IMPERIAL OIL LIMITED
PRODUCTION DEPARTMENT – WESTERN REGION

TAGLU GAS DEVELOPMENT

INFORMATION IN SUPPORT OF LAND TENURE AGREEMENT APPLICATION

SEPTEMBER, 1975

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1. OVERVIEW SUMMARY

This submission is being made to the Department of Indian Affairs and Northern Development (D.I.A.N.D.) in support of a Land Tenure Agreement for a proposed gas development at Taglu in the Mackenzie Delta, Northwest Territories.

D.I.A.N.D. has indicated to Imperial Oil Limited in a meeting in Ottawa on August 6, 1975 that the Overview Summary be left for D.I.A.N.D. to prepare for both the Environmental Assessment and Review Process (EARP) and the Public.

2. PROJECT PROPOSAL

In November, 1974, Gulf Oil Canada Limited, Imperial Oil Limited and Shell Canada Limited made a joint application to the Department of Indian Affairs and Northern Development for "Approval-in-Principle" of a Mackenzie Delta gas development system. The six-volume application to the government was supported by an extensive environmental report by F. F. Slaney & Company and a socio-economic report and community atlas by van Ginkel Associates.

D.I.A.N.D.'s response was to advise the industrial proponents to apply instead for a Land Tenure Agreement for which a set of guidelines was issued. The application was to be as detailed and site-specific as possible, two conditions which would make another joint submission rather cumbersome since the industrial proponents propose to operate from different areas and could not all furnish the same degree of detail requested by D.I.A.N.D. Therefore, the information supplied herein by Imperial Oil Limited is for land tenure for the Taglu gas development facility only.

2.1 Rationale

2.1.1 Purpose of Development

The proposed Taglu development is to produce and process natural gas from the Taglu gas field and possibly neighbouring fields if and when they are discovered, to the specifications required by a gas transmission line.

2.1.2 Gas Supply and Demand

In its report of April, 1975, the National Energy Board noted that natural gas supplies in Canada will not be adequate in the near-term to meet both projected increases in domestic demand and existing export commitments. While it is government policy, as stated by the Honourable Donald S. MacDonald in a release on July 16, 1975, to meet Canada's obligations to existing U.S. customers to the greatest extent possible, some curtailment of the export contracts, as well as restraints in the growth of gas demand in Canada will be required until frontier supplies of gas are made available. The Applicant contends that development of gas reserves in the Mackenzie Delta including those in the Taglu proposal, are urgently required to alleviate this shortfall in the supply situation. These reserves are currently Canada's largest source of new gas supplies that can be economically exploited.

2.1.3 Role of Proposed Facilities

Imperial's portion of the Mackenzie Delta Gas Development System would consist of two groups of gas production facilities, a gas plant and supporting facilities all concentrated in one location near the geographic centre of the Taglu gas field, just south of Big Lake, Richards Island, N.W.T. Because of the contiguity of these facilities, there would be only a short gas flowline system from wells to gas plant. After processing, the gas would be fed to a Mackenzie Valley pipeline.

2.1.3.1 Gas Production

Gas would be produced from two groups of directionally-drilled wells. Each group of wells, known as a cluster, would be drilled from a large gravel-fill pad. Wells would be deviated sufficiently to provide acceptable well spacing at the pay zone for proper reservoir drainage.

Each cluster, accommodating about ten production wells, would be supported on a rectangular gravel pad measuring approximately 400 feet by 1,600 feet. The gravel pads would be sufficiently thick to prevent the surface of the 1,800 feet or so of permafrost from melting and to protect the facilities from seasonal flooding.

The technology for safe and efficient drilling and production in the arctic under firm environmental controls is available through years of research, engineering and experience in similar surface and subsurface conditions.

Cluster equipment would include wellheads and flow lines. Raw gas would be piped from wells through flow lines, insulated and supported above ground, to the adjoining gas plant a short distance away.

All operations would be remotely monitored and fully controlled from the processing plant. There would be little rig activity at the clusters initially, but infill drilling and workovers may be needed subsequently.

Cluster pads would be provided with a perimeter dyke to contain minor spills. In addition, the surface grading would ensure that precipitation is channelled to a holding pond for subsequent disposal.

2.1.3.2 Gas Processing

The gas processing plant would be placed on a gravel pad with all heat-generating buildings set on piles above the pad. A roadway would connect the plant with the clusters. Gas processing at the plant would include gas-liquid separation, dehydration, refrigeration and compression.

Viable gas plant design and operating practices in a cold environment are available from experience in northern Alberta and British Columbia. The process design is straightforward chiefly because of the lean composition of the raw gas and the absence of hydrogen sulphide. The extracted liquid hydrocarbons, the major by-product of the plant, would be used as fuel or reinjected in disposal wells. Major equipment would include heat exchangers, separation vessels, propane refrigeration units, compressors, turbine drivers and generators. Maintenance shops would be provided to meet maintenance requirements. The plant and clusters would be automatically and centrally controlled by a sophisticated computer capable of making operating adjustments and emergency shutdowns if necessary.

The plant would not normally emit noxious gases. In an emergency, gas may be smokelessly flared for the period required to normally re-stabilize the situation. A minimum amount of waste effluents would be produced and these would be appropriately treated.

Plant support facilities would include living quarters for about 50 men, a 2,500 foot airstrip, a helicopter pad and a dock facility with maximum utilization experienced during plant construction. Crew transportation would be by fixed wing aircraft and helicopter. Maintenance supplies would be transported by barge in summer, snow and ice roads in winter, and by aircraft year-round.

2.1.3.3 Gas Pipeline

The proximity of the gas processing plant to the production well clusters would eliminate the need for specially designed flow lines. The short system of flowlines would be supported above-ground on piles and insulated. Heat-tracing will not be necessary since the high flow rate of the gas, the short distance between wellhead and plant and the small pressure drop in the large diameter flowline should inhibit hydrate formation.

Custody transfer of the sales gas would be at the plant discharge point which would be hooked up to a Mackenzie Valley pipeline.

2.1.4 Interrelation with Other Developments

The Taglu gas development project would undoubtedly interact with other development projects proposed for the Mackenzie Delta area. Notably, among these would be the Mackenzie River gas pipeline, other gas field developments onshore and offshore, possibly highway construction and future oil field development including a Mackenzie River oil pipeline.

These projects would compete for local land resources such as granular and other construction materials, for existing transportation facilities, suitable staging areas, manpower and other common needs. There would be an impact on the environment from emissions and human and industrial activities and on the socio-economic conditions of local people though every effort would be made to limit such impacts to within acceptable levels.

Four main areas of interaction can be identified:

Socio-economic impact
Environmental impact
Granular Material Use
Transportation & Logistics Needs

The socio-economic issue has been jointly addressed by Imperial, Gulf and Shell in a separate report.

Physical environmental constraints often preclude integrating individual facilities so that separate gas facilities, staging areas, etc. may be put up by other industrial proponents. However, basic environmental considerations for such facilities would be very similar to Taglu's but interactions would not be considered significant. Initially, the Taglu facility would process natural gas from the Taglu reservoir as now delineated, but extension of the reservoir or discovery of additional reserves near the plant site could make future expansions in plant processing capacity necessary.

Exploration in the offshore areas is expected to continue and it is possible, though not certain, that Imperial could bring gas from offshore discoveries to the Taglu plant for processing.

The Beaufort Delta Oil Project consortium, of which the Applicant is a member, is studying the feasibility and environmental impact of an oil pipeline to transport future oil reserves from the Mackenzie Delta. The availability of such a line would provide an outlet for the surplus liquid hydrocarbons from the Taglu plant.

Two major highways could feature in the development of the Mackenzie Delta region. The Dempster Highway from Dawson City in the Yukon to Inuvik is nearing completion and a highway from Inuvik to Tuktoyaktuk is in the planning stage. Neither road, when completed, would have a large impact on the proposed Taglu development but the highway from Inuvik to Tuktoyaktuk could put an additional drain on the general gravel deposits in the area.

Granular material requirements for pads, embankments, roads and airstrips would be quite heavy when considering the cumulative demand of all the proposed development projects. The availability of sand and gravel in the Delta is quite limited and wise exploitation of this resource would be needed. Gravel deposits at Ya Ya Lake are adequate for all proposed onshore gas development programs. Offshore developments would most likely have to meet their needs from other sources, probably offshore. Suitable sand deposits are equally scarce in the Delta but a potential deposit at Big Horn Point on Harry Channel, Richards Island is under study.

Transportation is an activity where the various development projects can interact very heavily. Because several of these projects may go on concurrently, some traffic congestion would be expected. By far, the largest impact on transportation would be from the Mackenzie Valley gas pipeline. This pipeline project is expected to procure and operate its own transportation system. An industry committee is currently investigating ways in which other projects may co-operate with the Mackenzie Valley pipeline transportation system for higher efficiency and lower environmental and socio-economic impacts.

2.1.5 Life of Project

In light of considerable potential reserves of gas in the Mackenzie Delta and offshore, it is expected that the Taglu gas plant would operate for a long time.

The life of a gas plant is determined by its processing capacity (size) relative to the volume of recoverable gas reserves. Since the latter is a matter of some speculation at this time, the choice of initial plant size and possible future expansions are therefore, still under consideration. However, gas is sold typically under 1-in-8 type contract which means that the average daily throughput is 1 bcf for every 8 Tcf of total recoverable reserves. This rate of depletion would fix the life of the project at about 22 years. To construct a 1 bcfd plant at Taglu means, therefore, that some 8 Tcf of recoverable gas reserves would have to be found to sustain plant operation for 22 years. Such reserves are considered well within the potentials of the general area around Taglu.

Initial plant size would be based on a near-term cumulative reserve forecast, with future expansions decided by the outcome of future exploration. A minimum gas plant life of some 20 years is considered a reasonable period from an investment standpoint as well as long-term supply obligation, and it is anticipated that the plant may operate well beyond that.

2.2 The Industrial Proponent's Declaration

The information contained in this document is submitted by Imperial Oil Limited to support an application for land tenure on a proposed natural gas development site on Richards Island in the Mackenzie Delta region of the N.W.T. It is the result of engineering and environmental investigations and analysis that have been under way since 1972 and are continuing. These investigations and analysis have been conducted by a large number qualified experts both within the company or retained by Imperial Oil Limited as members of consultant or contract firms. The information represents the current stage of development of the project and, in our opinion, adequately covers the environmental assessment of the proposed development.

Since the design of the system is not complete, the environmental assessment has been based primarily on preliminary project concepts such as the material balance for Richards Island Gas Plant found in Figure 3 of Part 2 of F. F. Slaney & Company Limited's Impact Assessment, May, 1974. As noted on page 174 of the Assessment, no sulphur has been measured in the condensate at Taglu. Although not anticipated, significant variations in emissions in the final design could change the impact assessment. Recent site-specific investigations relating to potential project changes include a fisheries and hydrological survey in the vicinity of the Big Horn Point sand deposit, a hydrological survey in the channel at Taglu and a gravel inventory for possible enlargement of the borrow area at Ya Ya Lake. Reports of these surveys will be forwarded when completed.

2.3 Project Description

This section describes in as much detail as available the entire project from its location through design, well drilling, plant and support facilities, construction and operations. The environmental background of the area is also covered.

Wherever possible, the alternatives open to the Applicant are discussed along with the reasons for the final choice.

2.3.1 Project Overview

The following project overview describes the facilities and operations necessary to produce the gas and condition it for transmission to southern markets in a buried pipeline.

Figure 1 depicts the production wells and process plant in relation to the various support facilities such as personnel housing, airstrip, dock and connecting roadways. The dock, to be located south of the plant, would be built of steel sheet piling placed in the river bottom and infilled with gravel. Beside it would be a staging and storage area of about 500 x 350 feet. This storage pad, as well as all other pads, and the roads and airstrip, would be built of granular materials. The pads would be thick enough to protect the permafrost and prevent flooding.

Sources of gravel in the Mackenzie Delta are scarce and costly. The source nearest the plant site is the gravel esker deposit at Ya Ya Lake, approximately 30 miles to the south. Because of the high cost of gravel and the large amount of granular material needed, considerable effort has been devoted to investigating the possibility of using the nearby sand deposit at Big Horn Point. The use of conventional rigid insulation would also be considered.

The drilling pads, while seemingly large, reduce rig moving costs, permit concentration of surface facilities in a relatively small area, and minimize environmental disturbance. The drilling pads would contain the waste fluids used in the drilling operation in large sumps.

The roadway system that connects the dock area, airstrip and drilling site to the plant site would be as short as possible.

All plant components are to be pre-built into modules which will be placed on piles and supported above flood level. Around and beneath the plant modules will be a gravel pad surrounded by a perimeter dyke to keep flood waters out and contain liquid spills should they occur, until clean-up operations could be carried out.

Most wells will be deviated for efficient reservoir drainage and are expected to produce 50 million cubic feet of gas per day each at an initial wellhead pressure of about 3,400 psia and a temperature of 120°F. It would be necessary to refrigerate the top 60 feet of the wellbore and take special measures in the design of the well to protect against the effects of thawback.

The gas from each production well on a cluster would be piped in its own flow line from the wellhead to the inlet separators of the plant. The lines would be approximately 8 or 10 inches in diameter operating at a maximum initial pressure of 3,600 psig and a maximum temperature of 120°F. To protect the underlying permafrost, it would be necessary to insulate and support these flow lines above ground. The insulated pipes would be provided with expansion configurations to minimize thermal stresses.

Once it had passed through the inlet separators and metering facilities, the gas would be dehydrated by a dry-desiccant system. After dehydration, it would be refrigerated, compressed, and cooled by propane refrigeration before entering the sales gas pipeline. Initially, all liquid hydrocarbons produced from the process not needed for fuel would be reinjected into a suitable underground formation. Housing for all process equipment and service facilities would be designed to protect the equipment and facilitate service during bad weather.

Because of the remoteness of the area, all operating and maintenance personnel would be lodged in a permanent housing complex next to the plant. Associated with the housing would be the necessary support facilities, which would include a power plant, water and waste treatment plants, a solid-waste incinerator and a communications network.

2.3.2 Project Location

The location of the proposed development is a few miles south of the arctic coast in the Mackenzie River Delta. The 1:250,000 scale map sheet that is enclosed with this application pinpoints its location and also illustrates other features surrounding the development.

Facilities needed to produce the gas from this location include three basic components:

- The production wells
- The gas processing plant
- The gas transmission line

The Applicant believes the proposed location will provide for these components while keeping the necessary disturbance of the environment to a minimum.

The sites were chosen with due consideration for:

- Drilling and operating the wells
- Locating and operating a manned process plant
- Access demands for both the construction and operation phases
- Minimum environmental disturbance of the area, which is within the Kendall Island Bird Sanctuary.

At Taglu, the need for remote production equipment and sophisticated gathering systems would be eliminated by placing the process facilities as close to the well clusters as is consistent with safety and security. The transmission line for the sales gas up to the plant would be built by the pipeline owners.

Figure 1 shows the present proposed layout of facilities on the land area beside the proposed well sites. At this small scale, it is difficult to show exactly where the sites for, say waste and sewage disposal would be, or where the various gaseous emissions would originate (indeed, their precise positions have not yet been fixed). However, the detailed discussions later in the application will mention the approximate locations. Similarly, the connection to the transmission pipeline cannot be detailed, although the Applicant feels it would probably be in the general area shown.

The proposed development is about a mile inside the presently defined boundaries of the Kendall Island Bird Sanctuary. The Applicant feels this location is the best place to build for the following reasons:

(i) It is close to the production wells, which require constant attention during their operating life. A location farther away from them (i.e. outside the Bird Sanctuary) would entail a more extensive layout of pipelines, roads and other facilities necessary for production and maintenance.

(ii) It eliminates the need for building pipelines and roads across any large river channels.

(iii) It is close to a navigable waterway.

(iv) Since it permits a compact development system made up of contiguous units, it lessens hazards to the environment or wildlife.

2.3.3 Land Required

This application for land tenure seeks permission to occupy the following areas of crown land necessary for developing the Applicant's Taglu gas field. These are:

(a) The land occupied by and immediately surrounding the specific facilities presently proposed in this application description. These facilities include the roadways, airstrip, well clusters plant site, and other associated items, including the above-ground flow lines - all of which are expected to remain in use for the life of the project.

(b) The land that would be required for possible future expansion of the project.

(c) Such land, around the specific facilities, as would enable the Applicant best to manage the undertaking as a whole. Examples would be land for the approaches to the airstrip runway, for safety areas around docks and producing wells, and for deployment of contingency apparatus.

The areas described in the above paragraphs are shown on Figure 2.

In laying out the overall development plan, the Applicant has endeavoured to make the facilities as compact as possible, thus enabling better operation control and hence greater environmental protection. Indicated on Figure 2 is a gross area of about 1,000 acres which encompasses the three areas described. Of course, not all of it would be occupied, and most of it would remain physically undisturbed by construction.

2.3.4 Environmental Maps

The following maps are attached:

1A Terrain (Taglu)
1B Terrain (Ya Ya Lake)
2A Vegetation (Taglu)
2B Vegetation (Ya Ya Lake)
3A Bird Habitat (Taglu)
3B Bird Habitat (Ya Ya Lake)
4A Mammal H bitat (Taglu)
4B Mammal Habitat (Ya Ya Lake)
5A Aquatic Resources (Taglu)
5B Aquatic Resources (Ya Ya Lake)
5C Aquatic Resources (General)

2.3.4.1 Geotechnical Conditions

The plant and associated support facilities would be located in the flood plain of the Mackenzie Delta. The surficial geology of the site as interpreted from area photographs is indicated in Figure 3.

As would be expected, flood-plain deposits dominate the area with traces of old channels having largely been buried or modified by flooding. The second most widespread terrain unit is the topographic lows related to drained or infilled lake basins and shallow depressions.

The area is generally underlain by continuous permafrost that extends to a depth of approximately 1,800 feet below the ground surface. Surface features indicate extensive low center polygons and the presence of ice wedges.

As topography of the plant site is flat, with less than five feet of variation in elevation, a contour map of this area has not been prepared. Generally, the land surface slopes from south to north.

The plant site has poor drainage and the ground surface is generally saturated. These conditions make for high ice content in the near-surface soils.

The vegetation is typical tundra, consisting of mosses and grasses growing in small hummocks. Willow shrubs grow along the river banks.

Geotechnically, the site is very homogeneous, its general stratigraphy consisting of peat overlying silt and occasionally sand. Detailed geotechnical information for the site is summarized in cross sections presented in Figure 4.

The peat layer, typically two to three feet thick, consists of medium brown, very fibrous organic material containing many roots and twigs.

The silt stratum consists of uniform, medium-brown silt which at depth changes to a dark grey. Its clay content is typically less than 10%, while its sand content varies from nil to very sandy. Below a depth of approximately 40 feet, the silt in many places grades into very fine silty sand strata.

Excess-ice contents measured in the field for various soils and areas are indicated in the cross-sections. As estimated visually, the ice content can be categorized into divisions of approximately 20% increment. Many areas of higher or lower ice content that were too small to map have been delineated in borehole logs in the report by E.B.A. Engineering Consultants.*

In the peat and the very ice-rich silt, the ice formation was typically random, while in the less ice-rich silt it was stratified. Below approximately 20 feet, no ice was visible. Generally, ice content increased to the north of the plant site, as is especially evident in cross-sections 2 and 5.

2.3.5 Well Production System

The well production system is described in the following sections:

2.3.5.1 Production Well Drilling

The duration of the drilling phase is not fixed at this time, but drilling is expected to be concentrated within the period 1978-1980. It is anticipated that Imperial's drilling department would carry out the drilling as an independent operator, apart from the process plant activities.

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* Report will be filed with D.I.A.N.D. in due course

Efficient depletion of the Taglu gas reserves would require from 20 to 30 wells ultimately. Initial drilling to provide productivity over the first five years or so could require as few as 14 producing wells. The number would be determined by gas withdrawal requirements and by the productivities of the wells. About 15 to 20 percent additional wells would be drilled to provide spare productive capacity for use as required in case of well problems, lower than expected production rates, or declining productivity. When not producing, these wells could serve as observation wells to monitor reservoir conditions.

