulations, there are expected to be no significant effects on aquatic biological resources resulting from the tailing/sewage decant.

5.6.2.8 Facilitated Harvest

The most significant potential impact of the MacTung development on aquatics is the secondary impact of increased angling pressure by sports fishermen. This could apply not only to the Arctic grayling and Dolly Varden char stocks of Dale Creek and the Tsichu River, but also to the lake trout in Gill Lake and Lost Guide Lake. However, this can largely be controlled through the establishment of site specific catch limits by the appropriate government agency.

5.7 VEGETATION

From its branch with the Canol Road, the new access road will pass, in sequence, through the following vegetation complexes: meadow, birch-lichen, lichen-heath, willow-forb, birch-lichen, willow-forb, birch-lichen, lichen-heath, meadow, willow-forb, and will terminate at the alpine meadow of the plant/residence complex. The Cirque Lake access road will pass through a series of alpine meadows and alpine lichen-grass complexes. Vegetation within the tailing area, including dams and bypass canals, is comprised of a combination of lichen-heath, willow-forb, and meadows. The source of rock for backfilling the mine would be the epilithic lichen complex on the south face of Mt. Allan. The airstrip would occupy what is predominantly a birch-lichen complex with some meadow and birch-moss intermixed.

Construction activities will destroy, at a maximum, a total of approximately 228 ha of the vegetative complexes listed above. As with terrain, some of the primary impacts on vegetation have already occurred in the form of the existing access road, campsite, test pits, etc., and perhaps as much as 75% of the total disturbance will occur during the relatively short construction phase of the project. No rare, threatened or endangered plant species have been sampled in the area.

As alteration of groundwater flows is anticipated to be negligible, so also will be the effect on vegetation surrounding Mt. Allan. Fugitive particulate emissions will be minimal and should therefore not affect vegetation; dust blowing from exposed tailing will be minimal because the tailing will be largely controlled by underwater tailing deposition and by the long seasonal snow cover. Potential impacts on terrain such as thermal degradation of permafrost may result from removal of the vegetative layer, but will be minimized by avoidance and the employment of appropriate engineering techniques.

Secondary impacts on vegetation will be limited to the summer months, and, as with secondary impacts on most other environmental aspects, be dependent upon the number of people, and their desire and ability to access the surrounding area.

5.8 WILDLIFE

The number of people frequenting the MacTung area will increase following project construction. Effects of increased human presence on wildlife in the area may be positive or negative, depending on many variables such as species, seasonal distribution, accessibility to wildlife areas, and game management policies. However, the secondary impact of increased human activity has the greatest potential for affecting wildlife.

5.8.1 WOODLAND CARIBOU

Potential effects on caribou can be categorized as follows (Calef 1974):

1. direct mortality,
2. behavioural alterations,
3. alterations in movement and distribution, and
4. habitat destruction or loss.

5.8.1.1 Direct Mortality

Direct mortality includes losses from hunting, accidental falls, vehicle collisions and deaths in stampedes. Hunting appears to be the greatest mortality factor for caribou in the study area. Although the numbers of animals taken by residents and trophy hunters in recent years has not been verified, it appears that resident hunting intensity has increased. Probably the most significant potential impact on local wildlife population is an increase in hunting associated with the influx of people because of mine developments. However, because the camp is located in the N.W.T., implementation of a personnel rotation system may mean that some personnel will not meet the N.W.T. residence requirement for big game hunting licenses. Inability to meet this requirement may serve to minimize hunting pressure increases as the services of a licensed outfitter are necessary.

Accidental animal death could result from lost footing along sheer drops associated with the project (e.g. roads). The probability of this occurring at MacTung is low. Woodland caribou in good health are sure-footed and inhabit extremely rough, precipitous terrain during the fly season. Furthermore, during the 1981-1982 surveys, caribou were not common in the areas proposed for development construction disturbance.

Caribou may concentrate movement along roads and as road traffic increases, the potential for caribou-vehicle collisions may also increase. However, based on the lack of accidents during past years, the probability of such occurrences also appears to be low. When present, most of the caribou confine their activities to higher elevations and are infrequently exposed to this potential danger.

Stampedes following disturbance by low-flying (i.e. less than 300 m high) aircraft are recognized as a potential mortality factor in herds of barren ground caribou. However, observations during the MacTung wildlife surveys suggest that smaller groups of woodland caribou (e.g. less than 8 animals) seldom demonstrate escape behaviour. In addition, the nearest caribou calving area is approximately 16 km east of the proposed airstrip and outside the zone of influence of aircraft on approach to the airstrip.

5.8.1.2 Behavioural Alteration

The effects of stress associated with disturbance include "elevation of metabolism and adrenocorticoid levels, loss of weight, increase in susceptibility to disease, absorption of embryos, abortion and lowered birth weights" (Calef 1974). Disturbances such as the presence of low-flying aircraft, the presence of humans, and the noise associated with blasting and generating stations may produce this type of response. However, use of an area by caribou does not seem to be affected by continuous noises or stationary objects; it is also expected that caribou adapt to frequent noises.

Four periods in the life history of caribou can be identified as sensitive times during which disturbance should be minimized. These are (1) late winter; (2) calving; (3) fly season; and (4) rut. These correspond with the periods during which the MacTung aerial surveys were conducted. In all surveys few or no caribou were observed in the areas that will be directly affected by development of the MacTung Project.

5.8.1.3 Alterations in Movement and Distribution

Movement and distribution of caribou in the study area appear to be along the main trend of the valleys and then upward to higher elevations. In 1981-1982 few observations were made of caribou in the main low elevation valley bottoms including the mine access road. It would appear that little disruption of movement and distribution will result from the MacTung development. However, summer and fall surveys were conducted at a time when both the roads and the mine site were active. Consequently, these data may or may not reflect movement and distribution patterns during those seasons that existed prior to 1970, when exploration activity was initiated.

5.8.1.4 Habitat Alteration

Habitat alteration can be a significant factor affecting the health and maintenance of caribou. Caribou utilize the study area during approximately one third of the year and during this time calves develop rapidly and adults must regain the weight lost over the previous winter. Based on 1981-1982 survey results it is apparent that caribou make minimal use of the area to be directly affected by the MacTung project. Significant portions of more heavily used caribou range are unlikely to be adversely affected by development.

Caribou calved near the eastern border of the study area, approximately 25 km east of the mine site, beyond areas anticipated to be disturbed by development do not lie within traditional calving areas. Two mineral licks within the study area are referred to as the Hess River Tributary mineral lick, approximately 8 km west of the mine site in the Yukon, and the Tsichu River lick, located approximately 28 km east of the mine site. The former is used by caribou, moose and Dall's sheep while the latter is visited by caribou and moose.

Only aircraft use for recreation or an occasional hiker would be expected to pass near the Hess River lick. Loud noises (e.g. those generated by blasting) carry substantial distances and can result in a fright response. Animals at the Hess lick would probably hear such noises only in winter when the sound of the nearby river is muffled beneath ice and snow cover and would not necessarily be alarmed by them. The distance to the Tsichu River lick would greatly reduce the audibility of noises initiated at the mine. Extensive use of the Tsichu River airstrip, 12 km from the Tsichu River lick, is not anticipated.

5.8.2 MOOSE

5.8.2.1 Direct Mortality

Unlike caribou, moose concentrate in the valley bottoms and are year-round residents in the valleys below the project. Moose are subject to the same secondary impacts discussed for caribou and hunting may continue to be a significant mortality factor for moose in the area. No moose/vehicle collisions have been reported in the area. Unless road improvements result in substantially increased vehicular speed, the probability of accidents occurring is low. In winter, it is possible that moose will use the raised, cleared road surfaces for travel and then be unable or unwilling to leave the roadway during deep snow periods. Areas slated for development construction are outside of the 1981-1982 observed distribution of moose. Therefore it is not anticipated that this type of hazard would be significant to moose.

5.8.2.2 Behavioural Alteration

Unlike caribou and sheep, moose generally are solitary animals, except when calves remain with cows and during the rut when pairing occurs. Cow/calf bonding is very strong. Low-flying aircraft might cause an escape response but separation is unlikely. Since most MacTung construction development is not in moose habitat, it is anticipated that these disturbances will have little direct effect on this population. Recreational use of moose habitat will probably occur and the winter use of over snow vehicles is expected. The extensive use of oversnow vehicles in these areas could increase stress during the sensitive winter period.

5.8.2.3 Alterations in Movement and Distribution

Moose seem unaffected by the presence of the 40-year-old Canol Road and have been observed both above and below it. There is no indication that the road presents a barrier to movement.

5.8.2.4 Habitat Alteration

Moose in the study area have been noted to frequent areas close to human habitation and within hearing of generator noise. The few localized areas of tall, willow-dominated plant communities in valley bottoms represent the major moose habitat in the study area. Development plans are such that significant impacts in this type of habitat will not occur.

5.8.3 DALL'S SHEEP

The Dall's sheep population in the study area is small, with only three barren ewes noted in the 1981-1982 surveys. As previously discussed, the area is marginal Dall's sheep habitat and the current low population supports this conclusion. The limited sheep range, low numbers and marginal quality of the habitat in the area make it difficult to predict the potential impact of the project on Dall's sheep.

Noise travels for substantial distances in this environment and mountain sheep tend to respond to unexpected loud noises by fleeing to the sanctuary of cliffs. This appears to be an innate response to avalanches and rockfalls. Dall's sheep have also shown unusual adaptability to mining related noises and activities.

5.8.4 GRIZZLY BEAR

A moratorium on the hunting of grizzly bears is currently in effect in the N.W.T. portion of the study area. This fact, in conjunction with the rotation-based camp residency constraints previously discussed, may serve to keep bear hunting to a minimum.

The greatest potential impact of the MacTung development on grizzly bear is a possible increase in man/bear confrontations. Proper waste management (Section 3.13) will reduce encounters with bears frequenting garbage dumps. However, the potential for chance encounters with bears remains and could result in an attack (e.g. by a surprised or sick animal or a sow with cubs).

Dale and Cirque Lake valleys appear to be excellent grizzly habitat. However, no grizzly bears were sighted in these valleys during the 1981-1982 surveys, althought camp personnel reported the presence of a bear on one occasion. Development in these areas will result in a reduction of bear habitat in the study area, but the amount of reduction is so small, the impact is expected to be insignificant.

5.8.5 SMALL MAMMALS

The impact of the project on the small mammal populations would be in the form of habitat alteration or loss and would probably be insignificant to total population numbers.

5.8.6 AVIFAUNA

The greatest primary impact of the project on avifauna communities will result from physical alteration (as opposed to destruction) of the present habitat in the upper Dale Creek Valley where the tailing pond and diversion canals will be located. Whereas mammalian habitat may, indeed, be destroyed by a tailing pond (or other components of the project), avian habitats will change from the present willow-forb/sedge meadows to open water/beach areas. The resulting change in habitats will cause an associated shift in avian species composition and diversity. In the case of the tailing pond, 70 ha of Ptarmigan, Sparrow, and shorebird breeding habitat will shift to types used to some degree by waterfowl (particularly resting and migrating) and Mew Gulls as well as shorebirds.

Areas cleared for borrow pits, access roads, and the airstrip will tend to increase the abundance of species requiring more open, bare ground or short grass areas (Horned Larks, Semipalmated Plovers, etc.) while decreasing the abundance of shrub-oriented species. The construction of buildings and bridges/culverts will attract greater numbers of Cliff Swallows and Say's Phoebes. Access roads constructed through large expanses of a singular habitat type (e.g. birch-lichen tundra) will create new avian habitat and associated ecotones. These additional habitats can be expected to increase the overall avifauna diversity within that expanse, while possibly decreasing the overall abundance of those species which were specific to that singular pre-disturbance habitat. Thus, the general impact of the project on birdlife will be to change species compositions, diversity, and abundance (particularly in upper Dale Creek, areas of new access roads, and at the airstrip site) rather than to eliminate the pre-disturbance avifauna community.

The most important habitats and use areas are not expected to be disturbed to a great extent. The construction of roads and the airstrip facilities will alter uplands habitat, but will not affect the most important wetland areas such as Airstrip Pond, the Tsichu River channels, and the avian habitats along the Upper Tsichu River above and below the Dale Creek confluence.

The project is not expected to directly impact any threatened, endangered, or sensitive species. The nearest known Golden Eagle eyrie is 5 km from the mine site. The nearest Gyrfalcon eyrie (GYR 5) is located approximately 1 km from the mine site and potentially could be disturbed by noise incursions. This eyrie was unoccupied in 1981 (and probably in 1982); the breeding pair opting for an alternate nest site 9 km from the mine site.

The degree of secondary impacts of the project on the avian community will depend, in part, on the mobility of personnel during the summer months. With the exception of the occasional vehicle-bird collision, the main potential secondary impact will relate to increased pressures resulting from expanded human recreational access. In the Tsichu River Valley, Willow Ptarmigan and waterfowl would probably bear the primary risk of this pressure, with some raptors and other large species (e.g. Mew Gulls, Ravens, etc.) also being affected. The overall impact of the MacTung Project on the local and regional avifauna community would be minor.

5.9 HERITAGE RESOURCES

The construction of the mine site, camp site, roads, airfield and related support facilities of the MacTung project is thought not to represent a significant impact to the heritage resources of the Mackenzie Mountains or, in a wider perspective, the Yukon or Northwest Territories. Known or predicted historical resources present no major conflicts to the construction of the project.

5.10 SPECIAL USE LANDS

Commencement of the MacTung mining operation is predicted to have several impacts on special use lands. Should the Cirque Lake area be designated as an IBP Site AMAX already has collected extensive data on the major environmental aspects of the area which would prove extremely useful in meeting the purposes for which the site was proposed.

Provision of heritage interpretation and recreation facilities would likely be achieved more quickly as a result of the MacTung project creating a greater demand through the number of people it would bring into the area. Kershaw and Kershaw (1982) summarize the impacts on the Keele Peak area and these could be generalized for other areas: an increased level of human activity can adversely affect a wilderness area through the removal and/or destruction of vegetation, archaeological sites and natural features, the harassment of wildlife or the depositon of garbage. The potential for fires during dry periods will also increase.

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6.0 ENHANCEMENT & MITIGATION

CHAPTER SIX

ENHANCEMENT AND MITIGATION

6.1 INTRODUCTION

This chapter examines the circumstances available to mitigate adverse effects arising from the MacTung project and also to identify enhancement opportunities. In many cases impacts can be mitigated in the planning and design stages. Where this is not possible, other mitigation measures can be employed. In the development of the MacTung project, the major single mitigation process is the reclamation plan (as discussed in Section 3.19) and refered to in the subject areas which follow.

6.2 AIR QUALITY

Reduction of potential emissions associated with project operation will be achieved by the installation of dust collection or equivalent systems on relevant emission sources. As indicated in the previous section, emissions are not expected to be extensive and those which do occur will be mitigated by the excellent dispersion characteristics at the minesite.

6.3 TERRAIN

The main techniques available to mitigate project impacts on terrain are reduction of the total area of landscape modification and disturbance, employment of appropriate engineering practices and implementation of the process of reclamation. The first is exemplified by use of currently disturbed areas wherever possible, such as construction of a new access road utilizing the present roadbed to as full an extent as possible. Development is planned to avoid problematic terrain (e.g. areas of permafrost) where possible. When thermal degradation is predicted such as under the tailing material, this fact has been acknowledged in project design in order not to compromise the integrity of the tailing dams. Erosion will be minimized by the employment of appropriate engineering construction techniques and maintenance of vegetative cover where possible. Reclamation practices to be employed whenever practicable include topsoil salvage and revegetation of disturbed sites as soon as possible after disturbance.