Liquid hydrocarbons and water, processed by the plant, would be reinjected into two hydrocarbon injection wells and two produced water disposal wells respectively. It is proposed that an existing well, IOE Taglu D-43, near the plant site, would be converted to a condensate injector. The water disposal wells would be shallow. The relatively fresh produced water would be disposed of into the unconsolidated sands near the top of the tertiary sediments, somewhere between 3,000 and 4,000 feet.

Initial drilling program would comprise about 20 wells, 10 from each cluster. Production wells would be directionally drilled to a measured depth of about 12,000 feet (10,000 feet true vertical depth). Present indications are that each well would require from 45 to 60 days to drill and would then be suspended. With additional time required for well to well and pad to pad moves, the entire schedule could take 2.5 to 3 years of rig time to complete. It is proposed to use only one rig. This would reduce service, manning, and support activities, spreading them over a three-year period. If, however, the drilling schedule would take longer than programmed, or the delivery of rig equipment would slip, then the drilling would be supplemented by a second rig, in the last year before plant start-up.

2.3.5.1.1 Rig Equipment

The proposed Taglu wells would be drilled by a modified land-type drilling rig designed specifically for the arctic environment and capable of being moved on the pads. The rig would be driven by diesel-electric generators. Total horsepower would be about 4,400 hp. A standby generating system would also be provided to power emergency circuits in the event of a failure in the main system.

To further minimize fuel consumption, the diesel engine cooling system would be incorporated with the rig heating system. In addition, a waste heat recovery system would be installed on the engine exhausts. Fuel consumption at an average 50% load would be about 3,480 gallons per day.

To increase drilling rate, the mud system on the development rig would have about 50% more circulating capacity than an exploratory rig. The mud system would have a storage capacity of 1,200 - 1,400 barrels with extra solids control equipment for better mud weight control.

The well control equipment and systems would meet or exceed federal oil and gas drilling standards. All well control equipment would be enclosed and heated except for the lines to the flare.

Hole-to-hole moves would require the development of a moving system integrated into the framework of the rig. This would allow the complete structure to be either skidded, rolled, or floated the 100 feet between holes.

Approximate area of the drilling complex would be 60 feet by 200 feet, situated parallel and as close as possible to the sump to reduce the length of the discharge lines.

2.3.5.1.2 Drilling Operations

With only minor modifications, development drilling would be similar to exploratory drilling now taking place in the area.

After the first drilling pad is completed, well locations would be surveyed in a straight line 100 feet apart. A small portable auger would then drill a 48-inch conductor hole, 60 feet deep with a 'mouse' and 'rat' hole at each well location. Twenty-inch refrigerated conductor pipe would be cemented in place with the top level with the pad top surface. That the wells line up and are the same height is critical to the rig moving system.

After the first two conductor pipes are completed, the rig complex can be 'rigged-up' over the first hole on the pad. The first of the two shallow water injection wells would be drilled first. The design of these wells would be finalized upon approval of an injection interval.

As a single unit, with the mast up and all auxiliary equipment in place, the rig would be moved to the second location. The second hole drilled would be the first of the production wells. With the completion of the tenth well on this pad, some one and a half years later, the rig would be dismantled and transported by truck to the second drill pad where an identical program would be carried out.

Drilling material for three to four wells would be stockpiled on-site to allow the drilling operations to continue through spring break-up and fall freeze-up when the rig could not be conveniently re-supplied. Re-supply material would be stored at Bar C, the Applicant's existing base camp.

The principal differences in casing design between development and exploratory wells would be in the elimination of the 500-foot protective permafrost casing string and the inclusion of the non-freezing gelled diesel in the intermediate surface casing annulus.

A proposed well design is shown in Figure 5. With the refrigeration system operating to keep top hole frozen, a 17-1/2-inch hole would be drilled to 3,000 feet. The drilling fluid used would be a floculated KCl, XC, Gel system to allow adequate cleaning of the coarse sands and gravels encountered through the permafrost. Thermal erosion of the permafrost would be minimized by cooling the drilling fluid. At 3,000 feet, 13-3/8-inch casing would be run and cemented into the permafrost.

Next, a 12-1/4-inch hole would be drilled to the top of the Taglu A sands. The drilling fluid used would be an XC-gel system. For the 1,000 feet above the reservoir, the drilling fluid would be weighted with barite to control a slightly overpressured formation. Wells would be deviated at 3,100 feet at the rate of 2 1/2° per 100 feet until the desired deviation angle is reached. A 9-5/8-inch casing would be run and cemented for the bottom 3,000 feet and at the 13-3/8-inch shoe to effect an annular pressure seal.

The remainder of the hole through the reservoir would be drilled with a fresh, unweighted XC-gel drilling fluids system using an 8-1/2-inch bit. A 7-inch liner set on bottom would be cemented back to the 9-5/8" shoe. At this point, the well would be suspended by placing a packer in the production casing and circulating gelled diesel to displace the drilling mud in the top 2,000 feet of the hole. This would prevent any casing failures due to freezeback of the wellbore fluids. After installing the wellhead, the rig would move to the next well on the pad and so on.

2.3.5.1.3 Drilling Materials

The major material requirements for a total twenty well program are roughly as follows:

Casing (300,000 feet)	6,770 tons
Bentonite	1,140 tons
Potassium Chloride	500 tons
Barite	2,700 tons
Caustic Soda	70 tons
XC Polymer	35 tons
Peltex (Lignosulfonate)	50 tons
Bi-carbonate of Soda	78 tons
Cement (Permafrost & Oilwell)	4,000 tons
Fuel	100,000 barrels
Miscellaneous	100 tons

Cement, barite, and bi-carbonate would be shipped from southern centres in bulk. The rig complex would include facilities to transfer, weigh, and mix material in bulk form. The smaller amounts of dry chemicals and additives would still be bagged but would be protected, as they now are in palletized containers. Fuel would be stored on the drilling pads in welded tanks within a dyked area protected with an impermeable barrier.

2.3.5.1.4 Drilling Fluids Sump

The drilling of an average Taglu well would generate approximately 2,500 barrels of drill solids. In addition, there would be a significant volume of drilling fluids continuously 'sumped' from the underflow of the solids control equipment or as tanks are dumped to reduce viscosity and weight. As each new section of hole is started, it would also be necessary to start with a fresh drilling fluid system. In addition to drilling muds being disposed, most of the wash water from the rig goes into the sump. This is expected to add about 2,000 to 4,000 barrels per well of extra fluid. The total fluid generated per well is expected to be about 35,000 barrels.

To limit the size of the drilling sump and facilitate its eventual restoration, it is proposed to use a subsurface injection scheme to dispose of a portion of the drilling fluid. During the winter, all liquids would be emptied into the sump. The solids would settle out after spring thaw. The liquid in the sump would be essentially water with soluble drilling products and some unsettled fines, mainly bentonite and barite particles. This liquid would be pumped out of the sump during the summer and injected into the produced water injection well that was drilled first on the pad. Between 50% and 80% of the sumped volume can be disposed of in this manner.

The practice of downhole disposal of sump fluids to reduce the amount remaining in the sump, has been carried out with little difficulty at several exploration wells in the area. In these instances, the liquids were injected into the formation at the bottom of the surface casing. Injection would require a 150 hp pump to deliver 5,000 to 10,000 B/D at pressures under 1,000 psi.

Less than a drum of corrosion inhibitor would be added to the tubing displacement fluid when injection operations cease at the end of each summer to protect the downhole equipment and the well would fall idle.

When no longer capable of receiving further waste drilling fluids, the injection zone can be abandoned and a higher interval would be completed for water disposal.

All effort would be made to eliminate severely toxic materials from the drilling program, in keeping with the "Interim Guidelines for the Disposal of Waste Fluids from Petroleum Exploratory Drilling in the Canadian North".

During normal drilling operations, the number of personnel on-site is expected to be about 35 people. During critical periods such as cementing, running casing, logging, or moving, there could be as many as 55 personnel on-site. These people would be rotated every two weeks or so by aircraft from Inuvik.

2.3.5.1.5 Contingency Plans

A detailed contingency plan will be submitted with the drilling program application. It will include, for each well, plans for spill containment and the drilling of a relief well if required, similar to the contingency plans for exploration wells.

2.3.5.1.6 Completion Operations

A separate rig (similar to the drilling rig but smaller) would probably be used for most of the completion operations. This phase of the activities would involve installing subsurface production equipment, perforating and stimulating, and initial production testing. The first few wells, however, are expected to be completed and tested with the original drilling rig, since the completion rig would not be available initially.

The operations of the completion rig would be similar to that of the drilling rig with manpower requirements of about 25 men, assuming 24-hour operation. Some of this work may be carried out on 12-hour daily tours, however. The completion activities could be conducted on the drilling pad along with the drilling operations, and most support facilities such as storage and accommodations would be common for both activities. It would take up to 15 days to complete an average well. The first few wells would take much longer.

As with the rig, other equipment required for completions would be similar to that for the drilling operations. The total quantities of materials required would be somewhat less. Two major items for a 20-well program would be some 200,000 feet or 2,000 tons of producting tubing and about 10,000 bbls of diesel fuel for the tubing-casing annulus. Significant differences between drilling and completions work include the possible use of acids such as HCl-HF with corrosion inhibitor and surfactant additives, the use of substantial quantities of perforating charges, and the flaring of some hydrocarbons.

A completion would involve up to 1,000 bbls of water and 500 to 800 barrels of gelled diesel for circulating and displacing. About 1,000 bbls of drilling fluid would be circulated out into the sump. The acid, used to remove wellbore damage caused by drilling fluids, is not expected to be required in large volumes, i.e. over 250 bbls per well. Acid would either be transported to the site in special containers or formulated on-site from stable and non-hazardous components. The same precautions against spills would be taken with the acids as with other stored liquids.

Effluent from initial well testing and cleanup operations could include spent acid and formation water, liquid hydrocarbons, and gaseous hydrocarbons. Test facilities would be used to separate liquids and gas. The spent acid-water would be relatively inert and could be disposed of in the drilling sump. The relatively fresh formation water, which would range in volume up to a few hundred barrels, would also be disposed of in the sump. A rough estimate of hydrocarbon volumes expected per well during an initial production test would be 200 MMSCF gas (mostly methane) and 3,000 barrels of condensate for the first few wells drilled and completed. Sufficient information and adequate well clean-up might be obtained from smaller produced volumes in subsequent wells.

Although completions and workovers normally take place in a production well, the blowout hazard would be expected to be somewhat lower than for a drilling well. In the latter, the hole is not fully cased and downhole conditions are not always well known. At Taglu, the contingency plan for completions and workovers would be similar to that for drilling.

2.3.5.2 Well Cluster Locations

As indicated in Figure 1, the Taglu production wells would be directionally drilled from two multiwell clusters. The clusters and associated production and maintenance equipment would be contained on rectangular pads constructed of granular material.

The cluster concept, although its scale may seem unduly large, has distinct advantages over current development-drilling practices common in the south. Locating several directionally drilled wells on one cluster minimizes the surface acreage of land required to develop the reservoir, thus reducing environmental disturbance. The locations and size of the clusters are determined by the bottom-hole locations of the wells to be drilled from the pads, and the space needed by surface facilities. Naturally, the extent to which the cluster concept can be utilized depends on the depth of the reservoir and the amount of deviation that directional drilling can achieve. To develop the Taglu reservoirs would require two clusters spaced a few hundred feet apart. Tentative locations for them are indicated in Figure 1. The wells would be drilled from the permafrost and failure of the sump. Since failure would be unacceptable from the standpoint of both the environment and the operations, the Applicant is proposing an above-ground containment system for each well cluster.

As indicated in Figure 6, the above-ground containment sump would consist of a dyked area beside the drilling pad. The dykes surrounding the sump would be impervious, to contain drilling fluids and to keep out flood waters. Rigid insulation would probably be placed within the dyke, to keep the embankment frozen and thus maintain its structural stability.

Once development drilling was complete and the fluids had been allowed to freeze within the sump, additional granular materials and insulation might be placed over the sump surface, to ensure future containment and provide a future work pad.

The definitive or preliminary design work for the cluster pads and sumps is still under way. Additional design considerations and construction methods for these facilities are discussed in greater detail in Section 2.3.8.1.2.

2.3.5.3 Well Cluster Facilities

Once development drilling was complete, wellheads with master valves would be installed. Each wellhead would also have a surface safety valve. In the event of abnormal temperature or pressure conditions, this safety valve, which could be operated either manually or automatically, would close to contain the gas below ground.

A temperature-monitored refrigeration system would be installed to ensure that the upper layers of permafrost around the well remained stable during production or injection. Whether this system would consist of individual small units at each wellhead or a centralized facility has yet to be determined. It would, however, be monitored and controlled from the plant central control building.

Methanol injection capability would be provided at each well to help produce hydrate-free gas, especially during start-up or shut-down. Here again, the design of the methanol injection system has not yet reached a point where individual or central pumping units can be specified. Methanol, however, would be stored in bulk steel tanks within the process plant storage area. The injection system would be monitored and controlled from the plant's central control building.

In addition to the above, provision would be made at each well for the injection of corrosion inhibitors. The amounts required to protect the tubing and flowline would be relatively small.
Local electrically driven pumps at each injection point would most likely be used to inject the inhibitor into the flowlines. The bulk inhibitor would be stored at a location within the central containment dyke.

Present plans call for the above facilities, whose functions centre around the wellhead, to be housed in a small building located at the well.

The above-described facilities would be all that occupy the well cluster during the operation phase of the project. They would operate unattended, and be continuously monitored from the control centre. Clusters would be equipped with permanent lighting, to allow safe inspection and maintenance of this equipment during the winter months.

2.3.5.4 Well Cluster Operations

This section discusses the operation of the two well clusters after the initial drilling work was complete and the wellheads and production facilities installed and operable. The operations would include routine inspection and maintenance and the occasional nonroutine well workover, which will see a build-up of equipment and people for a period of weeks.

Production operation policy would emphasize continuous production of the minimum number of wells at rates consistent with good reservoir engineering practices.

To maintain the design productive capacity, a certain percentage of the wells on the cluster would have to be held in reserve, ready to be started up and brought on stream.

Initially and for a number of years, the gas production wells would flow with enough surplus pressure for each to maintain its design rate.

Normally, the well clusters would be operated as unattended units. Simple systems would be used and the intention is to monitor key items on each cluster automatically. All equipment would be readily accessible from the process plant via a road. Operation personnel would visit the wellheads, etc., for routine inspections, which might be daily during the initial operation period. Once the initial operation had established that equipment was performing properly, these visits might be made less frequently.

The inspection visits would be facilitated by the proximity of the cluster to the plant. Routine inspections and maintenance visits would probably be carried out by two men, in continuous radio communication with the control room. The inspections would be similar to those at well sites in southern Canada, and might include examinations of rotating equipment, spot-checking for early signs of vibration and small instrument leaks, and, if necessary, the routine cycling of safety valves, etc.

With all pads and roadways elevated above the tundra surface, drifting snow is not expected to prevent these routine visits. In any case, snow-removal equipment would be available and, with the site facilities so compact, tackling an occasional drifted area would not be difficult.

On occasions, when the production or injection wells required maintenance, it would be necessary to bring a workover rig in to the cluster. This nonroutine operation would involve several planned activities that would require a minimal build-up of personnel and equipment at the cluster.

In general, there would be little rig activity for at least five years after the initial drilling and completion program. After that, some remedial well work and infill drilling would probably be needed. The remedial workovers would resemble the well completion operations in manpower, material requirements and activities. Workover frequency is estimated at one to two workovers per year, with each workover lasting 15 to 45 days. Additional infill drilling would be carried out as required and would be completed by about the tenth year of production.

Workovers would cover such activities as mechanical repairs to the well, or modifying production schemes downhole. As with infill drilling, this work would tend to take place during and immediately after the summer barging season. Since the sump areas would have been restored, well fluids would be collected in tanks. Up to 2,000 bbls of tank capacity could be required at the wellsite with a permanent 2,000-3,000 bbl workover fluids tank located elsewhere. The tankage at the wellsite would be removed when the workover was completed.

Infill drilling would require additional drilling pad area which would be provided during a previous winter. Whether such additional pad area would be an extension of the existing drilling pads or at a nearby location would be determined by drilling and production characteristics of the reservoir. Every effort would be made to avoid or minimize activities outside the working area established in the initial construction.

At some time in the life of the reservoir, individual wells become unproductive and would be abandoned unless they are required as observation wells. Abandonment would consist of cementing off all communication between the wellbore and the reservoir, pulling out recoverable equipment, placing cement at other intervals including the tops of all remaining pipe, removing the wellhead, and cutting off all casing strings below ground level. The rig activity involved is similar to that of a workover. Frequency would be one or two wells per year. After the plant was shut down, all the remaining wells would be abandoned as quickly as practical, to allow final site clean-up and restoration. Each well abandonment would take 15 to 20 days.

2.3.6 Offsite Piping Systems

This section discusses the outside piping systems, such as the well production and injection lines.

In all cases the pipes would be run above grade, supported on piles frozen in the permafrost. A minimum elevation above grade would be maintained, to eliminate the possibility of any adverse effect on the pipelines from seasonal flooding, or on the tundra because of the operating conditions of the pipelines.

All lines would be designed and insulated to function over a full range of temperatures, from a minimum ambient temperature to a maximum process temperature. Piping design would conform to the criteria laid down in the Canadian Standards Association Standard Z184, "Gas Transmission and Distribution Piping System".

Since portions lie outside the dyke areas, these lines might present an environmental hazard because of possible rupture. However, enough safeguards, such as leak-detection control and automatically closing block valves, would be designed into these pipelines and enough contingency equipment would be available to deal with any hydrocarbon leakage.

The most important offsite pipelines would be the production flowlines linking the wells to the processing plant. Although the proposed general gathering-system route is shown on Figure 1, detailed field surveys will be needed to determine the specific line route and prepare alignment sheets.

Other pipelines between the plant and the wells would carry water, liquid hydrocarbons for injection, refrigerant, methanol and possibly corrosion inhibitor.

Pipeline construction, including pile support, would be carried out mainly from gravelled areas, but where additional working space was needed, some activities would be undertaken in winter from the adjacent frozen tundra.

As much as possible of the piping systems would be prefabricated in the south, and pre-insulated lengths of pipe would be delivered to the site.

Hydrostatic-pressure test fluids would be re-used as much as possible before being eventually injected into a disposal well.

The compactness of the work areas would allow construction workers to operate from one camp, and activities would be scheduled to lessen the fluctuations in the workforce throughout the year.

2.3.7 Process Plant

2.3.7.1 General

The gas produced at Taglu would have to be processed to meet specifications and conditions for long-distance pipeline transportation.

The process would involve removal of excess water and liquid hydrocarbons from the gas, and compressing and cooling to produce sales gas to the following specifications:

Delivery pressure	1,680 psig
Delivery temperature	+25°F
Hydrocarbon dewpoint	+25°F at 850 psig
	-10°F at 1,100 psig
Water dewpoint	-10°F at 1,680 psig

The process scheme proposed includes inlet separation and measurement of gas and liquid hydrocarbons. Gas dehydration by absorption on activated alumina reduces the water content enough to meet the water dewpoint specification. Chilling the gas to -20°F at 1,080 psia removes liquid hydrocarbon to meet the hydrocarbon dew point specifications. The gas is then compressed to a pressure of 1,680 psig and chilled by air exchange and propane refrigeration to meet the delivery requirements.

2.3.7.2 Feed-Gas Analysis

Table 1 shows the feed-gas analysis for the inlet gas stream to the plant.

2.3.7.3 Material Balance

An over-all material balance for the Taglu plant is shown in Table 2 attached to this section. This material balance is based on the design feed-gas analysis shown in Table 1, which is drawn up for normal operating conditions. As the plant processes have not been fully optimized, this material balance could be changed in the future.

The major by-products developed in the plant would be the hydrocarbon liquids removed from the gas to enable it to reach the dew point specifications of the pipeline. Some of this liquid would be used in the plant fuel system; the rest would be injected to a suitable underground formation until an oil pipe was available in the area.

Another by-product would be the produced water, which would also be injected to a suitable underground formation.

Hydrocarbon liquids and water separated in the plant would be reinjected to wells specially completed at the cluster for that purpose.

The Applicant is investigating the feasibility of using one of the wells already drilled on the plant site as an injection well for the liquid hydrocarbons.

Fuel systems are being designed for three types of fuel:

(a) During construction, Number 2 Diesel Oil would be used for building heat, gas-turbine start-up, and electrical power generation.

(b) After plant start-up, stabilized condensate produced in the process would be used as fuel for the gas turbines, the fired heaters that the process requires and building heat.

(c) Gas would be used after start-up for electrical power generation and camp heating.

Figures 7 and 8 provide simple charts for the main processes of the plant.

2.3.7.4 Process Equipment

Major processing equipment would include heat exchangers, pumps, vessels, gas compressors for gas and propane, and gas turbine drivers for the compressors and electrical power generators. Other systems would include a propane refrigeration system, a re-generation system for the dehydrators, and a closed hot-oil circulation system for the process heat requirements. All major equipment would be located inside buildings.

Electric-motor-driven reciprocating compressors would supply air for the utilities and plant process instrumentation.

2.3.7.5 Plant Layout

The plant process layout would stress safety and security of its units. Its control room would be away from the process area.

Equipment would be fabricated in the south, installed in modules shipped to the site, and linked together on-site to form the total plant. Modules would be on rigid bases and enclosed in buildings.

An allowance for some expansion would be built into the plant layout, and ground space would be allowed for maintenance access to the units.

The storage tanks required would be set at a safe distance from the process, along with other support facilities such as maintenance shops, warehouses, garage, and the operators' life-supporting units.

2.3.7.6 Flare

The Applicant would design the plant to minimize liquid or gaseous releases to flare. The plant controls and an emergency shut-down system would be designed to reduce and/or shut off the plant feed before releasing major volumes to the flare system.

Liquid hydrocarbons would not be flared. In an emergency, the plant liquids would be released to the main flare system, where the drop in pressure would vaporize most of them. Any liquids that did not vaporize during this operation would be collected in the flare knock-out drum and pumped to an emergency storage tank for later disposal.

The size of the flare system and the location and type of stack structure have not been determined, but would be based on consideration for the time required to cut back and/or shut in plant feed in an emergency. The flare stack would be designed with special consideration for minimizing both the effects of radiant heat on permafrost and the height of the flare.

In extreme emergencies, when the plant could not be depressured over a reasonable period, short-term venting of gaseous hydrocarbons might be necessary. Any such occurrence would be extremely rare, and would be reported to the appropriate authorities. The environmental impact associated with this practice is considered to be less than would be posed by the exceedingly tall, large-diameter stack that would be needed to burn the gas at high rates.

2.3.7.7 Utilities

The plant would be completely self-contained with regard to utilities. Process needs would be satisfied by the following major utilities:

2.3.7.7.1 Electrical Power Generation

The electrical power requirements would be supplied by gas-turbine generators located near the process area, which, during normal periods, would supply offsite needs also. Five generators with a capacity of 2,500 kilowatts each are being considered. The total expected load for the complex would be approximately 10 megawatts. Turbine-generator units would ultimately be sized to allow operation of the plant and all life-support systems with one unit down for maintenance.

In addition, approximately 2,500 kilowatts of gas-turbine generating capacity, located next to the living quarters, would be provided for emergency life-support as well as stand-by power for process equipment. During construction, electrical power for the living quarters, construction power and area lighting would be provided by this additional capacity, which initially would be diesel-fired, and converted to gas after the plant began operation.

Power to be distributed to the remote areas, such as the well clusters, dock, and the airstrip would tentatively be routed in steel galvanized conduits buried in the gravel fill of the roads or pads, with a concrete encasement to ensure their protection. Where power conduits had to cross an unfilled area, the conduits would be thermally insulated to avoid disturbing the permafrost.

In all outside areas of the project where it was necessary for operators to carry out their work, floodlights or pole-mounted lights would be installed.

The power generators would be built into complete modular units and shipped to the site by barge. They would be placed on pile foundations, and only the final hook-up would be made in the field.

2.3.7.7.2 Tankage

Tankage for the plant for storing water, hydrocarbon, and other products would be installed as early as possible. In this way their capacity would be used for the construction phase when a large amount of diesel fuel would be needed.

Below is a list of the permanent tankage and the stored commodities as they have been identified at this time.

Commodity	Capacity	Type
Potable Water	7,000 bbl	Cone Roof
Diesel Fuel	16,000 bbl	Cone Roof
Hot Glycol/Water - Process	1,000 bbl	Cone Roof
Cold Glycol/Water - Process	100 bbl	Cone Roof
Methanol	3,000 bbl	Cone Roof
Lube Oil	250 bbl	Cone Roof
Glycol/Water - Camp Heating	500 bbl	Cone Roof
Liquid Condensate	4,500 bbl	Floating Roof
Gasoline	4,000 bbl	Cone Roof
Heat Transfer Fluid	500 bbl	Cone Roof
Glycol	600 bbl	Cone Roof
Corrosion Inhibitor	1,000 bbl	Cone Roof

Construction of the tank foundations and their containment dykes is described in Section 2.3.8.1.2. A number of the tanks required would be completely fabricated and shipped to the site by barge. The larger ones would be built on site, probably in summer early in the project.

When the plant was operating, all but the water and condensate storage tanks would be re-stocked once a year from barged supplies brought to the plant docksite. Present sizing specifications call for each storage tank to have the capacity to fill normal operating requirements for 16 months.

All liquids would be distributed by permanent piping. A loading-pump arrangement would also be installed for day-to-day fuelling of vehicles.

Piping would be installed between plant and dock to handle the large quantities of liquids brought to the site during the summer re-supply trip. This piping would be manifolded, to ensure that the liquids were kept in a closed system for as long as possible.

2.3.7.7.3 Fire Water

The plant housing facilities would be protected with a fire-water system of looped piping. Water under pressure would circulate continually through the system and, in the event of a fire, up to 1,000 gallons per minute would be available. The system would also provide utility water for the process buildings.

2.3.7.8 Industrial Water Use

Most of the process cooling requirements could be handled conveniently by air coolers. Where the cooler load was especially heavy, as in sales-gas cooling and refrigeration, the extra cooling capacity would be provided by exchangers using water from the Mackenzie channels. The water cooler would be a once-through system with the water being returned directly to the river at a point downstream of its intake. The Applicant is investigating the system for summer use and estimates it would require at most 40,000 gallons per minute of river water. This cooling water needs no treatment, and would be returned to the river channels in the same chemical condition as when it was taken from it. Design criteria for this system have specified a 10°F rise in water temperature at the river location. If a leak should occur in the exchangers, it would be detected by hydrocarbon monitoring and the system shut down.

2.3.8 Support Facilities

Operation of the plant will require the following key support facilities:

Foundations of the type required in arctic areas
Roads
Airstrip
Dock
Tank Storage
Buildings (such as permanent housing, maintenance, etc.)
Utilidors
Water and Waste-Water Treatment System
Solid-Waste Treatment System

These facilities are discussed in the sections immediately following.

2.3.8.1 Foundations

Foundations associated with the plant would be of two types:

1) pile
2) gravel pad

2.3.8.1.1 Pile Foundations

Most structures (buildings, utilidors, pipe supports, etc.) would be founded on piles. Buildings and utilidors would usually be elevated above the ground surface to prevent degradation of the underlying permafrost. Depending on the design requirements, piles would be either wood or steel. Wood piles (an estimated 1,500) would be used under lightly loaded structures where high bending moments and thrust forces are not encountered. Steel piles (an estimated 2,000) would be used under structures where the loads are heavier and high bending moments or thrust forces were encountered. Steel piles would probably be of standard-size pipe, between 12 and 24 inches in diameter.

The piles would have to be embedded deeply enough to satisfy two requirements:

1) that they provided enough anchorage to resist the uplift due to the seasonal freeze-thaw cycle.

2) that they were far enough down in the permafrost to develop an adfreeze bond strength that would prevent any appreciable settlement under service loads. For heated structures, insulating pile caps might be needed to prevent heat transmission down the pile to the permafrost.

Piles would be placed in pre-drilled holes a few inches larger than pile diameter, and backfilled with either a water-sand slurry or insulating material.

Detailed design criteria for piling are being investigated.

2.3.8.1.2 Gravel Pad Foundations

Gravel pad foundations would be required for the following:

Plant area
Dock staging
Drilling pads
Tank storage area
Airstrip parking
Airstrip
Roads

Preliminary locations and alignments for the above are indicated in Figure 1. As the pads would be underlain by permafrost and subject to annual flooding, their design will be based on the following criteria:

- Minimizing fill thickness. For areas such as the plant and drilling pads, insulation might be used within the pads, and impervious dykes along their perimeters. The feasibility of using sand cores to reduce the amounts of more rare or costly materials needed is being investigated.

- Avoiding (where possible) highly ice-rich soils.

- Ensuring the integrity of the pads under maximum flood conditions.

- Minimizing disturbance to the thermal regime. Under tanks that were not heated, insulation might provide sufficient protection. Under heated tanks, or warm floors on grade, natural cooling with forced ambient air through corrugated ducts in the pad might be used.

- Blending the pad as well as possible with the natural characteristics of the area.

- Minimizing the ponding of waters along the edges of embankments.

- Minimizing structural maintenance.

- Controlling heaving and subsidence from frost action.

- Controlling subsidence due to thawing of poorly drained permafrost.

- Complying with the objectives and requirements of all regulatory agencies having jurisdiction in the project area.

In most instances, the above criteria would be met by using granular fill materials with or without insulation to keep the foundation frozen below the pad.

Because of annual flooding, consideration would be given to elevating the pads and providing drainage through them. Culverts would be used to prevent water from ponding against the pads. Insulation would be placed below culverts to prevent degradation of the permafrost.

The construction on the tundra of pads suitable for airstrips, roads, and service pads would employ special procedures developed for arctic areas. Construction material would consist of granular fill and insulation. Sources of granular material and methods of transporting it are discussed later in this section. Fill material may be placed at any time of year. In winter, when trucks can operate from snow roads on the frozen tundra, conventional methods would be used. In summer, end-dumping methods would be used to protect the tundra. The previously dried and classified material would be spread on the fills in a series of shallow lifts. Initial conditioning would be with compactor dozers. Culverts would not be installed in winter; embankments built in winter would be ditched at watercourses before spring runoff and the culverts would be installed during the summer.

Insulation would be placed manually on a level layer of fine fill material. Another layer of fine fill material would be pushed over the insulation by a light dozer before heavy vehicles placed the top lift of the grade.

The first summer after construction, embankments might need further conditioning with graders and vibratory compactors. Material would be stockpiled near the site to provide the fill to compensate for embankment settlement.

Maintenance of embankments would start immediately after construction. The chief problem would be undulations caused by traffic and possible minor subsidence. These undulations would be removed by grading and, if necessary, addition of more fill. Minor snow clearing might be necessary in winter.

Drainage structures would have to be kept open, especially during spring breakup.

2.3.8.1.3 Granular Materials

Preliminary conceptual designs require an estimated one and a half million cubic yards of granular material for construction of the gas plant and support facilities.

The primary source of select material known at present is the esker and kame deposits to the south of Ya Ya Lake, the location of which is shown in the 1:250,000 map attached. These deposits are accessible by barge in summer, and by truck along the frozen river channels in winter.

The Ya Ya Lake deposits, which are now being developed, can provide the type of material necessary for construction quite adequately. The Applicant made a detailed survey of these sources during the winter of 1974/1975, under the auspices of the Arctic Petroleum Operators' Association. The results, which will soon be available, will provide detailed information on the quality and quantity of material in the deposits. A detailed plan will then be evolved for developing the deposits.

Environmental and climatic considerations dictate that the

Applicant would work the source in summer. The gravel would be bladed off to thaw depth and pushed into windrows in the pits. When the water had drained from the windrows, the gravel would be moved to a crusher screener if necessary, and the classified materials stockpiled. Trucking would begin as soon as winter haul roads were prepared and continue through the winter. The haul roads from the gravel pits to the plant site would be routed on channel ice, as shown on the map filed with this application.

Because both the gravel source and the plant are near river channels, some granular material might be barged in summer to extend the construction season.

Another source of granular material, although not an alternative to the Ya Ya Lake eskers, is a sand deposit at Big Horn Point approximately 3.5 miles northeast of the plant site. The river here is flanked on the east for a considerable distance by exposures of frozen ground moraine, which are constantly being eroded, sorted and deposited downstream.

The Applicant's survey of this source during the winter of 1974/1975 has indicated a potential 1.1 million cubic yards of very fine sand located in the river channel adjacent to Big Horn Point. Though the material would be unsuitable as a wearing surface, approximately 400 thousand cubic yards might be used as a core within the pads, which would mean that much less material would be needed from the Ya Ya Lake eskers. Environmental, technical, and construction studies are now under way to determine whether the Big Horn Point sand is a usable source. If it is, plans will be made for developing the deposit. Meanwhile, several methods for transporting and placing the sand are being considered. One would involve hydraulically dredging the sand from the river bottom and hydraulically pumping and placing it into gravel dykes on the site. Another would be to excavate the sand from the bluff by the river edge, barge it to the site, and place it by conventional methods. A third method would combine these two: dredge sand from the river bottom, allow it to drain on the bank, then barge it to the site and place it conventionally. The method finally decided on would depend on the findings of the current studies, and would be very important to the ongoing engineering program.

2.3.8.1.4 Timber Piling

Construction of the plant would require approximately 1,500 timber piles. Possible sources for this piling might be in the Fort McPherson area or elsewhere in the Northwest Territories. Piling dimension requirements would govern the choice of source.

2.3.8.2 Roads

Road transportation throughout the general Mackenzie Delta area would rely on the traditional river-channel network of winter roads.

Construction and operation of the Applicant's gas plant, however, would require a network of access roads connecting the plant facilities to the dock, airstrip, well clusters and flare.

Two classes of roadway are envisioned. The access road to the dock would carry the heaviest loads and would, therefore, be wider and built with higher-quality materials. This road would have a traffic surface approximately 35 feet wide, while those to the well clusters, flare, and airstrip would be about 20-25 feet wide. Maximum grades and alignment deflections would be dictated by the class of vehicle using the road.

Road routes would be planned to interrupt normal drainage as little as possible and at the same time, keep the amount of fill material required to a minimum. Preliminary roadway alignments are shown in Figure 1. Roads would be designed to provide all-weather service with special consideration given to:

- Controlling air and water pollution (dust, erosion, etc.)

- Facilitating safe and efficient vehicle operation.

Roads would probably be used by three classes of vehicle:

- Equipment to be used in the construction of embankments, pads and foundations.

- Oilfield equipment used during production drilling and plant operation.

- Module transporters to carry the heavy plant modules from the dock to the plant location.

It is anticipated that traffic would be heaviest during the construction phase of the project; after plant start-up, it is expected it would be light.

2.3.8.3 Airstrip

The use of aircraft is essential in the construction, routine operation and subsequent maintenance of production facilities. With no year-round highway access in the Mackenzie Delta, air transport is the only means of providing regular rapid service to the site during nonwinter months. Aircraft would be used to transport men and perishable goods, and for unscheduled equipment deliveries to the site.

An airfield would be built at the site, next to the central processing plant. The field could be classified as an unlicensed, limited access, privately owned facility.

The airstrip would be designed for use by STOL aircraft. The landing surface would be about 2,500 feet long and 80 feet wide. Critical airfield dimensions and runway lighting would conform to the appropriate Canadian Ministry of Transport Codes and Regulations.

The location and orientation of the airstrip would be based on the following criteria:

- Least likelihood of crosswinds

- Least interruption of normal drainage patterns

- Provision for future expansion to accommodate newer aircraft and/or future plant expansions

The tentative landing area is indicated on Figure 1.

The airstrip would have offstrip parking, to keep the landing surface clear as safety regulations require. This parking area would accommodate a number of aircraft at once, to handle the initial heavy movement of manpower. A single taxi-way would connect the airstrip to the offstrip parking.

Beside the parking area would be a shelter (approximately 30 feet x 70 feet) to provide waiting space for passengers, temporary in-transit storage space for light-weight freight, and permanent storage for a certain amount of emergency life-support and safety supplies. The building would have telephone and mobile radio communication, as well as air-to-ground radio facilities.

The Applicant would not have permanent aircraft-servicing facilities (hanger, fueling) at the site, but would use those at other airstrips already in the Delta.

The airfield and offstrip parking would be connected to the main process area by road, to facilitate movement of freight and supplies.

The airstrip, taxi-way, parking area, and access road would be elevated to permit all-weather use. Design and construction of these facilities is discussed in further detail in Section 2.3.8.1.2. It is proposed that construction of the airfield would be scheduled early, so that maximum use could be made of it during heavy and concentrated activity.

At this time, it is difficult to provide clear estimates of airfield use because construction and contracting methods have not been firmly established. Basic manpower movement in and out of the site during peak construction would require multiple flights daily. Destinations and departures of these flights would vary, but Inuvik Airport would be the most common. Not many long-distance flights would be likely to terminate or originate at the Taglu plant strip.

Once the plant was satisfactorily in service, aircraft use would decrease. Rotation of operating personnel and re-supply of perishable goods would require several flights weekly.

2.3.8.4 Dock

Water transport is important to the construction and operation phases. To handle effectively the many types of loads, especially the very heavy plant equipment to be installed in the plant, a permanent dock would be built on the shore of the river channel over which virtually all the plant materials would be moved. After the plant complex was completed, this same dock would be used to resupply the ongoing operations.

At present, both river and ocean-going barges are being considered for transporting equipment and modules to the site. The size of dock would depend on the type of barge used as well as the schedule and co-ordination of delivery during the available barging period. Whether the barges would be side-loaded or end-loaded has not yet been determined; a combination of both is likely.

The exact location and design of the dock depends on further investigation of the soil conditions along the river edge. The river channels at Taglu separate at the southern edge of the proposed site and, depending on the site chosen, may provide a distinct advantage for barge manoeuvering. This tentative dock site is indicated in Figure 1.

Present indications are that the dock design might incorporate an enclosing retaining wall built of steel sheet piling with granular backfill. The elevation of this retaining wall would be based on the unloading requirements of the anticipated barge and hydrologic information currently being collected. The dock would be streamlined to minimize or prevent ice jamming.

It is proposed to build the dock as early as possible, to have maximum use of it during periods of heavy concentrated activity.

Construction methods would be as follows: Sheet piling would be driven into the channel bottom. The dock facewall would be tied back to anchor piling firmly embedded in the permafrost. Gravel fill would be placed behind the piling, to raise the channel beach up to the level of the dock apron.. If necessary, protective insulation would be placed where the installation encounters permafrost that might be affected by the dock configuration. The river channel in front of the dock might require some dredging to facilitate unloading of barges.

Behind the dock a staging area would be built, for storing unloaded materials for the construction phases. The surface would be compacted gravel. The size is estimated at 500 feet x 350 feet, but final size would be determined after the detailed scheduling had begun. A small, temporary personnel shelter (approximately 20 feet x 15 feet) might be provided at this location.

Dock facilities would also include a fuel-unloading installation, consisting of a docksite manifold arrangement with either onboard or shoreside pumps. Spill prevention would be a special consideration in the design of this facility.

2.3.8.5 Tank Storage

Hydrocarbons and liquid chemicals necessary for plant operation would be kept in a tank storage area located next to the process plant and away from natural water bodies. Section 2.3.7.7.3 identifies the types and volumes of liquids that will be stored.

The tank farm would be enclosed by an impervious dyke, to prevent flood waters from getting in and spilled liquids from getting out.

This dyke would be large enough to contain the entire capacity of all tanks within the tank farm (Canada Oil and Gas Drilling and Production Regulations, Section 34[2]), as well as the maximum trapped precipitation that might be impounded. Transfer lines from the tank farm to the process plant would also be within a dyked area, so that in case of a line rupture, the spilled contents could be retained for clean-up.

Unpolluted surface water impounded within the dyke would be periodically pumped out.

The foundation design of the tank farm pad and dykes would be the same as that for embankments. Foundations for heated tanks might contain special corrugated ducts within the embankment, through which cold winter air would be circulated to maintain the permafrost table.

This facility would be built early in the construction phase, to provide temporary storage for construction fuels.

2.3.8.6 <u>Buildings</u>

All process equipment and service facilities would be housed, both to protect them and to facilitate servicing during bad weather.