6.4 HYDROLOGY

Alteration of water resources is expected due to the project requirements for water. This impact is largely not subject to mitigation although some degree of control over quantities extracted and discharged is possible, and engineered features such as ditches and berms will be designed to consider flood levels and icing potential. Overall effect on the Tsichu River below the project area is considered small in terms of mean flow conditions.

6.5 WATER QUALITY

Many potential impacts on water quality in the study area would be mitigated by project design and conscientious construction and reclamation practices. Elements of project design which would aid mitigation of potential water quality impacts include:

- provision of berms around fuel and chemical storage areas.
- underwater deposition of tailing to minimize potential oxidation.
- diversion of runoff around the tailing pond area to prevent flooding of the pond.
- fail-safe design of project site such that any spills or waste discharges on the site flow to the tailing containment area.

Construction practices which would reduce water quality impacts include:

- o avoidance of unneccessary disturbance of stream bank areas.
- o provision of proper drainage on the project site and access roads to minimize erosion.

6.6 AQUATIC ECOLOGY

A number of measures will be designed into MacTung specifically to minimize or avoid any deleterious consequences of the project. Potential fuel spills will be contined within dykes and domestic sewage will be sent to the tailing pond. The quality of the final decant liquid will be maintained within liquid effluent guidelines. The above preventive measures should eliminate most of the potentially deleterious effects of the MacTung development.

6.7 VEGETATION

Project impacts on vegetation can be mitigated in several ways. Areas of vegetation disturbance will be minimized through engineering design and on-the-ground control during construction. Maintenance of as much of the vegetative cover as possible in permafrost areas will reduce the associated impact of thermal degradation. Disturbed areas will be revegetated as soon as practical following construction or completion of operations as described in the overall reclamation plan (Section 3.19).

6.8 WILDLIFE

Several mitigation measures are available to reduce the impact of the MacTung project on wildlife populations during both project development and operation phases. These include:

- information programs to site personnel.
- restriction of firearms on AMAX - controlled property.
- implementation of management programs in cooperation with appropriate agencies.
- removal of vegetation (and therefore habitat) will be minimized through planning; reclamation will help to replace losses which occur.
- restrictions on use of oversnow vehicles on AMAX - controlled property during sensitive periods in the wildlife life-cycle.
- proper disposal of waste will minimize bear foraging and reduce the chances for man-bear encounters.

6.9 HERITAGE RESOURCES

AMAX has contracted for a field reconnaissance to identify all prehistoric, historic, paleontological and native sites which could be impacted by the construction and operation of MacTung. These resources will be assessed to determine their scientific and public values, and means found to provide for their protection through avoidance and/or mitigation of impacts.

6.10 SPECIAL USE LANDS

Impacts associated with increased numbers of people in the area could be partially mitigated through planning and cooperation with appropriate authorities in matters such as regulation of access to areas outside the immediate mine site.

7.0 SOCIO-ECONOMICS

CHAPTER SEVEN

SOCIAL AND ECONOMIC CONSIDERATIONS

7.1 THE SETTING

The MacTung project is being initiated during a period of considerable social, economic and political change in Canada north of 60°. These matters, combined with knowledge that northern mineral development activities of any significant scale and longevity may have important implications on social and economic patterns in the affected region, have encouraged AMAX to engage in discussions at an early stage with interested and potentially affected populations, communities and agencies. Through this public communications program it is hoped that measures may be identified to optimize benefits and to minimize possible concerns of northern residents about the project.

The setting in which social and economic considerations must be presented initially is defined by project logistics. Certain key logistics already have been presented in this document. These include the requirements for a maximum of 355 staff during construction; and 174 personnel to operate the facility during its 25 and more years of life, based on 900 t (1000 tons)/day production. There is the intent of AMAX to implement a travel-in/travel-out program for workers with the majority of these being transported to and from the site by aircraft. Only workers resident in Ross River and Faro reasonably might be expected to commute to and from the site by means of ground transportation. And there is the anticipation that Whitehorse will be utilized as the base for MacTung operations. Whitehorse would be the main point-of-hire for most workers who would be encouraged to locate their families in the territorial capital.

Considerable attention has been given to alternative strategies to determine how best to arrange for the location and servicing of employees engaged in remote locations in the Macmillan Pass-Howard's Pass region. The Macmillan Pass Task Force, for example, examined at length various options focussing on new townsite versus travel-in/travel-out arrangements. For the MacTung project in particular, socio-economic enquiries have suggested that the best development option for this project is a fly-in/fly-out commuting program (4 days in and 4 days out) with a work camp established at MacTung.

In work to date on MacTung, to determine what might be the "affected region" in a socio-economic context, this region has been defined by the approximate economic limit of 450 km from MacTung (Figure 7-1). Sixteen communities lie within the affected region. Of this total, six have been recognized as "high influence" communities, based on the following criteria:

a) communities with Conventional-Take-off-and-Landing (CTOL) jet service located south of MacTung;

b) communities within 250 km of MacTung with direct road connections; and

c) communities which lie between areas that have CTOL jet service and the MacTung site.

These potential high influence communities are:

Faro
Fort Simpson
Ross River
Watson Lake
Whitehorse
Wrigley

Precisely how these and other communities may be influenced by the project will be subject to several considerations, including, for example, opportunities for local contracting, expediting and supplies; the wish of