The units to be housed are:

Block Valve - Liquid Injection
Process
Process Utilities
Operation Control Centre
Personnel Housing
Domestic Support Systems for Personnel Housing
Heating and Ventilation for Personnel Housing
Waste and Water Treatment Systems
Main Generators
Miscellaneous Pumps
Warehouse, Maintenance, Garage
Airfield Waiting Room

A number of the above functions would most likely be combined in one building. At present, 9 to 12 buildings are envisioned, the largest of which would be the process building whose preliminary dimensions are 300 feet long by 180 feet wide by 40 feet high.

Because of the remoteness of the area, all operating and maintenance personnel would be accommodated in a permanent housing complex next to the plant. This facility would provide the operating staff not only with housing, but also with recreation facilities, to ensure a harmonious environment despite conflicting work schedules and constricted living conditions.

Buildings would be of rigid-frame construction. Roofs, walls and floors would be insulated. Floors would be steel or reinforced concrete, elevated on either steel or wood piles to protect the underlying permafrost. They would be high enough above the pads to allow adequate air circulation and to prevent snow from accumulating under the buildings.

Generally, the larger structures would be built as modules, complete with equipment and piping, and transported to the site by barge. Modules would be moved from the dock to their final locations by crawler transporters. Smaller light-weight buildings, such as the warehouse, maintenance, garage, and airfield waiting room would most likely be prefabricated in the south and erected on site. The erection of buildings would be phased over the construction period. It is proposed that the warehouse, maintenance shop and garage would be built as early as possible, so that they could be used in the construction of the over-all plant. Present plans are to build the permanent housing complex before arrival of the plant modules, so that operations personnel could participate in the final construction phases of the plant process.

2.3.8.7 Utilidors

A system of utilidors would connect the buildings throughout the main plant and housing complex. They would serve as pedestrian traffic arteries between the operating areas, as well as racks for pipe, conduit, etc., between buildings. It is intended that an operator would be able to walk to and from work without having to go outside.

The utilidors would be carefully laid out to minimize their total length, provide the most direct route between buildings, and permit free vehicle access to any area within the plant.

Utilidor structures would probably be rigid-frame, with insulation in roof, walls and floor. They would probably be supported on steel piles, and raised above the ground surface to minimize snow-drifting. There would be clear glass windows on both sides, so that operators could see outside, with some that would open to provide an escape route.

The utilidors would also carry at least two levels of pipe and electrical conduits.

A smaller utilidor (estimated at 4 feet by 4 feet) from the plant area to the dock, would carry electrical conduit and piping, such as fuel-water and waste-water lines. This utilidor would probably follow the main road, be supported by wood piles, and be raised above the ground surface.

2.3.8.8 Water Supply

Operation and construction of the plant would require a continuous supply of water for life support, fire water, and utility water.

Maximum raw water requirements for construction activities are expected to be approximately 36,000 Imp gallons per day. During plant operation, this demand would decrease to about 9,000 Imp gallons per day. Alternative summer sales gas cooling, with once-through cooling water, might require up to 40,000 Imp gallons per minute of additional fresh-water demand. This alternative use of water is discussed in greater detail in Section 2.3.7.8. Fire water would be supplied from a 7,000 bbl storage tank.

Two potential fresh-water sources are available at the Taglu site; the Kuluarpak Channel of the Mackenzie River immediately south of the plant, and Big Lake, the shore of which is approximately half a mile to the north.

The remote location of the pumping station and extensive pipeline utilidor that would be required at Big Lake make this source undesirable from the standpoint of maintenance and capital investment. Periodic salt-water intrusion from arctic storms is also a disadvantage to the use of the lake water. In addition, the potential thermal impact of summer cooling water could cause substantial changes in the lake's ecology.

For these reasons, the Kuluarpak Channel has been selected as the proposed water source for the plant.

2.3.8.9 Water Treatment

A water-intake structure would be integrated with the dock. Pumps and valve facilities would be housed in a structure above grade. The raw-water line would be routed within the utilidor connecting the dock to the plant.

Except for the process cooling water, all incoming water would be coagulated and precipitated by means of aluminum sulfate and organic polyelectrolyte. Silt thus removed would be returned to the river, along with the consumed treatment chemicals, in a waste stream comprising 3-5% of the raw-water flow.

During certain times of year, ion-exchanger softening might be required. The softeners would be regenerated with salt approximately once a month. Waste brine returned to the river each month would contain 20 to 40 lbs of total dissolved salts. Water-treatment plant waste streams would be combined with the sewage-plant effluent before being pumped back to the river.

Also at certain times of year, treated water might have to be polished for taste, and have the odour removed by activated carbon. Spent carbon would be incinerated.

Treated water would be disinfected with sodium or calcium hypochlorite and stored in a 7,000 bbl tank for pressurized distribution. This tank would also serve for storing fire water.

2.3.8.10 Waste-Water Treatment

During construction and plant operation, domestic sewage would come primarily from the kitchen, the showers and toilets, and the laundry. Quantities are expected to reflect the treated-water supplies, and are based on an expected consumption of 70 gallons per capita per day. Strength of the waste is anticipated to be 60 mg/l BOD and 500 mg/l suspended solids.

Waste water would be conveyed by gravity sewers to local sumps built into the floors of the structures. These sumps would be pumped out automatically with grinder pumps into an overhead line to an equalization tank. Here a rotary microscreen would remove trash and solids that might otherwise clog the treating equipment. The tank would be mixed to provide waste of uniform strength and aerated to prevent septic conditions and odours.

The actual treatment process has yet to be selected; meanwhile, both physical-chemical and extended aeration biological systems are being evaluated. As the treatment plant would be in a heated building, water temperatures would be between 45° and 70°F, so that both systems should be capable of consistently removing 85% of biological oxygen demand (BOD) and suspended solids. The Applicant believes that this level of treatment, which produces an effluent containing no more than 70 mg/l BOD and 50 mg/l suspended solids, would serve to prevent any deleterious effects on the receiving waters.

The treated effluent would be disinfected with sodium or calcium hypochlorite to yield a measurable chlorine residue after 30 minutes. The final effluent would be pumped back to the river in a heated utilidor and injected through a submerged diffuser.

The minimum flow for Kuluarpak Channel is on the order of 5,000 cubic feet per second, which would result in an effluent dilution factor of 10^4. At present, the river water contains approximately 10 mg/l dissolved oxygen, 20 mg/l BOD, and 20 mg/l suspended solids, at a pH of 7.5 to 8.0. The proposed discharge would not affect any of of these values within the limits of analytical detection. Some environmental stress could be induced by toxicity from excessive residual chlorine in the mixing zone; however, this is not expected to be a problem at present levels of dissolved oxygen.

2.3.8.11 Solid-Waste Treatment

During both construction and operating phases of the project, packaging, meal preparation, reading materials, and consumable office supplies would generate approximately 6 to 9 pounds of solid wastes per capita per day. Miscellaneous construction wastes, consisting primarily of packaging, crates, and skids would add a daily amount as yet unknown. Sludge from the sewage-treatment plant would amount to approximately 1 pound per capita per day.

All wastes would be collected in plastic bags and/or cans which would be carried daily to the incinerator-feed storage area in the waste-treatment building. Construction crates and skids that can be reduced to suitable dimensions would be trucked in periodically for incineration. Larger construction wastes and scrap metal would be trucked directly to the designated landfill site at convenient intervals. Sewage-plant solids would be centrifuged to maximum concentration before being pumped from a holding tank to the incinerator.

The incinerator would be a controlled-atmosphere, ram-feed model with manual stoking. Light-hydrocarbon liquid fuel would provide auxiliary firing.

The incinerator would be charged and fired once each day, then cooled down for ash removal as necessary.

Ash and noncombustible residues would be removed from the incinerator manually every few days, and stored in metal bins to await transportation to a designated landfill site.

2.3.9 Construction

2.3.9.1 General

Construction methods and schedules have been planned to meet three main criteria:

(i) Safety of all personnel under the particularly severe weather conditions

(ii) Maximum protection of the environment

(iii) Economical use of material, labour and financial resources

For maximum efficiency and safety of the project, the construction phase would be under one management. Work carried out by the prime contractor and his subcontractors would include preparing the site, moving and placing gravel or sand, installing piles for foundations, constructing a dock, erecting large field-fabricated storage tanks, and, if necessary, some dredging. Major engineering work done elsewhere would lead to the fabrication of large and small completed modules which would be installed on site to form the plant. Installation on the Taglu site would include interfacing, testing, and commissioning the prefabricated modules, erecting buildings including warehouse, utilities, control room, and both permanent and temporary housing. It would also include installating the interconnecting piping and controls, instrumentation, etc. from the wells to the plant itself.

Training in skills and in environmental protection would be a major part of the activities early in the construction phase and would continue during the course of the work.

Specifics on how construction might be carried out will be found throughout the application in the discussion of each aspect. This section serves only to draw the whole field construction activity together.

2.3.9.2 Construction Schedule

Because of the nature of the project, which involves some unique features, certain activities must be accomplished during specific times of year.

Specifically, all major shipments of material would have to be made in summer, while many other activities, such as gravel hauling, would probably be better carried out while the ground is frozen.

Scheduling would be designed to level work loads, allow projects to be carried out in the most suitable season, ensure efficient logistic support, and provide maximum protection for both personnel and environment.

The project schedule in Figure 10 shows the key dates for construction.

Assuming plant start-up in the spring of 1980, the following important milestones are identified early in the project for field activity:

1) Stockpile gravel at Ya Ya Lake in the summer of 1976.

2) Start site construction with gravel hauling and sundry preparation activities in the winter of 1976/1977. Gravel hauling might continue by barge through the summer of 1977. This period would see the erection of construction camps and their support facilities.

3) Start assembly of permanent camp and some plant modules in the summer of 1978.

2.3.9.3 Pre-Construction Activities

These activities would be limited to surveying and soil sampling at the jobsite and remote aggregate sources, and measuring and testing of the river. In all cases, this work would require only a few personnel who would commute from existing camps in the Delta or operate from one camp at the site.

The work would be done in both summer and winter and would require very little equipment. Transportation would be by fixed-wing aircraft, helicopter, boat and ground vehicles.

2.3.9.4 Foundation Fill

Construction of gravel pads on the tundra for aircraft runways, roads, and service pads would call for special procedures unique to arctic areas. Elevated granular embankments would be laid down on the undisturbed tundra.

Construction of the airstrip and roadway embankments would involve activity at the material source pits,in transportation and at the Taglu site. During summer months the gravels, which constitute part of the permafrost zone, would be excavated as the surface layers thawed, and stockpiled nearby. Enough would be collected in this way to provide for the next year's construction needs.

Fill material for the embankments would normally be placed during the winter construction season, when trucks can traverse the Mackenzie Delta area on ice and snow roads. When feasible or necessary, summer barging might be used to extend the transportation period.

2.3.9.5 Construction Camp

As the Taglu site is remote from all existing housing facilities, a modern construction camp would be needed to house all the manpower expected to be required at the jobsite. The camp would be designed in accordance with the latest available technology to provide a safe and comfortable refuge for the entire work force and to be completely self-supporting for several days at a time. It would contain sleeping rooms, laundry service, complete dining facilities, and fully equipped recreation rooms.

Personnel working at the remote Ya Ya gravel pit would require a similar but smaller facility.

Facilities closely associated with the construction camp are:

- Life-Support Systems
- Storage Facilities

(i) Life-Support Systems

The life-support systems, designed to remain permanently in place for the plant operation, would be built early enough to support the construction phase. They would include water and sewage treatment, waste disposal, electrical generation, heat and ventilation.

As the work force for construction would be much larger than is needed for operation, each life-support system would be designed in segments.

These systems are critical to existence in the arctic. Therefore, to assure survival and minimize the risk of pollution, they would have to be operated by well-qualified personnel.

(ii) Storage Facilities

Insofar as possible, the permanent storage facilities would be erected early enough to allow utilization during the construction phase. The proposed warehouse would also be used for storage as much as possible.

In addition, shelters made from rigid, pre-built panels would be used for temporary protection from the weather. Depending on the bulk of the material to be stored, an air-supported fabric shelter might be used to advantage. All temporary shelters erected for construction materials would be removed on completion of the construction phase.

All liquids needed for construction would be stored in steel tanks located either in the tank storage area or within a separate dyked area at least 300 feet from a watercourse.

2.3.9.6 Module Concept of Plant & Permanent Camp Construction

For the most part, equipment and facilities for the plant would be prefabricated and shipped to the site in large packages called modules. These structures, possibly weighing up to 1,000 tons each, would be sized to fit the transportation units available.

Modular construction is a concept commonly applied to the engineering of offshore structures. It had not been extensively used on land until the advent of major construction in the arctic.

Constructing facilities of the type and size planned for the proposed plant entirely on the site would require a labour force of over 700 skilled craftsmen. Such a force would not be practical in the arctic, as workmen would have to be transported from the south to augment the small northern manpower pool. The logistics problems, and the expense of supporting such an operation for possibly two years, would be extreme. Doing as much of the work as practical in a southern location, where manpower is more plentiful, would produce the best results.

In spring and summer, the Delta is subject to flooding that would complicate any large on-site construction. In winter, there is no appreciable daylight, and temperatures can fall as low as -60°F. These physical and climatic conditions at the site would make construction very difficult unless the packaging concept were applied. Once the modules were placed on their piles and enclosed, most of the other work would be done indoors where heat and light are available.

The major cause for environmental concern in the arctic is man and his actions. The amount of sewage and solid waste to be disposed of, the risk of fire, the possibility of damage to the tundra, the effects on animals -- all are in direct proportion to the number of men present. The modular construction concept, on the other hand, would protect the environment from undue disturbance by reducing the number of men needed in the area.

2.3.9.7 Manpower

Most of the construction manpower demand would be for skill levels more readily available in urban areas in the provinces than in the communities around the proposed construction site.

The severe nature of the northern environment presents a strong case for keeping field construction activity and hence field manpower to a minimum, by using, wherever possible, modules of plant and camp components, which would be constructed and assembled in the south. Assuming maximum use of modules, site construction would need, at the most, about 400 highly specialized tradesmen to handle and assemble very large loads in the harsh environment.

2.3.9.8 Construction Equipment

Construction equipment required for this project would be much the same as for an equivalent project anywhere else, except that the use of modules would reduce the quantity to some extent.

To minimize the risk of fire, onsite construction equipment would be powered by either electricity, air or diesel fuel rather than gasoline. Basically, only hand-held tools and some of the smaller equipment such as pumps and welding machines would be electric. Other small items such as impact wrenches and hydrostatic-test pumps would be air-powered. Obviously, all the large equipment, such as tractors, cranes, and transporters for hauling modules, would be diesel-powered. Most of the equipment would be kept at the jobsite where it was used, but the vehicles for excavating and hauling gravel or sand ould be located wherever was the most convenient.

To preclude accidents or environmental damage from poorly operating equipment, complete repair facilities would be provided at the jobsite.

2.3.10 Transportation

A major consideration in the successful construction and operation of the proposed project is the transportation of personnel, equipment, material, goods and services. Over-all transportation requirements would encompass all methods, conventional and otherwise, of travel to and in the arctic, including road vehicles, rail services, river and ocean barges, fixed- and rotary-winged aircraft, and special crawler-transporters.

2.3.10.1 General

Logistics and the environment are major factors in any Mackenzie Delta project (Figure 9). Air transportation to Inuvik from the south operates the year-round. As there are no road networks in the Delta area, heavy reliance is placed on the many meandering channels of the Mackenzie River. From mid-June through September, most areas in the Delta are accessible by water. With the coming of freeze-up, transportation is limited to the use of hovercraft and helicopters until the channel ice is thick enough to support vehicular traffic. Heavy transportation on ice generally cannot start until mid-January, and ends with the onset of river break-up in mid-April.

Transporting substantial tonnages of equipment, materials and supplies originating principally from the provinces would involve the following modes and types:

- Shallow-draft barges from Hay River and Fort Simpson. Deep-draft barges originating from west-coast points. Overland wheeled vehicles within the immediate area of Richards Island and local supply points in the Northwest Territories. moving over winter roads and the frozen Mackenzie River.

- Tracked vehicles, to transport large and/or heavy module structures for short distances from the plant dock/ staging area to permanent foundations in the plant area.

- Fixed-wing aircraft, to service the plant and production area. The 2,500-foot airstrip to be constructed at Taglu would handle small to medium-size fixed-wing aircraft.

- Larger propeller-driven and jet aircraft would be available between Inuvik and major airports in the south.

- Helicopters, to transport personnel and limited supplies.

- Rail and road transportation to Hay River.

2.3.10.2 Transportation during Construction Phase

Major modules fabricated on the west coast would be shipped around Alaska to the Mackenzie Delta. General bulk materials, equipment, and the small modules would be transported by rail to Hay River, then barged to the plant site.

Personnel, perishable goods, and equipment or material required in an emergency would be transported to the site by air.

2.3.10.2.1 Ocean-Barge Transportation

Modules built on the west coast would be moved from their near-water fabrication site to the dock with self-powered transporters. Use of these transporters would permit the movement of modules up to 1,000 tons while limiting track bearing loads to less than 3-1/2 tons/ft^2. At the dock, these transporters would load the modules onto barges, where they would be welded down on truss pedestals. The ocean-going barges would travel from the west coast to the Mackenzie Delta plant site via the Gulf of Alaska, the Bering Sea, the Arctic Ocean around Point Barrow, and the Beaufort Sea to the river delta. At the mouth of the river, in Kugmallit Bay, sea-going tugs might be replaced by river tugs and barges to reduce draft requirements to less than 7 feet (depending on the river level in the particular year). A preliminary survey has indicated that vessels of 7-foot draft can be moved from Kugmallit Bay to the Taglu site.

On arrival at the plant site, the modules would be off-loaded from the barges by the transporters, moved to their final location and set on piles.

2.3.10.2.2 River-Barge Transportation

General bulk materials, equipment, and small modules built elsewhere in the south would be transported via existing rail and road networks to a riverside staging area in Hay River. Here they would be loaded onto river barges and transported down the Mackenzie River directly to the plant site.

2.3.10.2.3 Road Transportation

At present no year-round roads connect the Mackenzie Delta with southern transportation networks. Although winter haul roads to the south have been built in the past, the Applicant does not expect any that might still exist to be very useful.

The Applicant would rely heavily on the local winter-road system in the Delta for transporting gravel, as well as minor items of equipment that might be flown into Inuvik.

2.3.10.2.4 Air Transportation

The use of aircraft is essential to the initial construction phase, routine operation and subsequent maintenance of production facilities. With the lack of highways in the Mackenzie Delta, air transport is the only means of regular access to the site during the nonwinter months. Aircraft would be used to transport men and perishable goods, and for unscheduled equipment deliveries into the Delta.

The Applicant would use both fixed-wing aircraft and helicopters in the construction, operation and maintenance of the facilities. The gas plant would have an airstrip on the site. This facility is discussed in further detail in Section 2.3.8.3.

Air-transport facilities would be used to varying extents as the associated projects were phased into existence. During preliminary investigations and the construction phase, the area would see sporadic heavy air traffic. Once the plant was operating and a movement plan worked out, flights would follow a reasonably regular schedule.

It is proposed that construction of the airfield should begin early in the construction program, so that the facility would be available during the periods of heavy and concentrated activity.

2.3.10.3 Transportation during Operation Phase

Once construction was complete and the process plant onstream, transportation requirements would become routine. Throughout the planning and construction of the plant, the Applicant would establish re-supply plans. These plans would provide for the acquisition, movement and storage of key items of mechanical equipment, replacement parts, consumables, fuels, etc. The transportation systems available to the Applicant are now well known and undoubtedly will continue to develop in the next decade.

Transportation during operation would encompass the following activities:

- Replacement of major equipment
- Routine re-supply of materials
- Movement of personnel

2.3.10.3.1 Replacement of Major Equipment

Generally speaking, the items most likely to require replacement would be rotary equipment. As far as possible, stand-by units would be built into the design of the plant, but certain large items might have to be replaced from offsite locations. Plant replacements would be delivered by barge or aircraft either to the site or to Inuvik. With the present combination of river barges and large aircraft operating to the airfields in the Delta, there would be only a few months in the year when large replacement items could not be easily moved. The Applicant believes that the maximum dimensions and weights of critical items of rotating equipment now planned for the Taglu plant would be within the lift capability of special aircraft now in service.