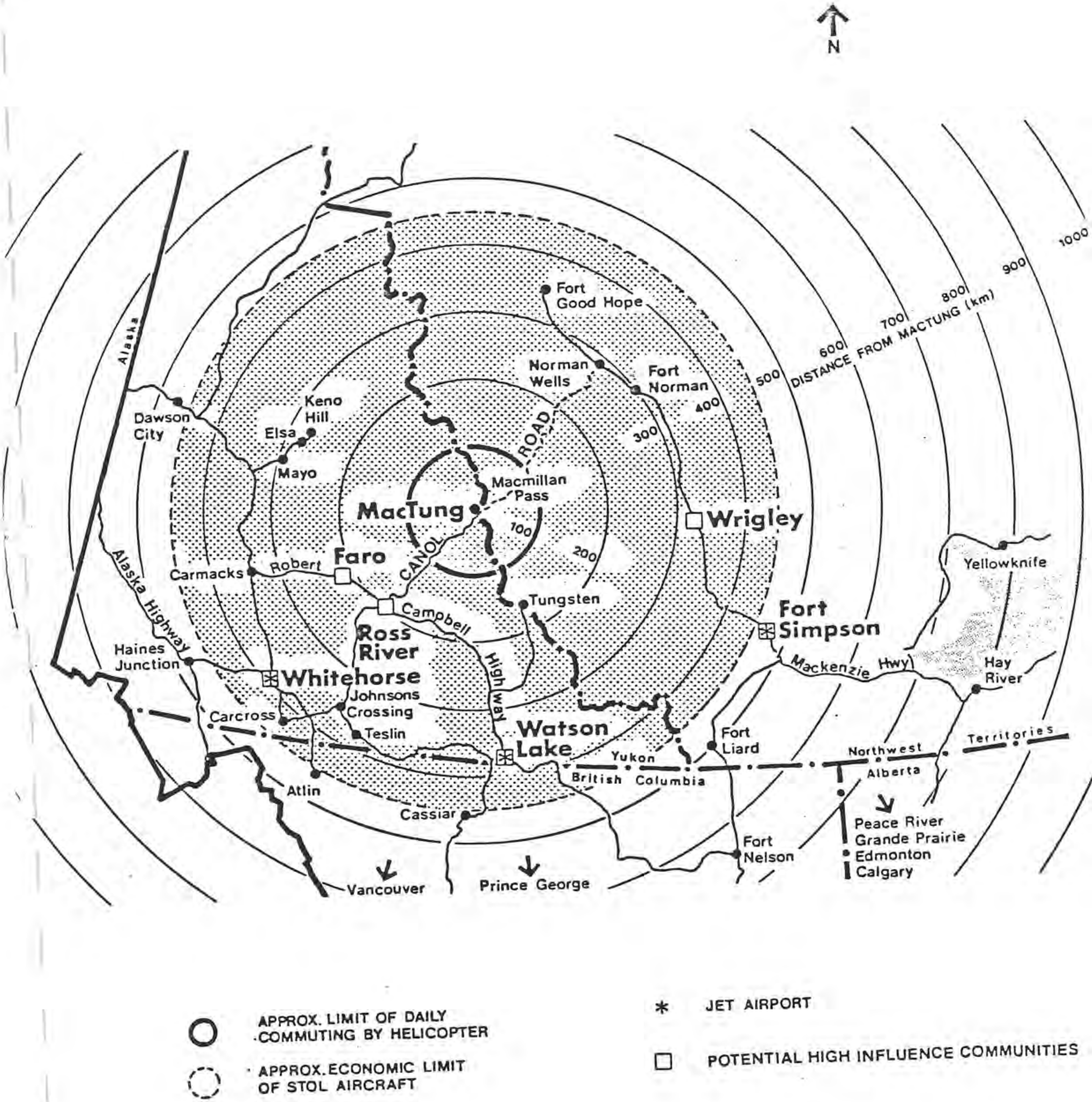

FIG. 7-1 **AFFECTED REGION**

residents to gain employment at MacTung and the opportunities for them to be so employed; the facility with which commuting arrangements may satisfactorily interface with individual communities; work skills in relation to job opportunities, on-the-job training, and so on. AMAX has committed itself to a process which will determine by the onset of project construction and operation, the mechanisms whereby the social and economic goals of northern residents and agencies can best be met by the company. To facilitate that process AMAX is examining several fundamental questions which it proposes to articulate as corporate policy once the public communications program has been more fully developed.

7.2 TOWARDS SOCIO-ECONOMIC PARAMETERS

The following questions are being posed by AMAX to facilitate public discussion and to develop corporate policy.

a) <u>Northern Employment</u>

i) What are the implications if preference on all jobs is given to northen residents for which they are qualified, during construction and operation?

ii) Is there the prospect of job training programs being offered in light of project parameters and public interest?

iii) What considerations should be given to encouraging northern natives to gain employment on MacTung should they be so interested?

iv) What approaches can be made to the task of developing a suitable labour pool?

v) Should in-migrants to the territories be encouraged, required to locate in specified communities?

b) <u>Community Development</u>

i) What changes regarding employment, land, population may occur in communities, especially high influence communities, as a result of MacTung so that orderly growth may be achieved?

ii) In what ways might native communities wishing to participate directly through significant employment in MacTung obtain infrastructure and housing upgrading assistance from government authorities?

iii) What strategies might AMAX employ to facilitate access to improved housing to avoid potentially limiting availability of qualified mine personnel?

c) Social Service

i) To what extent will there be social service (e.g., student, medical, police) demands placed on communities because of MacTung and how will the federal and territorial agencies plan for facility utilization?

d) Renewable Resource Use

i) What might be the impact of MacTung on hunting and trapping activities and how might any modifications be achieved?

e) Transportation

i) What will transpire with North Canol Road upgrading/maintenance and how may this be related to the needs of MacTung?

ii) What opportunities exist for northern air carriers to carry rotational shift-workers and others to and from MacTung?

f) Northern Purchasing

i) How may AMAX and its contractors ensure that during construction and operation benefits to the territorial economy will be maximized wherever possible?

ii) What procedures should be followed to ensure that supplies are acquired locally where prices and goods availability are competitive with southern supplies?

8.0 RESIDUAL IMPACTS

CHAPTER EIGHT

RESIDUAL IMPACTS

8.1 INTRODUCTION

The anticipated consequences of the MacTung project development on the surrounding environs have been described in Chapter 5, and opportunities for mitigation and enhancement of these impacts outlined in Chapter 6. This chapter will address residual impacts, which are defined as those which are irreversible, unavoidable, and very long term, i.e. in the order of 100 years following abandonment and reclamation.

8.2 AIR QUALITY

No residual impacts on air quality are expected.

8.3 TERRAIN

The only anticipated residual impact on terrain will be visual, in the form of a slightly modified landscape. Evidence of roads and other benches and excavations will remain after 100 years and the tailing area would probably remain as a marsh, moist meadow or a small water pool fringed with marsh, with attendant alterations in permafrost regime. The long term possibility of subsidence above underground working will be minimized by backfilling of the mine.

8.4 HYDROLOGY

Residual hydrologic impacts include the establishment of a tailing pond which is essentially a lake in Dale Creek valley, and alteration of flows in Dale and Cirque creeks through dams, spillways and decant flows.

8.5 WATER QUALITY

The tailing area will pose a potential residual impact in the form of siltation if the tailing dams failed. However, no real residual impact on water quality is anticipated. The quality of water 100 years following mining should be essentially identical to the present water quality. The tailing area should be completely stabilized and the mine is not expected to produce significant quantities of water.

8.6 AQUATICS

Residual impacts on water quality and aquatics are almost entirely interdependent. The high quality of water expected in the future would provide habitat to support an unaffected aquatic community. Fish habitat in Dale Valley is presently marginal. The portion of Dale Creek affected by construction of the tailing deposition area will be lost as fish habitat and it is expected that fish will be physically precluded from gaining access to the tailing area.

8.7 VEGETATION

It is anticipated that the only residual impact on vegetation over the long term would be a slight change of species composition in the area occupied by the tailing pond. The area is presently meadow and, over the long term, is expected to be first a shallow lake, then a marsh and finally return to meadow. Natural succession and invasion will take place on all disturbances and the resulting vegetation composition 100 years from mine closure probably will resemble the vegetation of the surrounding area.

8.8 WILDLIFE

Again, the only long term effect of the project on wildlife might be a temporary shift in the avian species utilizing the tailing pond area and a temporary displacement of large and small mammals presently utilizing the area selected for the pond. No significant residual impact is expected on wildlife.

8.9 HERITAGE RESOURCES

Based on current information residual impacts of the mining project on heritage resources are considered to be negligible.

8.10 SPECIAL USE LANDS

Residual impacts of the project on special use lands are difficult to anticipate. One of the purposes of establishing the IBP/Environmentally Sensitive Area classification was to study the effects of mining activity. Special use lands such as heritage interpretation sites or recreational facilities would be an indirect residual effect of mining activity brought about by increased numbers of people in the area.

APPENDIX I

APPENDIX I

Appendix I Mean Cumulative Plant Cover By Species in Each Habitat Type in the MacTung Study Area

Plant Species or Species Group	Plant Community Complexes: Tundra												Subarctic Forest				
	Epilithic Lichen	Cushion Plant	Alpine Meadow	Alpine Lichen-Grass	Lichen-Heath	Birch-Lichen	Birch-Moss	Willow-Forb	Riparian Willow	Sedge Meadow	Forb Meadow	Lowland Lichen-Grass	Krummholz	Fir-Lichen	Fir-Moss	Lowland White Spruce	Birch-Spruce
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Vascular Plants																	
BETULACEAE																	
Betula glandulosa		+			5	66	160	4	6	+		+	2	+	6		78
B. pumila var. *glandulifera*						+											
BORAGINACEAE																	
Mertensia paniculata			1	+				5	2		5		+			2	
Myosotis alpestris			+	+				+			+						
CAMPANULACEAE																	
Campanula lasiocarpa			+					+	+		+						
CAPRIFOLIACEAE																	
Linnaea borealis								+					+			3	
Viburnum edule													+				
CARYOPHYLLACEAE																	
Cerastium beeringianum			+	+					+		+						
Melandrium apetalum			+														
Minuartia biflora			+	+													
Minuartia sp.			+														
Sagina linnaei			+								+						
Silene acaulis		+	+	+													
Stellaria calycantha										+	+						
S. edwardsii																+	
S. laeta							+	+		+	+						
S. longifolia											+						
S. longipes											+						
S. monantha				+			+			+							
Stellaria sp.				+			+	+	+		+						
COMPOSITAE																	
Achillea millefolium									+		+						
Agoseris aurantiaca								+									
Antennaria densifolia									+								