2.3.10.3.2 Routine Re-Supply of Materials

The major portion of the annual re-supply of heavy consumables, fuel, chemical, and nonperishable stores would be barged to the plant site from the rail and road heads at Hay River. This barge traffic would be part of the annual downriver traffic to the developing western Arctic, and would not require special barges or tugs.

Fuel would be deliverd to the site in conventional bulk fuel barges. Once the barges were docked, it would be transferred via the fuel re-supply pipelines built for that purpose. The Applicant would determine the most suitable way to purchase, transport and transfer to storage fuels or chemicals that would form part of each year's supply operation. Steel drums might be used for certain liquids or chemicals not practically transportable as bulk cargoes.

Nonperishable bulk items of the plant warehouse stocks might be transported in freight containers that minimize loss and handling at both source and site.

Re-supply of perishable goods and nonscheduled items would be by aircraft. The food, etc., needed for the plant's accommodation centre would be flown from Inuvik according to a routine developed by the Applicant before plant start-up. This operation would probably require multiple flights weekly to the plant site.

2.3.10.3.3 Movement of Personnel

Operating personnel at the plant site would rely on aircraft for their routine transfers between the site and Inuvik. Inuvik would probably be the collecting point for personnel, whether their homes were in local communities or in urban areas to the south.

The Applicant now maintains its air traffic operations from Inuvik. Should aircraft be unable to operate to the runway at Taglu, helicopters normally available in Inuvik would be used as an alternative.

2.3.11 Operation Philosophy

Once on-stream, the whole Taglu gas production activity is envisioned as a locally controlled operation. Control would be centred in a computerized operation control room at the gas plant. The sophisticated system would be used to maintain production control of gas from the wells. The computer would also help optimize the gas plant processes and undertake routine surveillance and monitoring of key operations in the whole production chain. With this type of control, a minimum number of plant operators would be needed.

Equipment would be maintained by personnel stationed at the plant site. Maintenance workshops would be equipped to meet the day-to-day requirements of the mechanics and the electrical and instrument repair personnel, as well as those of special personnel brought in for some major mechanical repairs. Much of the mechanical equipment in the plant would be duplicated, and a comprehensive supply of replacements would be maintained.

Gas turbines and electric generator sets of proved performance would be used, to maintain a very high standard of onstream efficiency.

The whole operation at Taglu would be supervised by a plant superintendent who, along with the operating and maintenance personnel, would live on the plant site in suitable quarters. The Applicant has sought to plan this living area so that it would be socially complete and personally attractive, to encourage long-term employment.

2.4 Environmental Protection

2.4.1 Effluents and Emissions

Construction and operation of the 1 BCF Taglu Gas Plant would introduce some quantity of emissions to the natural environment. Every effort would be made to minimize the quantity, concentration and impact of these emissions, but in any industrial activity there will always be residues. This section presents a description and a quantified estimate of the emissions expected during all phases of the project.

2.4.1.1 Aqueous Effluents

2.4.1.1.1 Potable Water Treatment

Water supplies for the Taglu facility would be drawn from the Kaluarpak Channel of the Mackenzie River. All potable and service water would be treated by chemical coagulation, clarification, filtration and chlorination. Solids removed during treatment would be returned to the river concentrated approximately 30 times in a volume of 400-1,200 Imperial gallons per day. They would, however, be the same natural suspended solids that were initially present in the river.

About 1.1 pounds per day of organic polyelectrolyte coagulant aid (a high-molecular-weight acrylate) would be returned to the river in the rejected silt, along with about 22 pounds per day of aluminum hydroxide floc. The acrylate would add the equivalent of 2.4 pounds BOD per day to the river. Returned silt is expected to be quickly re-suspended in the highly stable natural silt load in the channel by river velocity, so that no abnormal silt deposition is likely and local bottom organisms would not be affected.

The pH of the returned effluent stream would be in the range of 6-8, which is quite compatible with the naturally flowing watercourse. The temperature of the stream would not exceed ambient air temperatures, and for most of the year would be in the range of 40-70^{o}F.

At certain times of the year raw water might need to be softened, in which case, conventional zeolite softeners would be used. Regeneration brine amounting to 22 to 44 pounds per month would be diluted into the normal waste-water discharge, to minimize salinity gradients in the receiving waters.

2.4.1.1.2 Domestic Sewage Treatment

Conventional waste-water treatment methods would be used to remove better than 85% of organic pollutants, and yield an effluent of approximately 70 mg/l BOD and 50 mg/l suspended solids. The effluent would be chlorinated to yield a 1 ppm measurable residue after 30 minutes of contact. The effluent flow is assumed to be approximately equal to raw-water treatment requirements, which during the construction phase of the project would be an estimated maximum of 36,000 Imperial gallons per day, and during plant operation equal to 9,000 Imperial gallons per day.

Total salinity of the waste water would not normally exceed three times the receiving-water concentration except when water softening was required. The pH would remain between 6 and 9 on an hourly composite basis, and the discharge temperature is expected to be normally from 40° to 70°. The discharge would be pumped to a submerged diffuser, downstream of the potable water-supply intake.

Kaluarpak Channel is a major discharge channel of the Mackenzie River. Minimum flows recorded in recent years are in the order of 5,000 cubic feet/sec. This flow would provide a minimum dilution factor of 10^4 for the proposed discharge. Present water quality of the river is approximately 10-15 mg/l dissolved oxygen, 20 mg/l BOD, 20 mg/l suspended solids, and pH of 7.5 to 8.0. The proposed discharge would not affect any of these values within the limits of analytical detection.

The waste-water treatment effluent has two potential areas of cumulative toxicity - chlorine residue and heavy-metal concentration. Overriding these two potential problems would be the tremendous dilution effect afforded by the Mackenzie River, a ratio of four orders of magnitude or greater. Unless an organism literally lived in the effluent pipe for a long time, any cumulative toxicity from the waste-water discharge is highly improbable. In any event, the chlorine residual would only be in the 1-2 ppm range and would be quickly nullified by the high dissolved-oxygen content of the river.

2.4.1.1.3 Process

Present design of the Taglu facilities does not include any continuous process-water requirements. Water for cooling seals and bearings, and for lube-oil coolers, would be in enclosed systems. Makeup would be minimal; losses would be to evaporation and to the process. All produced water and dehydration water from the wells would be filtered and reinjected into the original formation.

Water from process areas would be treated to separate oils, then filtered and reinjected. This water would include normal rainfall in the tank areas, as well as service water from equipment maintenance and process-area housekeeping. Recovered oils would be used as auxiliary fuel or reinjected.

Separate studies are under way to evaluate the desirability and economic feasibility of using trim water to cool the sales gas in summer. At present, that study is contemplating the use of some 40,000 gallons per minute of once-through cooling water, which would be pumped through the process heat-exchanger with no added chemical and discharged to the river as obtained. Maximum thermal rise of this cooling water would be 10^{o}F, and would be limited to those summer months when the air temperature and hence the river-water temperature were at their peak. Low river flows of about 5,000 cubic feet per second have been measured at the desired discharge point. Assuming perfect mixing, the maximum temperature rise in the river would be approximately 0.2^{o}F. Actually, a temperature rise of 2-4^{o}F over a mixing zone of several hundred metres of river length could be expected. The discharge would be constructed to avoid bottom scouring of the channel.

2.4.1.2 Atmospheric Emissions

Emissions from point and area sources would occur during every phase of the project from pre-construction through operation. At present, with much of the design still to be finalized, emission quantities are simply estimates based on such factors as fuel consumption, horsepower generated, pounds of solid waste burned, tank breathing losses, etc. The quantities presented are the best estimates of the pollutant emissions to the ambient that can be made at present. More detailed figures will be possible when process design has been completed and vendor data are available.

2.4.1.2.1 Pre-Construction and Construction

During this phase of the project the primary point sources for pollutants would be from the tank farm, camp heaters and generators, and vehicles such as pickup trucks. The camp incinerator would combust organic waste regularly with some supplementary fuel being required. The incinerator emissions included in the total are based on an estimated 1,000 pounds per hour of feed twenty-four hours per day. The emissions tabulated below are based on an estimated average annual jobsite fuel-consumption rate of 16,000 barrels of diesel fuel and 4,000 barrels of gasoline plus the incinerator combustion, and can be assumed as likely to emanate from the site.

Pollutant	Quantity
Particulates	2 lbs/hr
Carbon Monoxide	37 lbs/hr
Hydrocarbons	11 lbs/hr
Nitrogen Oxides	60 lbs/hr
Sulfur Oxides	3 lbs/hr
Water Vapour	2,200 lbs/hr

2.4.1.2.2 Plant Operation

The process plant would generate continuous atmospheric emissions in the form of exhaust gas from turbines and fired heaters, tank-farm breathing losses, and flare pilot gas. Intermittent emissions would emanate from emergency flare relief, incinerator combustion of solid waste, vehicle and aircraft movement and other minor point sources. The point and area source emissions would be controlled to the level required to meet the national ambient Air Quality Objectives No. 2 for Air Contaminants as promulgated under the Clean Air Act. It is anticipated that dispersion modeling will be used to finalize stack heights and locations and predict maximum ground-level concentrations.

Specific emission sources and their probable pollutants and quantities are as follows:

(i) Gas Turbines and Direct-Fired Heaters

Approximately 614 million BTU's per hour of fuel firing for generation of power, process heating and life-support heating would be required to operate the plant. Most of the heat would be provided by combustion of liquid condensate from well production; the rest by combustion of pipeline quality gas. Since no sulphur has been discovered in the raw gas, sulphur-oxide concentrations from fuel combustion can be assumed to be nil during normal operation. During initial plant start-up, when no plant fuel is available, diesel fuel can be fired and then only for a short period. It is anticipated that one-fourth of the plant capacity (250 MMSCFD) would be operated on diesel fuel for several days during initial start-up.

Combustion would be with excess air to maximize firing efficiency and minimize unburned hydrocarbons and carbon-monoxide production. Nitrogen-oxide formation is a function of flame temperature, and proper combustion control would ensure the most efficient temperature to produce the desired horsepower and satisfy heating requirements.

The emissions listed below for the turbines and fired heaters are for both start-up and normal operating conditions:

Pollutant	Normal	Start-up
Particulate	12 lbs/hr	13 lbs/hr
Carbon Monoxide	38 lbs/hr	10 lbs/hr
Hydrocarbons	61 lbs/hr	16 lbs/hr
Nitrogen Oxides	289 lbs/hr	75 lbs/hr
Sulfur Oxides	Nil	27 lbs/hr
Water Vapour	56,000 lbs/hr	10,900 lbs/hr

Because of the significant emissions of water vapour from the considerable fuel combustion, ice fogs could be expected to form under winter conditions. However, they would probably be confined to the plant site and only certain transportation activities would be affected.

(ii) Tank Storages

Some volatile hydrocarbons would be stored the year round for plant operation: Normal fill and breathing losses would contribute a small amount of hydrocarbons to the atmosphere. Particularly volatile and/or toxic materials, such as liquid condensate and methanol, would be stored in tanks equipped to control evaporation. The liquid condensate tank would normally be empty, as it would be used only in cases of plant shut-down or malfunction of the hydrocarbon reinjection system.

The estimated total hydrocarbon emission is 4 pounds per hour the year round. It can be predicted, of course, that most of the emissions would occur in the warmer months when the hydrocarbon vapour pressure is highest. highest.

(iii) Flare

The flare pilot would be continuously lit with a small amount of gas producing a minimal amount of particulates and nitrogen oxides. Occasionally, under process emergency relief conditions, large quantities of gas may be flared. Even at maximum instantaneous flaring rates, the quantity of flared gas decreases quickly as the process system is relieved. The flare would be equipped to burn smokelessly and no liquids would be flared. Also, enough excess air would be provided for complete hydrocarbon combustion.

The flare emissions below are for the minimum case of burning only pilot gas, and the case where rates of 0.5 BSCFD are released:

Constituent	Quantity, Lb/Hr Pilot	0.5 BCFD
Nitrogen Oxides	0.3	4,080
Water Vapour	150	34,000
Hydrocarbons	Nil	Nil
Carbon Monoxide	Nil	Nil
Sulfur Oxides	Nil	Nil
Particulates	Nil	Nil

(iv) Incinerator

Solid waste would be combusted regularly as required. The incinerator would be a dual-chambered unit equipped with primary and secondary burners for complete combustion. It would operate not more than 8-12 hours per day, at a rate of 250 pounds per hour.

The tabulated emission quantities are only for those periods when the incinerator would be operating:

Pollutant	Quantity
Particulates	0.1 lbs/hr
Carbon Monoxide	0.1 lbs/hr
Hydrocarbons	Neg.
Nitrogen Oxides	0.2 lbs/hr
Sulfur Oxides	0.1 lbs/hr
Water Vapour	350 lbs/hr

(v) Others

Other point sources that would contribute to the over-all air emission load are vehicles burning diesel fuel and gasoline. Aircraft emissions are virtually impossible to estimate at this time. Vehicular traffic is considered likely to account for about 10% of the emissions during construction, as tabulated below:

Pollutant	Quantity
Particulates	0.1 lbs/hr
Carbon Monoxides	3.6 lbs/hr
Hydrocarbons	1.0 lbs/hr
Nitrogen Oxides	5.6 lbs/hr
Sulfur Oxides	0.1 lbs/hr
Water Vapour	1,000 lbs/hr

Finally, there would be thermal emission from the air coolers. An estimated 330 million BTU's per hour would be transferred to the ambient atmosphere at a height of approximately 6-8 metres above grade.

Maximum rise in air temperature across the air coolers would be 10-15^{o}C. No contaminants would be added to the air drawn through them.

2.4.1.3 Solid Wastes

Solid waste disposal for construction and operation at the Taglu site would be by incineration, with the residual ash going for landfill. All combustible trash, paper, packaging, food waste, and sewage solids would be incinerated in a controlled-atmosphere furnace. The emissions associated with the operation of the incinerator have been presented above. Ash would be stored in containers for periodic removal to an approved landfill site, or frozen into the pad structure. Scrap equipment, noncombustibles and construction wastes too large to be incinerated would be stored for periodic direct transport to the fill site, or barged back to the fabricator for salvage.

2.4.1.4 Other Emissions

2.4.1.4.1 Dust

During the construction phase of the project, dust emissions could be expected from the movement of vehicles, personnel, construction materials and equipment. The primary source would be the movement of gravel or other granular material from offsite to Taglu. However, this would usually be in winter and environmental hazards should be minimal. Placing the granular material for pads, dykes, roads, etc., would also generate some dust. Vehicular traffic moving on the built-up pads and roads during construction and plant operation would generate a small additional amount of drifting dust. Even though it is impossible now to quantify the total volume of dust emissions, it is reasonable to say that it would not exceed the National Air Quality Ambient Objectives for particulates.

2.4.1.4.2 Noise

The installation would be designed, constructed and operated within the following noise limitations:

The over-all plant installation would be designed not to exceed 65 dBA at a distance of 750 feet from the plant. An exception would be the landing and taking off of aircraft from the Taglu airstrip. However, since no jet-powered aircraft would be involved, this traffic should not be a significant noise source.

The individual plant equipment would meet a noise-emission standard of less than 100 dBA at a distance of 3 feet from the equipment, thus assuring an over-all plant noise level below 90 dBA, in conformance with the Canadian National Labour Code.

To achieve these objectives, the following measures would be necessary:

(i) Gas Turbines

The several gas turbines that would be utilized would require:

Complete acoustical enclosures
Inlet and exhaust silencers

(ii) Centrifugal Compressions

Control for both casing and fluid-born noise would require:

Inlet and outlet silencers

Case lagging or complete enclosure

(iii) Air Coolers

Lower fan tip speed in the 9,000 FPM range

Increased number of fan blades

(iv) Gear Boxes

Case lagging or enclosure

External oil coolers

(v) Control Valves

Special low noise valves

Lagging of valve bodies

(vi) Vents and Blow-offs

Silencers

(vii) Process Building(s)

Complete wall insulation, 5 to 6 inches thick

Acoustic-lined interior

(viii) Construction Activities

Efforts will be made to reduce the use of noisy pile-driving equipment at this site. Most piling would be inserted into augered holes.

All motor-driven equipment would be diesel driven, utilizing latest available noise-control equipment.

2.4.1.4.3 Odours

Fugitive losses of highly volatile chemicals usually produce odours. In a typical gas processing plant, the common odour source is sulphur compounds. Fortunately, the Taglu raw gas contains no sulphur. Odours might arise from evaporative hydrocarbon losses in the tank farm or from hydrocarbon spillages. Both are anticipated to be minor problems unless a severe rupture should be encountered. Continuous generation of fugitive emissions should be negigible.

2.4.1.4.4 Radiation

During the construction phase, field welds would be X-ray tested to ensure that material specifications were met. It is projected that field-fabricated tanks and field-welded piping also would be X-ray tested for faults. The radioactive source would probably be Cobalt 60, and would always be under direct supervision of a responsible foreman. Proper shielding from stray radioactivity would be inherent in the design and operation of the equipment.

2.4.1.4.5 Unexpected Releases

A major effort would be directed toward preventing unexpected releases during both construction and operating phases of the project. The only hazardous materials that would be stored at Taglu in any quantity would be fuels, glycol, methanol, lube oils, chlorine, and possibly welding supplies. The liquids would be stored in dyked areas to prevent their dissemination into the environment in case of a spill. Smaller amounts of solid or liquid materials would be stored in designated, supervised areas equipped with counteraction equipment. Within the realm of predictable probability, an unexpected release affecting the offsite environment seems rather remote.

Probably the most likely chance of chemicals being released to the environment would be at the dock when liquids were being transferred to or from a barge. At such times, oil booms, skimming devices and absorbent materials would be available. Of all the materials that would be handled in large quantities, only diethylene glycol, chlorine and methanol are sufficiently water-soluble to affect aqueous organisms.

The most significant release, but the least likely to occur, is in the rupturing of piping, e.g., a fuel line to the dock, or the flare line, or a wellhead flowline. If the line were a raw-gas gathering line, most of the hydrocarbons would eventually diffuse into the atmosphere because they are lighter than air. Liquids could escape, but in the case of a long flowline, would be confined to the release of condensate fluids to the atmosphere.

2.4.2 Environmental Protection Measures

This section will discuss some of the general measures for environmental protection that would be an integral part of the plant design, construction and operation. Some of these measures have been described in detail in the individual sections dealing with specific activities or facilities. General measures that would protect the environment from normal activities will be described here. Abnormal occurrences such as a pipeline rupture or barge collision will be only mentioned, as they are dealt with more specifically under Contingency Plans.

2.4.2.1 Construction Phase

In a normal environment, the design and construction of gas facilities such as those contemplated for Taglu would be a large and complex undertaking, but not particularly unusual. However, the unique conditions in the arctic require unusual construction techniques to solve engineering problems that are not encountered elsewhere. These techniques concern foundation design and modular construction.

2.4.2.1.1 Gravel Roads and Pads

The proposed plant site is in an area of continuous permafrost that may be ice-rich near the surface. Vegetation and underlying organic material form an insulating blanket, which limits the depth of thaw to about two feet. The surface layer must, in no case, be damaged if degradation of the underlying permafrost is to be prevented.

Detailed design parameters for permanent all-weather gravel roads and pads are covered in Section 2.3.8.

2.4.2.1.2 Winter Roads

Although permanent gravel roads would serve plant facilities, vehicles might sometimes have to visit temporary sites, or travel across the tundra during the construction phase before permanent roads had been built. In winter, snow roads would be built or the vehicles would travel on frozen streams. For summer travel off permanent roads, helicopter, fixed-wing aircraft or waterborne transportation would be provided.

2.4.2.1.3 Disposal of Construction Waste

Construction of a gas plant and related facilities would generate various wastes. The construction itself would produce both combustible and noncombustible solid wastes, hydrocarbons and other volatile liquids, and some contaminated water. Camps housing the construction workers would generate combustible and noncombustible solids and sewage.