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Antennaria isolepis								+	+								
A. monocephala			+	+	+			+				+	+				
A. pedunculata									+		+						
Antennaria sp.									+								
Arnica lessingii			+	+			+	+									
Artemisia arctica		+	2	2	1	+	1	1	+	+	3	1	1				
A. tilesii							+	2	+		+						
Aster sibiricus									3								
Erigeron acris						+											
Erigeron humilis			+			+		+	+								
Hieracium gracile					+												
H. triste				+			+										
Petasites frigidus			3	+		+	3	3	+	1	4		+			5	2
Senecio lugens			+	+				+	+	1	+		+				
S. triangularis			2	+			+	1			7		2				
S. yukonensis		+		+	+	+						+					
Solidago multiradiata			+				+	1	+		+		+			+	
Taraxacum sp.			+														
CORNACEAE																	
Cornus canadensis						+		+					+			+	
CRASSULACEAE																	
Rhodiola integrifolia			+	+			+	1	1	+	+		+				
CRUCIFERAE																	
Arabis lyrata			+					+	+								
Braya humilis				+													
Cardamine bellidifolia		+		+	+												
C. pensylvanica										+	+						
C. pratensis								+		+	+						
C. umbellata											+						
Draba borealis											+						
D. longipes											+						
Parrya nudicaulis			+														
CYPERACEAE																	
Carex aenea											+						
C. aquatilis							+	7	+	55	5						
C. atrofusca				2		+											
C. atrosquama									+								
C. brunnescens									+	+		+					
C. capillaris										+							
C. gynocrates					+												
C. lachenallii				+								+					
C. macloviana									+			+					
C. media									+							+	
C. membranacea			+	+				+	+	+							

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Carex microchaeta		+		+	+		+	1			+						
C. microglochin										+							
C. nardina				+													
C. nigricans										+							
C. petricosa			+														
C. physocarpa										+							
C. podocarpa			3	+	+			+	+		2		+				
C. praticola										+							
C. pyrenaica					+												
C. rostrata										+							
C. rupestris		+															
C. saxatilis								+		+	1						
C. scirpoidea		+	+							+			2				
C. vaginata				+													
Carex sp.		+			+		+			+			+				
Eriophorum angustifolium				+				+		+	4						
EMPETRACEAE																	
Empetrum nigrum		+			2	+	+	+	+				+	+	+		5
EQUISETACEAE																	
Equisetum arvense			+	+				18	1	1	25					+	
E. hyemale																	
E. pratense									+							25	
E. scirpoides			+				+	+	+	+	+					+	
E. sylvaticum						+	+	+		+						7	5
E. variegatum								+	+	+							
ERICACEAE																	
Andromeda polifolia													+				
Arctostaphylos alpina					+			+									
A. rubra		2	+			+		+		+			+			1	
Cassiope tetragona		+	1	1	18							+	3	5	+		
Ledum decumbens						+	+					+	+	+			2
L. groenlandicum					+	17	+	+					1	+	+	+	2
Oxycoccus microcarpus								+									+
Phyllodoce empetriformis					+	+							+				
Vaccinium uliginosum		2			2	11	+	+	1		+	+	+	+	+	+	2
V. vitis-idaea		2		+	1	3	1	+			2	+	+	+	+	2	
GENTIANACEAE																	
Gentiana glauca			+	+	+	+			+			+	+			+	
G. propinqua								+	+							+	
GRAMINEAE																	
Agropyron violaceum									+	+	+						
Agrostis gigantea						+											

Appendix I continued - 4

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Agrostis scabra									+								
Agrostis sp.											+						
Alopecurus aequalis										+							
A. alpinus				+				1			+						
Arctagrostis arundinacea				+	+			+	+		+					+	
A. latifolia			+	+			+	+			+						
Calamagrostis canadensis				3	1	+		+	2		6						
C. inexpansa							3										
C. lapponica		+						+		+							
C. neglecta				2	+					+		+					
Deschampsia caespitosa			3	2	+			1			23	+	+				
Festuca altaica			7	11	1	+		6	33		15	7	6				
F. saximontana									+								
Hierochloe alpina		2		3	1				+			+					
H. odorata									+								
Phleum commutatum			+	+				+			+	+					
Poa alpigena					+				+		+						
P. alpina			+			+		+	+		+						
P. arctica			+	5		+	+	+	1								
P. glauca			+														
P. lanata			+					+	+		4						
P. paucispicula			+														
Poa sp.							1										
Trisetum spicatum			1	+				+	4	+	+		+	2			
Vahlodea atropurpurea													+				
HALORAGACEAE																	
Hippuris vulgaris										+							
JUNCACEAE																	
Juncus albescens										+							
J. arcticus					+												
J. balticus								+									
J. biglumis									+								
J. castaneus							+		+		+						
Luzula arcuata			+	+	+												
L. confusa		4		1	1												
L. parviflora							+	+	+	+	+	+					
L. wahlenbergii					+				+								
JUNCAGINACEAE																	
Triglochin palustre										+							

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
LEGUMINOSAE																	
Astragalus umbellatus										+	+						
Astragalus sp.								+									
Hedysarum alpinum								+									
Lupinus arcticus		+				+					+						
LILIACEAE																	
Lloydia serotina				+				+									
Tofieldia pusilla										+							
Veratrum eschscholtzii													+				
LYCOPODIACEAE																	
Lycopodium alpinum					1								+	+			
L. annotinum						+	+						+	+			
L. complanatum								+									
L. selago		+	+	+	+	+											
MONOTROPACEAE																	
Moneses uniflora																+	
ONAGRACEAE																	
Epilobium anagallidifolium			+	+				+		+	+		+			+	
E. angustifolium				+			+	+	1		+		+			+	
E. davuricum										+			+				
E. latifolium			3					+	+		+		+			+	
E. palustre								+									
Epilobium sp.											+						
OPHIOGLOSSACEAE																	
Botrychium lunaria									+								
PINACEAE																	
Abies lasiocarpa													148	45	190		+
Juniperis communis									+								
Picea glauca																43	+
P. mariana																	8
POLEMONIACEAE																	
Polemonium acutifolium			+	+			1	1	1	+	2		+			+	
POLYGONACEAE																	
Koenigia islandica									+								
Oxyria digyna			+					+									
Polygonum viviparum			+	+				+	+	+			+			+	
Rumex arcticus							1	+		1	2					+	+
PORTULACACEAE																	
Claytonia tuberosa											+						

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PYROLACEAE																	
Pyrola asarifolia							+	+	+		+		+			+	
P. minor											+						
P. secunda													+				
Pyrola sp.																+	
RANUNCULACEAE																	
Aconitum delphinifolium				+				+			+		+			+	
Anemone narcissiflora					+	+		+			+		+				
A. parviflora			1	+		+		+	+	+	+		+			1	
A. richardsonii			+					+			+						
Delphinium glaucum								+	+		+					+	
Ranunculus eschscholtzii			+			+											
R. flammula										+							
R. gmelinii		+	+							+							
R. lapponicus													+				
R. nivalis			+														
R. sulphureus											+						
Ranunculus sp.			+														
ROSACEAE																	
Dryas integrifolia		8															
D. octopetala			3	3				+									
Geum macrophyllum											+						
Geum rossii			+														
Potentilla diversifolia							+										
P. elegans		+		+													
P. fruticosa			+				+	2	+				+			8	
P. hyparctica		+															
P. palustris								+	+	3							
P. uniflora		+		+													
Rosa acicularis																+	
Rubus acaulis							+	+	2	+	1	+	+			+	
R. chamaemorus						+	1	1			1	+	+		+		5
Sibbaldia procumbens			1		+	+	+		+		+	+	+				
Spiraea beauverdiana					1		+	+		+	+	+	+		+		
RUBIACEAE																	
Galium trifidum								+									
SALICACEAE																	
Populus balsamifera									+								
Salix alaxensis								1	52								
S. arbusculoides															+		
S. arctica		+	10	8	+			2			+		+				

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Salix barclayi																10	
S. barrattiana			3	+				3			+		3				
S. glauca							+	+								10	
S. lanata							+	35	24	+	2	1	10				5
S. myrtillifolia											+						
S. padophylla																2	
S. planifolia			+		+	+	14	84	24	+	2	1	10				5
S. reticulata		+	15	+			+	15	+	10	+		5			+	
SAXIFRAGACEAE																	
Chrysosplenium tetrandrum			+			+				1	+						
Parnassia fimbriata								+					1				
P. kotzbuei			+					+	+								
P. palustris								+	+	+							
Ribes triste																+	
Saxifraga cernua			+					+			+						
S. hieracifolia			+	+				+									
S. lyallii			+														
S. oppositifolia		+															
S. punctata			+						+		+						
S. radiata			+														
S. tricuspidata		+		+					+			+					
Saxifraga sp.			+					+			+						
SCROPHULARIACEAE																	
Pedicularis capitata		+						+									
P. labradorica							+	+									+
P. lanata			+	+													
P. sudetica			+	+			+	+	+	+	+		+				
Pedicularis sp.													+				
Veronica wormskjoldii			+				+	+	+		+		+				
SELAGINELLACEAE																	
Selaginella selaginoides								+									
SPARGANIACEAE																	
Sparganium minimum										+							
UMBELLIFERAE																	
Angelica lucida								+					+				
Heracleum lanatum								+									
VALERIANACEAE																	
Valeriana capitata										+							
V. septentrionalis								+									
V. sitchensis			4					+	+	1			+				

Appendix I continued - 8

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
VIOLACEAE																	
Viola adunca								+	+		+						
V. epipsila								+	+								
Viola sp.										+							
<u>Bryophytes</u>																	
Categories recognized during fieldwork																	
Hylocomnium splendens							17	15			15		40	10	30	60	5
Liverworts						+	+	+			+						
Misc. Mosses and Liverworts	1	+	25	13	1	2	28	20	23	18	20	+	13	1	5	+	15
Polytrichum sp.		3	1	11	5	2	8	+	+		+	2	+	2	7		5
Sphagnum sp.						+	+	1		40			+		30		20
<u>Moss Taxa</u>																	
AMBLYSTEGIACEAE																	
Amblystegium serpens																x	
Calliergidium dendroides																	
C. pseudostramineum									x								
Calliegon cordifolium											x						
C. giganteum										x							
C. sarmentosum							x	x									
C. stramineum							x	x		x							
Campylium stellatum			x					x		x	x		x				
Drepanocladus aduncus			x			x	x			x	x						
D. exannultus										x							
D. fluitans																	
D. revelvens							x	x		x	x						
D. tundrae																	
D. uncinatus			x	x		x	x	x	x	x	x		x		x		
Scorpidium scorpidioides										x							
AULACOMNIACEAE																	
Aulacomnium palustre							x	x	x	x	x		x				x
BARTRAMIACEAE																	
Bartramia ithyphylla								x									
BRACHYTHECIACEAE																	
Brachythecium sp.										x							
B. erythrorrhizon									x								
B. groenlandicum																	
B. nelsonii								x	x		x						
B. salebrosum			x					x			x		x				
Tomenthypnum nitens							x	x		x	x			x			

Appendix I continued - 9

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
BRYACEAE																	
Bryum sp.		x					x	x								x	
B. caespiticium								x									
B. pseudotriquetrum			x	x				x	x	x	x		x				x
B. weigelii								x									
Leptobryum pyriforme								x	x		x						
Pohlia cruda				x				x			x					x	
P. nutans	x			x	x		x	x		x	x		x	x	x		
P. wahlenbergii																	
CATOSCOPIACEAE																	
Catoscopium nigritum								x		x							
Philonotis fontana			x					x			x						
CLIMACIACEAE																	
Climacium dendroides			x					x		x	x						
DICRANACEAE																	
Cynodontium strumiferum			x														
C. tenellum													x				
Dicranella subulata																	
Dicranum acutifolium				x	x	x		x					x		x	x	
D. elongatum		x		x	x	x	x				x						
D. fuscescens				x	x	x	x	x					x	x		x	
D. groenlandicum							x						x				
D. muehlenbeckii																	
D. scoparium				x			x	x			x						
D. spadiceum											x						
D. undulatum							x										
Dicranum sp.							x	x									
Kiaeria starkei		x					x										
ENTODONTACEAE																	
Pleurozium schreberi			x		x	x	x	x		x	x	x	x	x	x		
GRIMMIACEAE																	
Grimmia affinis		x															
G. apocarpa		x															
Grimmia sp.		x															
Rhacomitrium canescens			x	x				x	x		x		x				
R. fasciculare										x							
R. heterostichum					x				x								
R. lanuginosum	x	x		x	x												
HEDWIGIACEAE																	
Hedwigia ciliata			x														

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
HYLOCOMNIACEAE																	
Hylocomnium pyreniacum								x									
H. splendens			x	x	x		x	x			x		x	x	x	x	x
HYPNACEAE																	
Hypnum pratense								x		x	x						
H. revolutum		x															
H. vaucheri		x															
Pylaisiella polyantha								x									
LESKEACEAE																	
Leskeela nervosa								x									
MEESEACEAE																	
Meesia triquetra								x									
M. uliginosa							x	x		x							
Paludella squarrosa							x	x		x							
MNIACEAE																	
Mnium sp.										x							
Plagiomnium ellipticum				x						x	x						
Rhizomnium gracile							x	x			x						
R. pseudopunctatum							x	x					x				
POLYTRICHACEAE																	
Pogonatum alpinum	x	x	x								x						
P. contortum			x														
Polytrichum commune			x		x	x	x	x		x		x	x	x	x		x
P. juniperinum				x		x	x	x	x		x	x					
P. piliferum	x	x	x						x			x					
P. sexangulare										x							
P. strictum				x	x	x	x	x		x	x	x	x	x	x		x
POTTIACEAE																	
Tortula norvegica																	
T. ruralis								x									
SPHAGNACEAE																	
Sphagnum sp.						x	x	x		x			x		x		x
S. angustifolium																	x
S. fimbriatum										x					x		x
S. fuscum						x	x										x
S. lindbergii										x							
S. magellanicum										x							
S. nemoreum							x						x				
S. obtusum						x											
S. riparium										x							
S. rubellum								x									
S. warnstorfii							x	x		x					x	x	x

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SPLACHNACEAE																	
Splachnum sp.															x	x	
<u>Liverwort Taxa</u>																	
CEPHALOZIACEAE																	
Cephalozia lunifolia																	
JUGERMANIACEAE																	
Anastrophyllum sp.				x	x					x							
A. minutum					x		x	x		x			x	x			
Barbilophozia hatcheri								x				x					
B. lycopodioides			x	x				x	x		x		x	x	x		
B. trichophyllum																x	
Lophozia sp.		x		x	x		x	x			x	x	x	x	x	x	
L. kunzeaea										x							
Tritomaria sp.								x									
T. exsecta						x											
MARCHANTIACEAE																	
Marchantia polymorpha								x			x						
MARSUPELLACEAE																	
Marsupella sp.						x				x							
PLAGIOCHILACEAE																	
Mylia anomala						x								x			
PTILIDIACEAE																	
Blepharaostoma trichophyllum								x									
Ptilidium ciliare				x								x					
P. pulcherrimum																x	
SCAPANIACEAE																	
Scapania irrigua							x										
Scapania sp.							x	x		x							
<u>Lichens</u>																	
Categories recognized during fieldwork																	
Alectoria ochroleuca	+	2		+	6	4						6			+		
Cetraria cucullata		3		3	2	2	+	+				1					
C. islandica	+	+	+	1	+	+	+	+			+	+	+	+			
C. nivalis	+	2	+	3	17	6		+				10	+	2			
C. richardsonii		+	+	+	1	+						+					
C. tilesii		1	+														
Cetraria sp.		+			+												