Solid, combustible construction waste would be burned in a suitable incinerator. Any noncombustible residue would be compacted with other noncombustive trash and buried in suitable landfill sites. Liquid combustible waste (used lube oil, contaminated diesel fuel and/or gasoline, solvents, paints and thinners, etc) would be consumed in a suitable incinerator.

Any contaminated water generated by construction activities would be commingled with construction-camp sewage and delivered to the sewage-treatment plant. Sewage would be treated for 85% removal of BOD and suspended solids and discharged to the river.

2.4.2.1.4 Other Construction Activities

Construction activities outside the plant area such as mining of granular fill, dredging, and transportation of material to the Taglu site would require their own extensive protection measures. The primary concern in these activities is the discharge of material to a watercourse or directly on the tundra. Sand and gravel sources would be developed generally as follows:

(i) All clearing and stripping would be disposed of as directed by the authorizing agency. All brush and other vegetation would be disposed of by burning or other approved method.

(ii) All sources would be worked so that the final excavation would blend as well as possible with the area's natural contours.

(iii) If ground water should have to be drained from the excavation, steps would be taken to prevent erosion and silting by providing flat-bottomed escape ditches, gravel ditch-lining, check dams or settlement basins as necessary. If the sources were worked as a bail site, stockpiles would be located to allow drainage of muddy water into the pit and prevent its escape to the surrounding area. If necessary, dykes, berms and ditches would be built for containment.

(iv) During or after completion, pit faces above the water level would be graded off to smooth, stable, gentle slopes and blanketed with the stockpiled waste material. Any such material left over would be carried beyond the edges of the pit to form a broad, low berm with gentle side slopes. Matting or other means would be used to prevent erosion.

(v) Any source to be used as a future maintenance site would be left so that future operations would cause no serious disturbance. Enough space would be kept for a working area and waste storage; depleted portions of the pit would be restored as described under iv) above.

It might be necessary to dredge some river channels and the river area where the dock would be constructed. It is anticipated that a suction dredge with enclosed cutters would be used to minimize suspension of bottom silt in the river. The dredging operation would, of course, be carried out in summer, during periods when the effect on aquatic organisms - particularly fish - would be least. Collected silt would be disposed of where it would have the least impact.

Movement of significant quantities of fuel by barge is cause for some concern. Although the chances are slight, a barge collision, spillage during material transfer, or onsite spillage from normal use would release quantities of hydrocarbons to the environment. The contingency plan would provide specific countermeasures to deal with such situations, as outlined in detail later in this section.

2.4.2.2 Operation Phase

2.4.2.2.1 Air

(i) Emissions Control

The Taglu gas plant would process sweet gas, i.e., gas that contains no hydrogen sulphide or other sulphur compounds. The plant would be designed so that normally no process vapours would be emitted. The only continuous emissions would originate from fuel combustion for power and heat generation, and the quantity of atmospheric contaminants would be kept to a minimum by burning with excess air, and selecting stack locations and heights to ensure that ambient ground-level concentrations would be affected very little.

A flare system would be needed for safety, to provide pressure relief in case any equipment failure should result in vessel overpressure. Gas would then be released to the flare system, but the plant emergency shut-down system would immediately cut off raw gas production to minimize flaring. Such conditions would be rare in any event, and the flared volumes small. By far the largest volume of flared gas would be released during plant start-up, when flaring would be necessary until the residue gas was suitable for introduction into the sales pipeline. The flow rate, however, would be kept at the lowest practical level for establishing process operations. Procedures would be developed to minimize the flare rate at start-up by bringing on process trains in sequence, and recycling gas through the process as far as possible. The flare system installed in the plants would be designed to operate smokelessly by ensuring complete combustion of hydrocarbons. Present design concepts include air blowers or a stack-head design to provide 100% excess air at critical flaring ratios. A potential problem would be the heat released at the flares and turbine exhausts. The design would ensure that the ground beneath these heat sources was adequately insulated by gravel or other means, to protect the permafrost against thawing.

(ii) Air Quality Monitoring

The ambient quality of the air around the gas plants would be monitored continuously. Instruments would check wind velocity and direction, air temperature, humidity, rainfall, snowfall, and the presence of contaminants such as sulphur dioxide. The information would be transmitted via telemetry to the plant control rooms. Either portable or stationary instruments would be used to monitor ambient conditions.

Gas-detection equipment would be installed in the process areas to initiate appropriate remedial action.

2.4.2.2.2 Water

(i) Process Water

The gas-processing plant at Taglu would be designed to produce a minimum amount of waste-water effluents. The only waste water from the process would be the produced water from the wells and the water removed during dehydration of the gas. This water would require only to be filtered before being injected to a suitable underground formation, through a disposal well located on each well cluster. Also, hydrocarbon-contaminated water accumulated onsite would be treated for oil removal and the aqueous phase reinjected. These small quantities of hydrocarbons would be incinerated or reinjected with the liquid condensate.

Once-through cooling water in quantities up to 40,000 gpm would be used as process trim cooling during summer. As discussed in Section 2.4.1.1.3, the environmental effects or contamination would be nil because no chemical additives are anticipated. Hydrocarbon monitoring of this stream would be instituted to detect leaks in the heat exchangers. An alarm system would announce detection of such a leak, and appropriate shut-down and countermeasure procedures would be initiated.

The only direct environmental effects of the cooling system would be thermal. However, the temperature rise of the cooling-water stream would be limited to 10^{o}F above the ambient river-water temperature. The estimated effects of this thermal input are discussed in Section 2.4.1.1.3.

(ii) Sewage

Liquid wastes arising from washrooms, laundries and kitchen facilities would undergo secondary treatment to provide water acceptable for discharge to a nearby watercourse. Sewage-treatment facilities would be provided to handle both construction and operating stages, at expected rates up to 36,000 Imperial gallons per day during construction and 9,000 Imperial gallons per day during normal plant operation. The sewage-treatment system considered has been described in more detail in Section 2.3.8.10. The treated water from this type of system would be suitable for release to a natural watercourse. Excess activated sludge from the aeration tanks would be incinerated.

(iii) Surface Water

The plant areas would be laid out and graded to provide natural drainage or run-off water to catch basins, where the quality might be checked by hydrocarbon analysis before the water was released. Facilities would also be provided for any oil-skimming and treatment that might be necessary.

(iv) Quality Monitoring

The quality of injection water would be monitored regularly for suspended-solid content, to ensure good performance of the injection wells. Treated water from the sewage plant would be tested regularly for BOD and suspended solids, by trained technicians in laboratory facilities provided at the plant. Monitoring of once-through water has already been discussed.

2.4.2.2.3 Noise

To reduce noise levels in and around the plant to acceptable limits, sound-attenuation devices would be installed on equipment as needed. Plant equipment would be designed to meet a noise-emission standard of 65 dBA at a distance of 750 feet from the plant and less than 100 dBA from the equipment inside the plant. Considerations for reduction of noise levels during both construction and plant operation have been discussed in Section 2.4.1.4.2.

2.4.2.2.4 Solid Wastes

Refuse from the camp, and the waste sludge produced by the sewage-treatment plant, would be incinerated and the ashes buried in a designated landfill site. Solid waste that would have to be disposed of is estimated at up to 6 tons per day during construction, and up to one ton per day during operation.

2.4.2.2.5 Other Monitoring and Surveillance Activities

(i) Transient Activities

Personnel with a broad knowledge of the northern environment and a basic understanding of industry activities would be assigned to monitor all field activities during the pre-operations stage of development. They would report to an appropriate level of the Applicant's management, but be able to make judgments and decisions in the field. Through their management contact, they would have the ultimate authority to shut down field operations that would contravene the Applicant's and government environmental regulations.

Monitoring and surveillance measures for well-control, developed over the past few years of Mackenzie Delta exploration drilling, would be in effect for drilling of all development wells.

(ii) Long-Term Operations Activities

a) Flowlines

The central control room would include programmed computerized equipment to provide selective automatic shut-down of any part of the plant or system registering an alarm or emergency situation. The central control room computer could be programmed for automatic operation of a pre-determined shut-down procedure. Provisions would also be made for manual operation or interruption of the shut-down procedure as required by the operator.

Besides the facilities at the central control room, independent instrumentation would be provided to protect and isolate individual sections of the systems in case of an alarm, or a failure of the central control system.

Continuous stress-monitoring systems might be installed at points where a design stress analysis showed that maximum stress levels could be expected.

The flowlines might be equipped with facilities capable of running internal wall-thickness checks on the pipe.

b) Well Cluster Systems

For production operations, wells would be equipped with safety valves both at the surface and below the base of the permafrost. Besides providing automatic shut-in for surface emergencies, the valves would be designed to fail closed in the event of severe subsurface damage. The critical functions of these valves could be monitored continuously at the central control room with its remote shut-in capability.

Well-cluster operations would normally be unattended, but well pressures, temperatures and flow rates would be monitored continuously by the central control room system. The same system would also be able to monitor refrigeration systems and well-annulus pressures.

c) Plant Systems

The plant would be designed as a simple process and mechanical flow. Therefore, simple control loops would be provided, and the process would be able to operate within a wide range of turn-down. The central control room computer would monitor trends within the process systems. Corrective action would be taken by the operator, who would receive the necessary alarm indications.

As in the case of clusters and flowline systems, the plant instrumentation would activate shut-down before flaring. The flare tips would be continuously scanned.

d) General

A regular preventive maintenance and repair schedule would be developed, to minimize the possibility of failures due to poor condition of the mechanical components.

Monitoring of subsoil conditions would ensure that original design assumptions with respect to permafrost were being maintained. Thermistor cables would be installed at critical locations to record any changes in the temperature regime.

2.4.2.3 Abandonment and Site Restoration

The following points summarize the abandonment procedures and the extent of terrain restoration that would be carried out at the end of the useful life of the project or portions thereof.

a) All wells that had ceased to be productive and were no longer usable as observation wells would be plugged and abandoned in accordance with existing regulations.

b) Any pad or embankment no longer needed would be examined to determine what degree of removal could be carried out without disturbing the insulating quality it provided. Any drainage structures that were built into the embankments would be removed to permit free flow of surface waters. All gravel that could be salvaged without damaging the area of abandonment would be removed and transported to other construction locations. Any gravel or granular fill that it was considered unwise to move would be left in place and, if possible, the area affected would be reseeded.

c) All elevated pipelines or electrical transmission lines would be removed. Pipe supports would be cut off at ground level or below, and the right-of-way restored as nearly as possible to its natural state.

d) Processing plant and other large items of equipment would be salvaged wherever feasible.

2.4.3 Contingency Plans

2.4.3.1 Operational Control

2.4.3.1.1 Loss Detection

(i) Production and Injection Systems

At Taglu, the wells would all have short individual flowlines to the plant inlet. Production storage is limited to the condensate surge and emergency storage tanks, and the produced water storage tank which are very small. In the event of a major mechanical failure, potential losses would include raw gas, condensate and water from the production flowlines, condensate from the condensate injection lines or from the condensate tanks, and water from the water injection lines or water storage tank. Containment of the liquids in the storage tanks is discussed elsewhere. Gas detectors would be the prime means of leak detection for hydrocarbon lines and vessels in enclosed areas.

As discussed in 2.3.5., the production wells would be equipped with fail-safe shutdowns which would act automatically in the event of serious flowline failure. Small leaks would not be sensed automatically but would be detected by one of several indicators - sound, vapour cloud, or smell.

In general, no spills of any consequence would be expected from the water disposal system. Small leaks would be detected during visual checks by operating personnel.

(ii) Transportation and Storage

Section 2.3.7 contains a tabulation of the proposed permanent tankage and stored commodities at the Taglu site. Diesel fuel, gasoline, lube oils and chemicals will be barged to the site each summer from the rail and road heads at Hay River. The principal river carrier, Northern Transportation Company Limited, currently has an effective operational action plan for spills occurring on the Mackenzie River. At the off-loading point, NTCL's established procedures include overflow detection devices such as mechanical or electrical alarms and on-the-spot continual surveillance. It is expected that similar or improved detection systems will be in operation for the Taglu project.

2.4.3.1.2 Stoppage

(i) Production and Injection Systems

As noted in 2.4.3.1.1, the production wells will be equipped with fail-safe shutdowns which would act automatically should a flowline fail.

In the event of a serious failure of a flowline, both the surface safety valve (SSV) and the subsurface safety valve (SSSV) would close. The SSV would shut off in about 10 seconds so that an out-of-control well flowing 200 MMcfd would produce only an additional 25 Mcf during the 10-second period. If the wellhead were seriously damaged, the SSSV would stop the flow after a period of 2 to 5 minutes. A check valve on each flowline at the plant end would prevent any back-flow from the plant.

The two condensate injection wells would be equipped with a safety shutdown system similar to that for the producing wells.

There would be two water disposal wells, one on stream and the other on stand-by. The wellheads of the water injectors would have a minimum pressure rating of 2,000 psi at -75°F, and would be equipped with check valves also. Safety shutdowns on this system would include high and low pressure.

(ii) Transportation and Storage

Transfer of fuels and chemicals would take place under controlled conditions. Any leaks in the connecting flowlines could be stopped by shutting down pumps or closing valves. However, large ruptures in barge or storage tanks could result in a spill of all or most of the contained fluids, but spills from the on-site storage would be contained within dykes.

2.4.3.1.3 Undetected Losses

(i) Production and Injection Systems

The maximum potential undetected loss in the production and injection systems would depend on the size of tubing and flowlines and the reaction time of the installed automatic fail-safe shutdown valves.

Since the detailed engineering design of this system is not yet started, only preliminary potential losses can be provided at this time. Based on preliminary assumptions, a ruptured production flowline shut at both ends could release up to 300 Mscf of raw gas. The likelihood of more than one line failing at the same time is quite low. In the case of an out-of-control well flowing 200 MMscfd for 5 minutes before shutdown by the automatic sub-surface safety valve, there would be a release of 700 Mscf of raw gas plus 130 Mscf from tubing above the valve. Therefore, in the event of a complete wellhead failure, at initial reservoir pressure and at minimum temperature condition, a maximum of 1,130 Mcf of raw gas would be vented to the atmosphere.

Again, based on preliminary design assumptions, 65 bbls of condensate could be released from the injection system. In case of serious wellhead damage, there could be an additional release of less than 10 bbls. Although no spills of any consequence are expected from the water disposal system, potentially some 20 bbls of water containing a freeze-point depressant such as methanol or glycol could be spilled. Furthermore, the injection water would contain up to 15 ppm of corrosion inhibitor of a type commonly used in water flooding and salt water disposal.

(ii) Transportation and Storage

All on-site tanks would be placed within dykes to hold 100% of total tank capacity.

2.4.3.2 Countermeasures

2.4.3.2.1 Detection in Environment

As noted above, the response time in detecting an accidental spill in transportation, drilling, construction and production phases of the proposed facility is relatively short. In the transportation phase, the responsibility rests with the carrier who normally has the necessary expertise and the organizational structure to detect any losses which might occur during movement or transfer of fluids with his system. During unloading operations, this expertise would be augmented by specific surveillance duties provided by the Applicant. Since most of the fuel would be transferred in the lon daylight hours in summer, any leaks or ruptures should be readily apparent. Early detection of any spills during drilling, construction and operation of the facility is greatly facilitated by the compact and contiguous layout of the main components of the facilities. Spill detection would be assigned to personnel with a broad knowledge of the northern environment and a basic understanding of industry activities.

2.4.3.2.2 Containment and Recovery

Containment and recovery of lost fluids, particularly oil, is a key part of the Applicant's contingency plans in the north. The same plans would be applied to the Taglu development with appropriate adaptations and modifications to suit the particular project. For example, during unloading of diesel fuel, containment booms would be in place on a routine basis. Also, pump skimmer units would be in readiness to begin recovery operations if needed. Adequate storage facilities would be provided to accommodate recovered liquids. The shallow gradients and resultant low currents of the Mackenzie River system in the vicinity of the project are within range of conventional floating boom techniques.

The Applicant's response to emergencies are contained in such documents as "Arctic Well Control Contingency Plan" which has been filed with D.I.A.N.D. and the "The Region Major Oil Spill Response Team" (1975). The Applicant has also integrated Environment Canada's National Emergency Equipment Locator System (NEELS) into his oil spill contingency plans and is also a member of the Delta Environmental Protection Unit which, in the past few years, has accumulated a good deal of experience in operation in the Mackenzie Delta.

The Delta Environmental Protection Unit has equipment and materials stored at base camps at Tuktoyaktuk and Bar C (Tununuk Point). Equipment includes booms, watercraft, skimmers, pumps, sorbents, oil proof clothing, generators, communication equipment, portable power plants, hand tools and emergency rations. It is expected similar equipment and material will be on-site at the Taglu facility which will be backed-up by the facilities of the Delta Environment Protection Unit at the two locations mentioned. Although not yet determined, it is expected some earth moving and snowplowing equipment will be available both during construction and operation of the facility. Recovery techniques would need to be adjusted according to the sensitivity of the receiving body and the season. For instance, heavy equipment could be used in winter to collect oil-contaminated snow but recovery of spills on the tundra in summer would place more emphasis on use of manpower and on portable equipment.

Plant areas would be graded to provide natural drainage of runoff water to catch basins where the quality could be checked by hydrocarbon analysis with provision for recovery of contaminants before release of water to the environment. As noted in Section 2.3.9.5, tank farms would be enclosed by an impervious perimeter dyke to prevent intrusion of flood waters and escape of spilled fluids.

It is unlikely that spills of methanol, gasoline or condensate beyond the confines of the dyking system could be recovered to any large extent. Therefore, prevention of dispersal to the environment would be of primary importance although subsidiary to safety of personnel.

2.4.3.2.3 Disposal

There are portable burners available that can efficiently burn recovered oil. It is expected this type of equipment would be operated at a safe distance from the plant facility.

2.4.3.2.4 Rehabilitation

Fuels and chemical spills would damage primarily vegetation and waterfowl. Fertilization and re-seeding of effected areas could hasten re-vegetation. In the last few years, a considerable amount of work has been carried out in this area and it is anticipated, expert advice on advisability of revegetation and the techniques to be used would be available.

Provisions for waterfowl rehabilitation would be included in the final contingency plan. These would incorporate some of the advancements that have been made in recent years on clean-up of contaminated birds.

The impact on waterfowl might be greatly reduced by deploying automatic propane guns to frighten birds away from the spill site.

2.4.3.3 Fire Prevention

2.4.3.3.1 Facility Areas

Since detailed engineering design of the facility is not yet complete, it is not possible to provide much information on fire prevention or fire fighting systems. As in all gas plants, fire prevention is a major consideration in design. It is expected that fire fighting provisions would include both dry chemicals and water. It was noted in Section 2.3.9.8 that firewater supply will be from a storage tank.

2.4.3.3.2 Surrounding Areas

The Taglu development is proposed for an area of predominantly low-centred polygons which generally does not support the type of vegetation that could carry a fire. Furthermore, the numerous channels and lakes would confine any tundra fire and facilitate putting it out with hand pumps or other portable equipment.

Upland areas bordering the Ya Ya gravel location would be somewhat more prone to tundra fires. Most of the summer activity would be confined to cleared areas which greatly reduces the chances of starting fires. Educational programs should be effective in preventing potential fires started by project personnel during recreational or rest periods.

3. ENVIRONMENTAL ASSESSMENT

This section discusses the interactions between the Applicant's proposed gas development activities and the Mackenzie Delta environment. The environmental background data upon which the impact assessment is based is found mainly in the F. F. Slaney & Company Limited reports on the 1972-1974 Environmental Program, Mackenzie Delta, N.W.T. Frequent references are made in this document to the Slaney reports which are listed below:

Volume 1 - Meteorology and Climate
Volume 2 - Hydrology
Volume 3 - Landform and Vegetation
Volume 4 - Birds
Volume 5 - Mammals
Volume 6 - Aquatic Resources
Volume 7 - Environmental Quality
Winter Study Supplement
Impact Assessment

To a large extent, the environmental impacts identified are similar to those discussed in the Slaney Impact Assessment with adjustments for project changes where these were judged to be significant.

Three points appear worthy of introductory comment. Although possible sulphur dioxide emissions are discussed in the Slaney reports, the current view is that both gas and condensate are essentially sulphur-free, and there should be no such emissions.

Recent calculations indicate that NO_x emissions will, on the other hand, be in excess of those outlined in the earlier reports. No appreciable change in environmental impact is anticipated, however.

Finally, it is possible that there may be a considerable incentive to use water to supplement the air cooling in the process plant during warm weather. Hydrologic studies indicate that this can be implemented without serious environmental consequences.

3.1 Climate

3.1.1 Existing Conditions

Most of the northern Mackenzie Delta including Richards Island lies within the Marine Tundra Climatic Zone and is characterized by long cold winters and short cool summers. Modifying climatic influences by Arctic Ocean waters characterize the difference between Marine Tundra and Continental Tundra, i.e. mean daily winter temperatures are higher in marine areas because of heat supplied through sea ice and lower in summer because of heat lost to the sea surface.

Since most historical climatological records have been produced only at locations of human habitation, long-term climatic records for Richards Island in the remote Mackenzie Delta region were non-existent. Also, turbulent factors which characterize the typical micro-climate of the region had never been studied. Closest Department of Environment weather stations are at Inuvik Airport, Tuktoyaktuk, Aklavik and Shingle Point.

The most comprehensive description of the climate of the Mackenzie Valley has been presented by Burns, 1973. This study presents a broad overview of climatic factors pertinent to the Mackenzie Valley - Beaufort Sea and is used extensively in this report. The physical geography of the Mackenzie Delta has been described by Mackay, 1963.

In 1972 and 1973, atmospheric measurements were taken at three Delta sites as part of a program of baseline data collection. Results are presented in Volume 1, Slaney, 1974.

At Taglu G-33, measurements of wind speed, wind direction and air temperature were taken at three levels up to a height of 80 feet (8 feet, 40 feet and 80 feet). Dew point temperature was monitored at the lowest level. Sampling was once an hour and results were telemetered to Calgary for computer storage. Battery powered chart systems (Meteorological Research Incorporated, Model 1071) were utilized as back-up for the telemetry system.

Tower wind speed and direction were sampled by a delicate cup anemometer and vane. Temperatures were sensed by thermistors mounted in aspirated radiation shields at each height. Humidity was measured using a dew point hygrometer and a Lyman-alpha sensor.

Use of these data, along with short-term continuous measurements of fluctuations of temperature, humidity, horizontal wind velocity and vertical velocity, enabled the characteristics of atmospheric turbulence to be determined. The program at Taglu G-33 was initiated on July 16, 1972 and continued until November 1, 1973. Short-term continuous measurements were conducted from July 15 - 30, 1972.

Map 1-2 (Vol. 1) shows the locations of Environment Canada weather stations in the vicinity of the study area. Historical weather records were used from Aklavik, Inuvik, Tuktoyaktuk and Tununuk. These stations provided useful sources of background climatic information with which to assess the general climate of the region.

Averaged monthly temperature and precipitation summaries are shown in Appendix 1-1 for each of the stations. Yearly means are shown in Table 1-1 (Vol. 1).

The annual variation in temperature is large for all stations. Maximum mean monthly temperatures of 55^{O}F are reached in July and minimums near -20^{O}F in January. Tuktoyaktuk on the coastal fringe has the coldest climate of all stations with an annual mean temperature of 12.3^{O}F.

The precipitation regime is variable across the Delta with all stations showing less than 12 inches / year. Inuvik has the highest total yearly precipitation with 11.5 inches. Coastal stations, such as Tuktoyaktuk, are usually less affected by local topography and hence experience considerably less total precipitation, i.e. 5.32 inches / year for Tuktoyaktuk. The wettest month for all stations is August with most of the precipitation falling as rain showers. Approximately 39 percent of total yearly precipitation falls as rain between May and September at Inuvik compared to 57 percent at Tuktoyaktuk. This would infer a much heavier snow cover at Inuvik than Tuktoyaktuk.

Wind distribution across the Delta is partially affected by local topography but tends to display a predominant northerly component in summer - fall and an easterly component in winter - spring. Figure 1-1 (Vol. 1) shows average monthly wind roses for Inuvik Airport, 1961-70. Mean monthly winds are highest in summer - fall and lowest in winter - spring. Yearly average speeds vary from 6 mph at Inuvik to greater than 10 mph along exposed coastal areas.

Features of the local climate of the Taglu study site and of the general Mackenzie Delta are presented in Vol. 1, Part 2, Slaney, 1974 from interpretation of data collected in 1972 - 73 and from historical records available from Department of Environment weather stations.

3.1.1.1 Air Masses and Weather Systems

The predominant air mass encountered in the Mackenzie Delta is continental Arctic (cA). However, several modifications occur. In order of decreasing occurrence but increasing temperature and moisture content they are:

1. cold maritime Arctic (cmA)
2. maritime Arctic (mA)
3. maritime Polar (mP)

Details of each weather system in relation to the Taglu area are contained in Vol. 1, Part 2.1.

3.1.1.2 Solar Radiation

In the Mackenzie Delta the angle of incidence of the sun's rays is small compared to that of lower latitudes. Hence at any one time smaller amounts of incoming solar radiation are received at the ground per unit surface area. In the summer, this is compensated by longer hours of available solar energy.

In winter, the sun is completely below the horizon from December 2 to January 10 (Burns, 1973). No solar radiation is received at the ground directly and only small amounts from arctic twilight. The result is a depletion from back radiation at the surface resulting in colder air temperatures.

Cloud cover is the most important solar reflector and prevents a large percentage of the short-wave radiation from reaching the earth's surface (Burns, 1973). Much the same is true for fog. As a result, measurable differences in the amounts of annual incoming radiation can often occur between coastal areas more susceptible to cloud and areas further inland.

The albedo of the ground surface is also important. Snow and ice have a high albedo and reflect a large percentage of incoming radiation whereas water has a low albedo (depending on solar angle). These differences are very important in the late spring when snow and ice begin to melt, exposing water surfaces and bare ground. Details on solar radiation at various arctic locations are contained in Vol. 1. Part 2.2.

3.1.1.3 Air Temperature

Temperature controls the growth and development of plants, depth of permafrost, rate of organic decay and duration and amount of snow and ice cover.

The annual variation of mean monthly temperature is large on the Mackenzie Delta. Values range from near -25^{o}F in January to 55^{o}F in July (Vol. 1, Part 2.3, details air temperature in the Mackenzie Delta area).

3.1.1.3.1 Temperature Observations - Taglu G-33

Appendix 1-3 (Vol. 1) shows time series measurements of important climatic parameters at Taglu G-33 from July 16, 1972 to November 1, 1973.

Appendix 1-4 (Vol. 1) shows monthly averages of hourly temperatures plotted about their monthly means for an average day at a height of 8 feet. Each graph portrays what the typical daily variation of hourly temperature would be for an average day at that month. The largest diurnal variations appeared in spring - summer and the smallest in fall - winter.

3.1.1.3.2 Comparison of Air Temperatures at Inuvik Airport & Taglu G-33

Temperature data from Inuvik Airport and those from Taglu G-33 were compared for one year's duration in order to relate temperatures measured at Taglu G-33 to historical temperature records collected at Inuvik since 1957 (Vol. 1, Part 2.3.2, Slaney, 1974). Correlation coefficients were calculated using sections of data from each station during two identical time periods (September 11 to October 16, 1972 and March 13 to April 14, 1973).

3.1.1.3.3 Comparison of Air Temperatures at Taglu G-33, Swimming Point and Parsons Lake

In order to determine any horizontal temperature variations in the Delta regions, additional remote temperature measuring devices were installed at Taglu G-33, Swimming Point and Parsons Lake in an expanded program in 1973, (Vol. 1, Part 2.3.3, and Winter Supplement, Slaney, 1974).

3.1.1.4 Inversions

Arctic inversions are perhaps the most conspicuous element in Arctic meteorology. Their increased temperature with height is caused by negative radiation balance from the snow / ice covered surface. Subsidence creating warmer air aloft and the shallow solar angle also help to intensify it. Only in the few months of summer is there enough solar energy to override inversions. Ground surface temperatures are higher then and produce convective plumes and local instabilities which break up lower inversion layers. Early summer mornings can still show signs of ground-based inversions. Inuvik Airport reports 61 percent occurrence of surface-based temperature inversions at 04.00 L.S.T. each day from June to August.

Associated with inversions are numerous types of visibility obstructions. Fogs, ice fogs and stratus cloud types are common occurrences along with inversions. Inversions can also act as a lid or barrier to prevent vertical distribution of pollutants. Smoke plumes from chimneys will frequently level off in the presence of inversions keeping high emission concentrations near ground-level. In some cases, this can cause local discomfort and reduced aesthetics.

Hourly temperature readings from thermistors at three vertical levels enabled the observations of inversion structure and occurrence at Taglu G-33. Measurements were begun in July, 1972 and continued to November 1, 1973. Details are contained in Vol. 1, Part 3.1.1, Slaney, 1974.

3.1.1.5 Wind Speed and Direction

Coastline features near the Mackenzie Delta are important to the distribution of prevailing winds. Between Barter Island and Aklavik, the Richardson and British Mountains rise steeply to about 3,000 feet, five to 40 miles inland. This high interior terrain acts as an effective barrier to the wind whose orientation is WNW to ESE (Wilson, 1974). From Aklavik to Cape Bathurst, the coastline is flat with a gradual rise to 1,000 feet about 100 miles inland, offering little or no restraint to surface winds (Wilson, 1974). Mean annual distribution of winds at Shingle Point and Tuktoyaktuk display these topographical differences. At Shingle Point, the highest percentage of winds come from the WNW octant and at Tuktoyaktuk from the ESE. Preferred directions for strong winds are from the WNW at both stations.

Westerly winds over the Richardson Mountains cause subsidence, turbulence, lee waves and chinooks across the western Delta, especially near Aklavik (Burns, 1973). In winter, well known "chinooks" bring warmth and relief from the bitter cold.

Easterly winds in the area of Reindeer Hills cause low-level turbulence and downdrafts along the western slope. Buffeting caused by the turbulence can pose problems for small aircraft operating in these conditions.

3.1.1.5.1 Wind Observations - Taglu G-33

The Taglu G-33 wind station was very susceptible to high winds in 1972 - 73 because of its location on a flat low-lying delta plain and its exposure to storms from the Beaufort Sea. Details are contained in Vol. 1, Part 2.4.1, Slaney, 1974.

3.1.1.5.2 Comparison of Winds at Inuvik Airport & Taglu G-33

Wind data from Inuvik Airport and those from Taglu G-33 were compared for one year's duration in order to relate winds measured at Taglu G-33 to historical winds records collected at Inuvik since 1957. (Vol. 1, Part 2.4.2, Slaney, 1974). Correlation coefficients were calculated using sections of data from each section during two identical time periods (September 11 to October 16, 1972 and March 13 to April 14, 1973).

3.1.1.5.3 Comparison of Winds at Taglu G-33, Swimming Point & Parsons Lake

In order to determine any horizontal variations in wind speed and direction in the local Delta study area, remote recording weather stations were established at Taglu G-33, Swimming Point and Parsons Lake. (Vol. 1, Part 2.4.3, and Winter Supplement, Slaney, 1974).

Tables 1-8 and 1-9 (Vol. 1) show calculations of monthly mean hourly wind speeds and monthly extreme mean hourly wind speeds from July to October, 1973. Parsons Lake showed both highest monthly means and highest monthly peaks of all three stations, the reason probably being its higher elevation and greater exposure to upper winds. Lowest winds were at Swimming Point, probably due to influence of the Reindeer Hills to the southeast.

Table S-5 (Supplement) shows monthly mean hourly wind speeds at Taglu G-33, Swimming Point, and Parsons Lake for the period October, 1973 to June, 1974. Taglu G-33 and Parsons Lake were the windiest of the three stations. Mean speeds were highest at Taglu G-33 until January, 1974 after which there was a shift to higher winds at Parsons Lake. January to March is also the time of the strongest inversions (Vol. 1) so it would appear that the low-lying air at Taglu G-33 became more stabilized with the encroachment of the strongest inversions than did the higher air mass at Parsons Lake. January was the windiest month for all stations sampled.

During January, February and March, several hours of data were lost at each station due to ice jamming of the wind vanes. Because each station incurred these losses at different times, comparison of directional differences between stations is difficult for these months. However, in general, it appears that wind distributions are similar for all stations. South and west quadrants shared the predominant winds at all stations until January, 1974, after which there was a shift to more northerly components. This pattern was also indicated for the highest winds measured (Table S-6, Supplement).

3.1.1.6 Wind Shear

The vertical gradient of mean wind speed or wind shear is important when describing the amount of vertical mixing and the longitudinal spread of aerial debris. The magnitude of the gradient is determined by the roughness of the surface and the atmospheric stability. Under neutral conditions the vertical velocity profile is usually logarithmic.

3.1.1.6.1 Wind Shear Observations - Taglu G-33

Hourly measurements of wind speed at three vertical levels enabled calculations of the wind shear at Taglu G-33. Measurements were begun on July 17, 1972 and continued to November 1, 1973. Details are contained in Vol. 1, Part 3.2.1, Slaney, 1974.

3.1.1.6.2 Seasonal Variation of Drag Coefficient - Taglu G-33

Using the formulae discussed in Appendix 1-2 (Vol. 1) and hourly values of wind shear from Taglu G-33, the drag coefficient was calculated on an hourly basis and monthly averages calculated. Because the formulation was for near-neutral conditions and the predominant stability class in the Arctic is the stable inversion, a correction was applied to the wind shear using the average monthly Richardson Number Ri and normalized wind shear S. Table 1-15 (Vol. 1) shows the seasonal variation of the drag coefficient at Taglu G-33.

3.1.1.7 Turbulent Flux Measurements

The objectives of these types of measurements were to establish quantitative values of the spectral energy associated with the fluctuations of temperature, humidity, horizontal wind speed, vertical wind speed and direction over the tundra surface and compare these to areas where turbulence studies had been more extensive, i.e. Russian steppes. Calculations of the heat, momentum flux and drag coefficient would also be made by the eddy correlation technique (Miyake, 1970) and compared to those calculated by profile methods to test the tower monitoring system. Methods and results are described in Slaney, 1974, Section 3.3, Vol. 1.

3.1.1.8 Precipitation

Precipitation is light across the Mackenzie Delta as it is in other parts of the Northwest Territories.

Rainfall is generally confined to the months June to September, with July and August being the wettest months. Most rainfall is associated with frontal and cyclonic activity and falls as showers. Periodic downpours of one inch or more have been reported at some arctic stations (Department of Environment 1945 - 74), however, showers of 0.1 to 0.3 inches are more common in the Richards Island region.

Snowcover is not established over the Mackenzie Delta area until late September with the heaviest falls in October (see Historical Records, Appendix 1-1, Vol. 1). Although the snowfall may be nearly uniform across sections of the Delta, it soon becomes re-distributed and compacted by wind. Freshly fallen snow is characteristically of low density because of its numerous crystal-line shapes.

In some areas, interception of snow by the vegetation canopy can limit the amount of snow reaching the ground. Greater accumulation therefore occurs in deciduous vegetation where wind speed is reduced and light, fluffy snow is able to reach the ground. In open areas, under the influence of wind, freshly fallen snow is rapidly broken into smaller particles causing increased density and compaction.

3.1.1.8.1 Variations in Precipitation Across the Mackenzie Delta

Although annual precipitation is light, there is significant variation of precipitation across the Mackenzie Delta 1) but with a decided summer maximum. Comparisons are outlined in Vol. 1, Part 2.5.1, Slaney, 1974. Annual totals vary from five to 12 inches and hence, the area is often termed a "polar desert". However, thawing of the active soil layer and river flooding in summer cause vast tracts of wet-lands, giving the impression that the Mackenzie Delta is a wet region. Historical records from Tuktoyaktuk, Tununuk, Aklavik and Inuvik show precipitation is highest at Inuvik (average yearly precipitation is 11.15 inches and elevation is 200 feet above MSL), and lowest at Tuktoyaktuk (average yearly precipitation 5.32 inches and 60 feet above MSL). Aklavik (28 feet above MSL) and Tununuk (100 feet above MSL) also receive considerably less precipitation than does Inuvik.

Since Tununuk and Tuktoyaktuk are located on the coastal fringe of the Beaufort Sea, their values are most typical of the low-lying coastal stations. In general, coastal areas receive less precipitation than do areas located further inland at higher elevations.

3.1.1.8.2 Precipitation Observations - Taglu G-33

Daily weather observations from Taglu G-33 were taken during the summer of 1972 - 73. Daily observations of rain or snow occurrence indicated 8.3 percent occurrence in May, 6.7 percent in June, 12.9 percent in July and 32.3 percent in August. Precipitation in these months was predominantly rain showers associated with nimbostratus and cumulus cloud. Snow flurries were noted once on August 15, 1973. As indicated in Table 1-10 (Vol. 1), these results are typical of coastal stations such as Tuktoyaktuk.

3.1.1.9 Fog

Fog occurrences are common across the Mackenzie Delta. They take the form of radiation fog, advection fog, or ice fog.

Radiation fog forms in a layer of air near the ground when the temperature and dew point are equal, or nearly so. Most favorable meteorological conditions for formation are calm clear nights when long wave radiation from the ground is lost to the atmosphere and the surface is cooled. A ground-based inversion is formed, making for a very stable fog layer. Where air drainage is possible, the fogs may flow downslope like a misty river (Mackay, 1963).

Advection fog is fog carried to the Delta by prevailing winds from another source region. Over the Beaufort Sea, thick fog banks form in cold air, overlying warmer surface waters. Periodically, prevailing onshore winds carry the fog inland. Prolonged winds may bring fog as far south as Aklavik, Inuvik and Eskimo Lakes.

All the above fog types may prevail in the general study region for several days but there would usually be dissipation near noon of each day with increased solar input.

3.1.1.9.1 Variations in Fog Occurrences Across the Mackenzie Delta

Table 1-11 (Vol. 1) shows mean monthly and annual days with fog for the stations of Aklavik and Inuvik. May-June and September-October are times of highest fog occurrence. These periods correspond to general times of break-up and freeze-up conditions across the Delta.

There is much interaction between cold Arctic air and either surface water or moistened surfaces at these times and hence large amounts of fog.

3.1.1.9.2 Fog Observations - Taglu G-33

Fog observations were made during the summer of 1972 - 73 at Taglu G-33. Frequency of fog occurrence was 50 percent from May 19 - June 1, 33 percent for June, 10 percent for July and 6.5 percent for August. Because the topography at Taglu G-33 is flat and the location is only a few miles from the Beaufort Sea, Taglu G-33 is susceptible to both fog banks and low-lying blowing in from the Beaufort Sea.

3.1.1.10 Air Quality

Concentrations of seven air quality parameters (dustfall, suspended particulate matter, sulphur dioxide, hydrogen sulphide, ozone, nitrogen dioxide and hydrocarbons) were collected at seven sites during 1972 and 1973. Methods of collection, analysis and results are presented in Vol. 7, Slaney, 1974.

Comparisons were made with published data with particular reference to values in the natural environment.

3.1.1.10.1 Dustfall and Particulates

Suspended particulates were measured in only one of six samples taken. The sample was taken at Sampling Site 7 during late August, 1972, in clear weather over a continuous 52-hour period and yielded a concentration of six micrograms per cubic meter of suspended particulates.

Dustfall was collected from snow samples and in open jars. Yields were in the magnitude of 0.046 to 4.34 tons per square mile per month. Inuvik (Sample Site 6) values were somewhat higher and ranged to 29 tons. Road dust would be expected to cause the higher values reported for the town of Inuvik. However, there are no records of dustfall levels in the arctic available for direct comparison.

3.1.1.10.2 Sulphur Compounds

Wet chemistry and gas chromatography analysis yielded levels of two sulphur compounds, sulphur dioxide and hydrogen sulphide. The sulphation index (sulphur oxides per unit area per unit time) is a convenient measure of airborne sulphur compounds. There is an empirical relationship between sulphation index and concentration of SO_2 in air. This relationship varies somewhat with circumstances at the test site.

A factor has been recorded in the literature, however, relating a large amount of comparative data and this factor may be used to get a reasonable estimate of SO_2 concentration at the site under study.

For values recorded as sulphation index, the SO_2 concentrations estimated from sulphation plates were less than 0.0026 ppm and had mean values of .00032 ppm in 1972 and .00026 ppm in 1973.