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Cladonia mitis				4	23	37	1	+			+	65	1	70		+	5
Cladonia rangiferina			+		+	5	3	+			+	+	+	1	+	+	3
Misc. *Cladonia* sp.		+	+	1	+	2	+	+	+		+		2	3	+	+	2
Crustose Lichens	15	9		+	1	+	+					+					
Dactylina arctica		+	+	+	+	+		+				+	+	+	+		
Dactylina sp.		+			+	+							+				
Epiphytic Lichens							+	+	+		30		23	50	50	30	
Nephroma arcticum			+	+	+	+	3	+	2	+			+	+	20	+	1
Nephroma sp.				+	+												
Peltigera aphthosa			+	+		+	+	+	1		+		+		+	+	1
P. canina			+				1	1	1	+			+	+	+	+	
Peltigera sp.			1	+	+		+	+									
Rhizocarpon sp.					+												
Saxicolous Lichens	6	3	+	+	1												
Solarina crocea	+		+	+	+			+					+				
Solicolous Lichens			3	2	1			+					1				
Stereocaulon sp.	+		5	7	2	10	+	1	10		+	7	1		+		
Thamnolia subuliformis	+	+		+	+												
Umbilicaria sp.	30	7		1	+							+					
<u>Lichen Taxa</u>																	
BAEOMYCETACEAE																	
Baeomyces rufus					x												
BUELLIACEAE																	
Buellia papillata				x													
Rinodina turfacea				x													
CALICIACEAE																	
Calicium viride											x						
CLADONIACEAE																	
Cladonia amaurocraea		x				x	x					x					
C. arbuscula			x		x		x	x				x				x	
C. bacillaris																x	
C. bellidiflora							x						x				
C. carneola				x		x											
C. cenotea																x	
C. chlorophaea					x			x	x				x				
C. coccifera		x	x	x	x	x	x	x			x	x		x			
C. cornuta						x	x	x					x	x			x
C. crispata				x		x							x	x	x		x
C. deformis			x			x	x						x	x			
C. ecmocyna			x			x	x					x	x				
C. fimbriata								x	x								

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Cladonia gonecha						x	x										
C. gracilis				x	x	x	x	x	x			x	x	x	x	x	x
C. macrophylla				x		x							x				
C. mitis				x	x	x	x	x				x	x	x		x	x
C. phyllophora						x						x					
C. pleurota						x						x	x				
C. pocillum				x													
C. pseudostellatum																	x
C. pyxidata			x			x		x				x					
C. rangiferina			x		x	x	x	x			x	x	x	x	x	x	x
C. stellaris			x	x	x	x	x					x					
C. subfurcata		x			x	x											
C. subulata								x								x	
C. sulphurina			x	x	x	x	x	x				x	x		x		x
C. uncialis		x		x		x	x					x	x				
C. verticillata				x		x									x		
Cladonia sp.		x	x	x	x	x	x	x	x		x		x	x	x	x	x
LECANORACEAE																	
Icmadophila ericetorum					x	x							x		x		
Lecanora epibyron		x															
L. polytropa						x											
L. supertegens	x																
Ochrolechia androgyna				x													
O. arborea													x				
O. frigida		x															
Ochrolechia sp.				x													
LECIDEACEAE																	
Bacidia alpina			x														
B. obscurata			x														
Lecidea atrata		x															
L. flavocaerulescens																	
L. granulosa													x				
L. jurana					x												
Lecidea sp.					x												
Lecidella stigmatea		x			x												
Rhizocarpon chioneum		x															
R. eupetraeoides	x	x			x												
R. geographicum	x	x	x		x	x											
R. inarense	x																
R. intermediellum	x																
R. riparium	x																
R. superficiale		x															

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Rhizocarpon umbilicatum		x															
Rhizocarpon sp.					x												
LICHENES IMPERFECTI																	
Lepraria neglecta												x					
Lepraria sp.						x											
PANNARIACEAE																	
Pannaria pezizoides			x					x	x				x				
Psoroma hypnorum								x									
PARMELIACEAE																	
Cetraria commixta	x		x		x												
C. cucullata		x		x	x	x	x	x				x					
C. delisei			x	x													
C. ericetorum	x		x		x												
C. hepatizon	x				x												
C. islandica	x	x	x	x	x	x	x	x			x	x	x	x			
C. nigricans	x	x	x		x							x					
C. nivalis	x	x	x	x	x	x		x				x	x	x			
C. pinastri						x	x	x									
C. richardsonii		x	x	x	x	x						x					
C. tilesii		x	x														
Cetraria sp.	x																
Dactylina arctica		x	x	x	x	x		x				x	x	x	x		
D. ramulosa				x	x			x				x					
Dactylina sp.		x			x		x						x				
Hypogymnia austerodes													x	x	x	x	
H. bitteri														x	x	x	
H. oroarctica					x												
H. physodes															x		
H. vittata													x				
Parmelia centrifuga																	
P. separata			x		x												
P. sulcata													x			x	
Parmeliopsis aleurites															x		
P. ambigua						x							x	x			
P. hyperota						x	x							x		x	
PELTIGERACEAE																	
Nephroma arcticum				x	x	x	x	x	x	x			x	x	x	x	x
N. expallidum			x	x			x	x	x							x	
N. parile									x								
N. resupinatum									x								
Nephroma sp.				x	x												

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Peltigera aphthosa			x	x		x	x	x	x		x		x		x	x	x
P. canina			x				x	x	x	x			x	x	x	x	
P. collina							x										
P. malacea			x					x							x	x	x
P. polydactyla							x	x					x				
P. pulverulenta							x										
P. rufescens								x	x			x					
Peltigera sp.			x	x	x		x	x		x							
Solarina crocea	x		x	x	x			x					x				
S. saccata			x														
S. spongiosa								x									
PERTUSARIACEAE																	
Pertusaria dactylina					x												
STEREOCAULACEAE																	
Stereocaulon alpinum			x	x			x	x	x		x	x			x		
S. paschale			x		x	x	x		x			x	x				x
S. rivulorum	x		x								x						
S. saxatile	x																
S. tomentosum										x		x					
Stereocaulon sp.	x		x	x	x	x	x	x	x		x				x		
STICTACEAE																	
Lobaria linita								x			x						
UMBILICARIACEAE																	
Agyrophora lyngei	x	x			x												
A. rigida	x	x			x												
Agyrophora sp.																	
Lasallia pustulata						x						x					
Omphalodiscus virginis	x																
Umbilicaria cylindrica	x	x															
U. deusta												x					
U. hyperborea	x			x	x							x					
U. krascheninnikovii						x											
U. proboscidea		x	x		x							x					
Umbilicaria sp.	x	x		x	x							x					
USNEACEAE																	
Alectoria nigricans		x		x													
A. ochroleuca	x	x		x	x	x						x			x		
A. sarmentosa													x				
Bryoria fuscescens													x			x	
B. lanestris															x	x	
B. pseudofuscescens																x	
B. simplicior														x	x		

Appendix I continued - 16

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Cornicularia divergens	x		x														
Pseudophebe pubescens	x	x															
Thamnolia subuliformis	x	x		x	x							x					
Usnea sorediifera																x	

'+' cover value of less than 1%

'x' collected during the course of the 1981-1982 survey or reported from previous studies.

APPENDIX II

APPENDIX II

APPENDIX II

AVIAN SPECIES RECORDED AT THE MACTUNG PROJECT AREA

Species		Breeding Evidence	Habitats
WATERFOWL			
Canada Goose	Branta canadensis	No	Tsichu River Island Ponds
Mallard	Anas platyrhynchos	Yes	Ponds; Sedge Meadows
Green-winged Teal	A. crecca	Yes	Ponds; Sedge Meadows
Blue-winged Teal	A. discors	Yes	Ponds; Sedge Meadows
Lesser Scaup	Aythya affinis	Yes	Ponds
Common Goldeneye	Bucephala clangula	No	Cirque Lake; Ponds
Oldsquaw	Clangula hyemalis	No	Tsichu River; Ponds
Harlequin Duck	Histrionicus histrionicus	Yes	Tsichu River; Ponds
Pintail	Anas acuta	Yes	Ponds; Sedge Meadows
Shoveler	Spatula clypeata	?	Ponds
Bufflehead	Bucephala albeola	No	Ponds
Red-breasted Merganser	Mergus serrator	?	Tsichu River
White-winged Scoter	Melanitta deglandi	Yes	Ponds; Tsichu River
Black Scoter	M. nigra	No	Ponds; Tsichu River
FALCOFORMS			
Marsh Hawk	Circus cyaneus	Yes	Sedge Meadows; Willow-forb;
Golden Eagle	Aquila chrysaetos	Yes	Rocky Ledges; High Tundra; Birch-Lichen
Gyrfalcon	Falco rusticolus	Yes	High Tundra
Merlin	F. columbarius	No	Birch-Lichen; Riparian Willow

APPENDIX

(cont'd)

Species		Breeding Evidence	Habitats
Bald Eagle	*Haliaectus leucocephalus*	No	Tsichu River Area
Peregrine Falcon	*Falco peregrinus*	No	Tundra
GROUSE			
Willow Ptarmigan	*Lagopus lagopus*	Yes	Riparian Willow; Willow-forb; Sedge Meadows; Birch-Lichen
Rock Ptarmigan	*L. mutus*	Yes	Alpine Lichen-Grass
WADERS AND SHOREBIRDS			
Semipalmated Plover	*Charadrius semipalmatus*	Yes	Disturbed Areas; Mudflats, Tsichu River Islands; Sedge Meadows
Spotted Sandpiper	*Actitis macularia*	Yes	Tsichu River Islands; Mudflats and Bars; Ponds; Sedge Meadows
Wandering Tattler	*Heteroscelus incanus*	Yes	Tsichu River Islands; Mudflats and Bars; Ponds; Sedge Meadows
Lesser Yellowlegs	*Tringa flaripes*	Yes	Tsichu River Islands; Mudflats and Bars; Ponds; Sedge Meadows
Baird's Sandpiper	*Calidris bairdii*	Yes	Tsichu River Islands; Mudflats and Bars; Ponds; Sedge Meadows
Least Sandpiper	*C. minutilla*	Yes	Tsichu River Islands; Mudflats and Bars; Ponds; Sedge Meadows
Northern Phalarope	*Lobipes lobatus*	Yes	Ponds; Sedge Meadows

APPENDIX

(cont'd)

Species		Breeding Evidence	Habitats
Common Snipe	*Capella gallinago*	Yes	Sedge Meadows; Ponds; Willow-forb
Sora	*Porzana carolina*	No	Ponds
Solitary Sandpiper	*Tringa solitaria*	No	Ponds; Sedge Meadows
CHARADRIIFORMES			
Parasitic Jaeger	*Stercorarius parasiticus*	No	Tsichu River Area
Mew Gull	*Larus canus*	Yes	Cirque Lake; Tsichu River Islands; Ponds
Bonaparte's Gull	*L. philadelphia*	No	Ponds
Arctic Tern	*Sterna paradisaea*	No	Ponds; Riparian Willow Tsichu River
OWLS			
Snowy Owl	*Nyctea scandiaca*	No	Willow-forb; Birch-Lichen
Short-eared Owl	*Asio flammeus*	Yes	Willow-forb; Birch-Lichen
Great Gray Owl	*Strix nebulosa*	No	Flying
Hawk Owl	*Surnia ulula*	?	Tsichu River; Riparian Willow
HUMMINGBIRDS			
Rufous Hummingbird	*Selasphorus rufus*	No	Willow-forb; Birch-Lichen
CORVIDS			
Gray Jay	*Perisoreus canadensis*	No	Riparian Willow; Birch-Lichen
Common Raven	*Corvus corax*	No	General

APPENDIX

(cont'd)

Species		Breeding Evidence	Habitats
DIPPERS			
Dipper	Cinclus mexicanus	?	Tsichu River
WOODPECKERS			
Common Flicker	Colaptes auratus	?	Riparian Willow
FLYCATCHERS			
Say's Phoebe	Sayornis saya	Yes	Rocky Cliffs; Bridges
LARKS			
Horned Lark	Eremophila alpestris	Yes	Disturbed areas; Willow-forb
SWALLOWS			
Cliff Swallow	Petrochelidon pyrrhonta	Yes	Bridges; Buildings; Banks
Tree Swallow	Iridoprocne bicolor	?	Riparian Areas; Ponds
THRUSHES			
American Robin	Turdus migratorius	Yes	Willow-forb; Riparian Willow
Gray-cheeked Thrush	Catharus minima	Yes	Willow-forb; Riparian Willow
PIPITS			
Water Pipit	Anthus spindetta	Yes	Birch-Lichen; Lichen-Heath; Forb Meadow

APPENDIX

(cont'd)

Species		Breeding Evidence	Habitats
SHRIKES			
Northern Shrike	*Lanius excubitor*	Yes	Riparian Willow
WARBLERS			
Blackpoll Warbler	*Dendroica striata*	Yes	Riparian Willow
Northern Waterthrush	*Seiurus noveboracensis*	Yes	Tsichu River Islands; Willow-forb; Riparian Willow
Yellow Warbler	*Dendroica petechia*	Yes	Willow-forb
Wilson's Warbler	*Wilsonia pusilla*	Yes	Willow-forb
ICTERIDS			
Rusty Blackbird	*Euphagus carolinus*	Yes	Willow-forb
FRINGILLIDS			
Gray-crowned Rosey Finch	*Leucosticte tephrocotis*	Yes	Forb Meadow; Lichen-Heath Tundra;
Common Redpoll	*Acanthis flammea*	Yes	Willow-forb
Hoary Redpoll	*Acanthis hornemanni*	Yes	Birch-Lichen
Dark-eyed Junco	*Junco hyemalis*	No	Willow-forb;
Savannah Sparrow	*Passerculus sandwichensis*	Yes	Willow-forb; Riparian Willow; Birch-Lichen
Tree Sparrow	*Spizella arborea*	Yes	Willow-forb; Riparian Willow; Birch-Lichen

APPENDIX

(cont'd)

Species		Breeding Evidence	Habitats
Chipping Sparrow	S. passerina	Yes	Willow-forb; Riparian Willow; Birch-Lichen
White-crowned Sparrow	Zonotrichia leucophrys	Yes	Birch-Lichen; Willow-forb
Golden-crowned Sparrow	Z. atricapilla	Yes	Willow-forb
Lincoln's Sparrow	Melospiza lincolnii	Yes	Riparian Willow; Willow-forb;
Song Sparrow	M. melodia	Yes	Willow-forb; Sedge Meadow; Birch-Lichen
Lapland Longspur	Calcarius lapponicus	No	Forb Meadow Lichen-Heath Tundra
Snow Bunting	Plectrophenax nivalis	Yes	Forb Meadow; Lichen-Heath

APPENDIX III

APPENDIX III

EXPLANATION OF UNITS

For submission of the IEE to a Canadian government body all units of measurement must be in the metric system. Therefore, information generated in the Imperial System has been converted to the Metric System and included as the first unit in the text followed in brackets by the original figure. For clarification the list below gives useful equivalent values in both systems.

Imperial		Metric
1 short ton	=	.907185 tonnes (t)
9 million tons	=	8 million t
2204.6226 lbs	=	1 t
1000 tons/day	=	907.2 t/day
2000 tons/day	=	1814 t/day
350,000 tons/year	=	317,515 t/year
1 in	=	25.4 millimetres (mm)
1 ft	=	.3048 metres (m)
1 ft^2	=	.0929 m^2
1 ft^3	=	.0283 m^3
1 US gal	=	3.785 litres (L)