Hydrogen sulphide concentrations were not detected in all samples, but concentrations of up to 0.036 ppm were recorded. However, this was an instantaneous sample, and when averaged over an hourly or daily period with the other samples, would be much lower.

3.1.1.10.3 Ozone

Ozone is a normal component of the atmosphere resulting from the action of ultra violet energy in the sunlight. Ozone may be synthesized by a complex mechanism catalyzed by ultra violet light and unsaturated hydrocarbons.

Air samples were collected and analyzed for ozone concentration at three stations in the Delta.

3.1.1.10.4 Nitrogen Dioxide

Measurable concentrations of nitrogen dioxide were found in only 25 percent of the samples taken in the Delta and values ranged from 0.006 to 0.0002 ppm.

3.1.1.10.5 Hydrocarbons

Concentrations of hydrocarbons in the study region ranged from 0.3 ppm to 2.4 ppm with a high of 4.1 ppm in Inuvik. The U.S. Department of Health (1970) reports mean value for methane of 1.6 ppm at Pt. Barrow, Alaska. This is approximately the mean of the collected samples from the Delta.

3.1.1.10.6 Apparent Trends

Air quality parameters were consistent with results of limited studies in other northern environments. The highest concentrations of air quality parameters were recorded at Station 6 in the town of Inuvik.

3.1.2 Possible Effects Upon Atmospheric Conditions

3.1.2.1 Transportation

3.1.2.1.1 Roads

On all-weather roads, local air quality will be affected by dust loading and hydrocarbon exhaust emission from operation of construction machinery, routine traffic and support facilities. Most machinery will be mobile and not congregated for long periods while operating so that effects should be non-cumulative and widespread.

Each operating engine in summer or winter will act as a mobile point source of heat, carbon dioxide, carbon monoxide, oxides of nitrogen, sulphur dioxide, sulphur trioxide, water vapour and unburned hydrocarbons. Any long-term increases of SO_2 levels adjacent to these roads should be very small and of little significance. Levels of SO_2 along well-used winter roads at Taglu G-33 in the winter 1972 - 73 were very low (Vol. 7, Appendices 4 and 5).

During calm cold sessions when temperatures are less than $-35^{\circ}C$ (see section 5.2.4.1, Environmental Impact Assessment, Slaney, 1974 for probability of occurrence), some localized ice fog will prevail along roads, of heaviest extent near the largest sources of heated water vapour emissions. It should be no more obvious than what now occurs during winter gravel hauls for exploration drilling pads and islands, or that which occurs near urban centres.

Dust and other suspended particulate will be introduced into the atmosphere by movement of vehicles along roads or by scouring during high wind sessions. Dust levels will be less than along many non-surfaced highways and secondary roads elsewhere. Dustfall during calm conditions will be restricted to areas within about 1/4 mile of either side of the road (Arnold, 1961). Particulate and other debris uplifted by heavy winds will be redeposited several miles downstream from roads, but in small quantities because of the wide dispersion. Particulate re-deposition from roads on the surrounding snow cover will lower surface albedo (the fraction of incoming solar radiation reflected back into the atmosphere by the surface) and thus increase the rate of snow melt in spring. As a consequence, vegetation would be exposed sooner nearer roads than elsewhere. The overall effect will be offset by snow piling and drifts along immediate sides of roads, but beyond the piles would be noticeable. The "dirty-appearing" road drifts of snow may be sustained right up to break-up and spring flooding or beyond.

Similar effects of a localized nature and short duration will occur around staging sites, gravel extraction areas, airstrips, and pads.

3.1.2.1.2 Boats

Only small amounts of hydrocarbon exhausts will be vented from barges and boats. Local air quality will not be affected to a degree measurable by standard techniques. Any effects would be localized and of short duration.

Wind scouring of particulate materials off barges will be minimal because of full container transport practices.

3.1.2.1.3 Aircraft

Fuel exhausts and disturbance of looser surface particulate by moving aircraft will cause small changes in physical and chemical parameters of air around strips. Warm water vapour from exhausts will cause localized ice fog during calm conditions when air temperatures are below -35°C on the strip, especially during take-off and landing procedures when maximum thrust or reverse thrust are utilized. Lengthy warm-up times and excessive exhaust emissions from the aircraft have been minimized by conversion from piston to turbine driven aircraft.

A combination of uplifted snow and ice particles from the ground surface plus the ice fog production will restrict visibility, but would only make operations a problem if there was heavy sustained traffic during the very cold periods. If attempts are made to restrict vehicular traffic and reduce other water vapour emission sources near the airstrip during conditions when air temperatures are less than -35°C., cumulative effects will be reduced.

There will be some disturbance of loose surface material and reduction of visibility during take-offs and landings at heliports as well as some additional, well-dispersed hydrocarbon exhausts. Both effects should be localized and of very short duration. Sound levels about these pads will increase during take-offs and landings, especially for the larger aircraft.

3.1.2.2 Taglu Gas Plant

The presence of plant facilities will act to change the surface roughness, the surface albedo, the heat-storage capacity of the ground, and the convective nature of the atmosphere in the immediate vicinity of the plant.

The surface roughness effect will cause more turbulence in the wake of the plant and also areas downstream. Emission stacks will have to be designed high enough to avoid downdrafts in the module wakes so that exhaust plumes are not carried quickly to ground levels.

These effects are of little consequence except in terms of dispersal of gaseous emissions, and then only if harmful levels of emittants are produced during some extension of the current project.

Change of heat capacity and albedo of the plant site will create an urban "heat island" effect. Temperatures on the pad may rise several degrees higher than adjoining areas during calm sunny conditions. The excess heating will be produced primarily by the large areas of gravel and module structures which absorb and store heat better than vegetation or soil and which impede transpiration cooling (Hobbs et al, 1971). In summer, the combined effect of heat supplied from the pad and plant combustion exhausts could enable a strong convective plume to reach the lifting condensation level and trigger a small cumulus cloud either above or slightly downstream from the plant (Scorer, 1968). However, the normal occurrence of local cumulus cloud at these times is high so that the effect will, in most instances, go unnoticed.

3.1.2.2.1 Water Vapour Emission

Water vapour emissions from hydrocarbon turbing at the Taglu plant will cause additional hoar frost, slight rises in relative humidity, additional fogging, some reduction of net radiation to the ground, high potential for local ice fog and increased deposition of ice crystals around the plant. The following paragraphs discuss these possibilities.

Hoar frosts occur when air with a dew point below freezing is brought to saturation by cooling. The usual form occurs when calm damp air sublimates and forms interlocking ice crystals on exposed surfaces, especially twigs, branches and wires. Its texture is light and fluffy, usually causing no damage to any vegetation it covers. Increased winds or any physical disturbance soon remove it.

The frost that will build up from water vapour emissions and atmospheric conditions around Taglu Plant will be the light, fluffy hoar frost type. Calm conditions in April, May, September, and October will be times of the highest frost occurrences. Deposition of ice crystals on the ground surface will add some additional snow and ice crystal cover around the plant and would require a longer thaw period to clear the area of snow if thaw were completely dependent on isolation. However, associated deposition of dust and particulate on the snow from plant activities will decrease albedo and increase snow melt because of increased absorption. Also, spring floods on the floodplain usually occur before full melt conditions so that this effect will be minimized around the Taglu Plant.

The net effect of frost build-up on thaw rates will be slight in the vicinity of the Taglu Plant.

Relative humidity (R.H.) in the area of the proposed gas plant is high during the summer because of extensive wet ground surfaces. R.H. seldom drops below 85%. During stable atmospheric conditions, when moisture from the gas plant would have an opportunity to accumulate, the relative humidity approaches 100% with fog occurrences common. Results of additional moisture from the plant would be some local increases in fog density and occurrence. As a result, there will be some reduction in net radiation to the ground during stable conditions in the immediate proximity of the plant.

During highly stable conditions in the winter when air temperatures are below -35^{o}C, ice fogs will build up near the Taglu plant. Appendix 1 (Environmental Impact Assessment) Slaney, 1974, show detailed calculations for ice fog build-up around the Taglu plant. When air temperatures are consistently around -40^{o}C at the ground, winds are very light or calm and an inversion temperature gradient of 0.24^{o}C/m exists, an opaque disk-like cloud of ice fog will build up near the gas plant which, for all practical purposes, is unavoidable. If these conditions are sustained for periods of time, the radius of such a cloud will increase. At the Taglu plant, the ice fog radius would be approximately 1,500 meters after one full day and approximately 3,300 meters after five full days. The maximum height of such a cloud would be approximately 138 meters plus the height of stacks.

The probability of such extended periods was examined from 1972 - 73 winter climatic data collected in the vicinity of the Taglu plant site. Since ice fog forms for air temperatures -35^{o}C or less, the occurrence of such periods was examined. Number of full days with sustained ground temperatures -35^{o}C or lower was approximately nine days in January and seven days in February. Number of full five-day sustained temperatures -35^{o}C or lower was approximately once in January and once in February. The inversion temperature gradient was never sustained continuously at 0.24^{o}C/m during these periods, it was usually weaker but because there were several hours in some of the periods when this rate was reached, this was the value chosen in the calculations for extreme conditions.

The Taglu plant site is very flat with highest topographic features levees along the channels, so that the ice fog will form a disk-like cloud whose centre is the plant emission stacks.

3.1.2.2.2 Other Gaseous Emissions

Taglu Plant will disseminate other gases into the local atmosphere from the burning of condensate fuels. The primary components of exhausts from the turbine and other sources are detailed in Part 5.2.2.2, Environmental Impact Assessment, Slaney, 1974.

Over half of the discharging by-products will be excess air which is used to insure complete combustion of the hydrocarbons. To assess the effects of these emissions on the local atmosphere, maximum concentrations of NO_2 have been calculated at ground level for four kinds of "worst case" atmospheric conditions at two different times of year. The atmospheric conditions considered were: stable fanning conditions, fumigation conditions, unstable looping conditions and neutral coning conditions. The two times of year were the summer growing season and winter snow-covered season. Appendix 2 (Environmental Impact Assessment) shows the detailed calculations.

Because the terrain around the Taglu plant is reasonably flat, high winds with neutral stratification will probably cause the highest normal sustained ground concentrations (coning) since these are the conditions for least plume rise. Using 40 mph as the maximum mean hourly wind speed experienced at Taglu G-33 under summer conditions, the maximum ground concentration of NO_2 would be .0208 ppm.

However, fumigation has the distinct possibility of causing even higher concentrations but for shorter periods of time and because of the high stability in boundary layers of arctic air, the occurrence of such conditions at the Taglu plant would probably be higher than in more temperature areas, especially in early summer and early fall. During fumigation, ground concentrations of NO_2 could reach 0.506 ppm.

Under very stable conditions, the only source of mixing in a plume emitted from a stack would be supplied by its buoyancy (heat) and only until it reached its equilibrium height after which the plume would level out at relatively constant concentrations (Environmental Impact Assessment, Appendix 2; Figure 1). Under typical conditions for highest stability conditions in summer at Taglu site, the highest concentration of one of the plumes emitted would be 1.51 ppm NO_2 at a height of 105 m. plus stack height. However, there are no topographic features at this height in the immediate vicinity of the Taglu plant, so that there must be mixing (such as fumigation mentioned earlier) to bring it to ground level.

During unstable conditions, looping of plumes bring momentary bursts of high plume concentrations to ground level, only to be replaced by effluent - free air as corresponding loops go aloft. It is calculated that such loops could bring puffs of maximum ground concentrations of 0.302 ppm of NO_2 at a distance of 200 m. from one of the Taglu stacks.

Under winter conditions, the highest ground concentrations would arise after stable fanning conditions had prevailed and fumigation had brought the emission to ground level. Assuming air temperatures -40^{o}C, an inversion temperature gradient of 0.36^{o}C/m and calm winds, the equilibrium height would be about 70 meters plus the height of stack. Concentration of NO_2 in the fan would be 3.55 ppm and much less on the ground.

3.1.2.2.3 Noise

Plant noise will produce no atmospheric effect except to raise the ambient noise level in the atmosphere about each operation. Plant equipment will meet a noise emission standard of 85 dBA at a distance of three feet for the working levels.

The Taglu gas plant will be designed to meet a noise level of 65 dBA at a distance of 750 feet from the plant. The living quarters for the plant personnel will meet a noise level of 50 dBA.

3.1.2.2.4 Flaring

No liquid hydrocarbons will be flared at any time. If the liquid hydrocarbon disposal system is inoperative for any reason, the plant will be shut down once surface storage has been filled. Gaseous hydrocarbons will be flared from time to time to prevent over-pressuring a piece of equipment, or during plant start-up operations, will be scrubbed of liquid hydrocarbons. The flaring will be carried out in a tall flare stack so that dispersal of combustion products will be maximized. Noise levels will be high but in a range similar to testing at exploration drill sites.

Taglu Plant

Anticipated maximum emergency flare volumes and rates at the Taglu Plant are detailed in Part 5.2.2.4, Environmental Impact Assessment, Slaney, 1974.

As no oxides of sulphur are expected in the gaseous emissions, there will be no dispersal.

3.1.2.3 Clusters

There will be some additional exhausts from rig engines and heaters at well clusters during the drilling phase only but of no significance to the local climate.

3.1.2.4 Garbage and Debris Disposal

Solid refuse from all operations will be incinerated together with sewage treatment residual and the ash and remaining non-combustible solids buried in an approved land fill. There will be some ash and unburnt hydrocarbons dispersed from each incinerator during fire-up but the affected area will be restricted to the immediate vicinity. The gaseous and heat emissions should be readily dispersed by local atmospheric conditions at each cluster.

3.1.3 Mitigation Possibilities

3.1.3.1 Aircraft Traffic

Cumulative water vapour emission and thus visibility effects would be reduced by restricting vehicular traffic near the airstrip when air temperatures are less than -35^{o}C.

3.2 Terrain

The Taglu gas plant and its related facilities are proposed for the Delta floodplain immediately west of Richards Island. There, the terrain is flat, the soils silty and the floods and ice of the Mackenzie River are dominating features.

Mackay has classified physiographic regions of the Mackenzie River Delta. The region of interest is located mainly within the Pleistocene coast-lands (Region III) and the Mackenzie Delta (Region II) (Mackay, 1963).

Turbid floodwaters inundate the floodplain during spring thaw and some summer storms. Water-saturated and submerged soils on delta sediments are products of featureless landscape and the impermeable permafrost. On the uplands, cryopedological processes form and drain lakes, erect pingos, collapse hills and imprint diverse geometric patterns on the landscape. Vegetation in the study region reflects the mosaic assemblage of drainage, relief and substrate instability.

The project area is within the zone of continuous permafrost. Ground ice may be intimately mixed with surficial materials or segregated into almost pure ice formations as lenses, ice wedges, or ice pockets. The active layer is the portion of the soil which thaws each summer. The shallowest active layer occurs in organic soils with a dry surface.

Intense frost action within the active layer in the region of interest has resulted in thermokarst topography, patterned ground and pingos in the uplands. The thickness of the active layer was found to correspond with the depth of organic deposits on the surface.

Soil profiles were described in each mapping unit and soil samples analyzed for chemical and physical properties. Soil classification is according to the System of Soil Classification for Canada (Canada Department of Agriculture, 1970).

Observations to identify in a preliminary way surficial geology, landform and the occurrence of ground ice were made by representatives of Ripley, Klohn and Leonoff International Ltd. on the ground, from the air and by air photo interpretation. Results of all studies are in Volume 3 of Slaney, 1974. Summaries are presented in Figures 3 and 4.

In 1972, mapping and reconnaissance activities were concentrated around the Taglu group and three wellsites north and east of Taglu (Map 1A). Some reconnoitering of gravel deposits near Ya Ya Lake was included (Map 1B). Emphasis was placed on defining mapping units and describing soils.

In 1973, emphasis was placed on quantitatively describing the mapping units, supplementing soil data and mapping new areas.

3.2.1 Description of Existing Conditions

3.2.1.1 Cryopedology

3.2.1.1.1 Permafrost

The project area is within the zone of continuous permafrost (Brown, 1965). Permafrost is defined as a layer of earth material, often hundreds of feet thick, which remains below 32°F for at least 13 consecutive months.

Mackay (1963) describes extensive areas of permafrost in the Delta region in which the soils contain 50 percent or more ice by weight, where massive sheets (lenses) of ground ice up to 20 feet thick underlie many tens of square miles of Pleistocene sediments.

3.2.1.1.2 Active Layer

The active layer is the portion of the soil which thaws each summer. Soil processes (weathering, leaching, eluviation, etc.) are restricted to this layer. Intense frost action in this layer results in many types of patterned ground typical of arctic terrain (Washburn, 1956).

The thickness of the active layer is a function of the amount of heat absorbed by the soil and the manner in which this energy is dissipated (Vol. 3. Appendix 3-18).

Field checks during the summer showed that generally the active layer was from six to 36 inches thick. On esker ridges and on levees with a high siltation rate, no permafrost was detected within 36 inches of the surface. Permafrost does not occur under large lakes which are deep enough not to freeze solid in the winter. The shallowest active layer occurred in organic soils with a dry surface. On mineral soils, active layer depth was inversely proportional to the amount of organic material in the upper profile.

3.2.1.1.3 Distinctive Landforms

1. Pingos

A pingo is an ice-cored hill or mound forced up by hydrostatic pressure in an area underlain by permafrost. Pingos may range in basal diameter from 100 to 2,000 feet and in height from 10 to 150 feet. There are over 1,400 pingos in the Mackenzie Delta area (Mackay, 1963). They develop on lacustrine deposits when permafrost encroaches on a lake bottom previously devoid of permafrost.

2. Thermokarst Topography

Thermokarst refers to a surface subsidence resulting from melting of ice lenses in the permafrost. Much of the area has been altered by thermokarst. Thermokarst lakes develop on soils with a high ice content. Once equilibrium conditions are disturbed, e.g. climatic change or rupture of insulating active layer, ground ice may thaw with subsequent subsidence of the ground surface. Water impounded in the depression may act further to degrade the ground ice. Localized areas are presently undergoing thermal erosion because permafrost has been exposed to above-freezing temperatures. Permafrost around many lakes along the Mackenzie River and the Mackenzie Bay has been exposed by slumping.

3. Polygons

Polygons are a conspicuous type of patterned ground in poorly-drained areas. Polygons may be either low or high-centered. The low-centered polygons consist of central flat terrain enclosed by relatively dry ridges. The rims develop over ice wedges. During the winter, water-filled cracks freeze to form ice wedges. As these ice wedges grow, they push up the soil surface and linear ridges are formed. The intersecting ridges result in polygons 20 to 100 feet in diameter. Recurrent fractures cause ice wedges to grow, particularly towards the top.

4. Peat Mounds

Peat mounds are oblong formations three to ten feet in diameter and one to two feet high, which occur in the continuous permafrost zone. They occur in wet soils with large amounts of silt and are most common on alluvial deposits, particularly near low-centered polygons. In the region, they are found extensively on recent river deposits. Peat mounds were initiated as subsurface ice accumulated to produce enough pressure to buckle the active layer. They may continue to grow as organic matter is produced and permafrost develops in older peat. Permafrost is generally within six inches of the surface.

3.2.1.2 Surficial Deposits

Map 3-2 and Table 3-1 of Vol. 3 (Slaney, 1974) show the distribution of surficial deposits and the relationship of surficial features and vegetation, respectively. Much of the Delta region is overlain with Pleistocene fluvial, estuarine and morainal deposits, but westernmost parts, including the Taglu site, are part of the present Mackenzie River floodplain or modern Delta. The Pleistocene sediments have been called Old Delta or upland tundra. Relief is level to strongly sloping. Altitude ranges from near sea level at Taglu to over 100 feet near Ya Ya Lake.

3.2.1.2.1 Recent River

The Taglu area is part of the floodplain of the Mackenzie River. This landform is level and subject to flooding during spring thaw and periodically by storm surges. Large amounts of silt and clay are deposited every year. In many areas, there is standing water most of the summer. Low-centered polygons and peat mounds are common on these deposits. Vegetation on this landform in the region of interest is primarily sedge and willow.

3.2.1.2.2 Lacustrine

Much of the Delta region has been covered by thermokarst lakes which were formed when large ice lenses in the permafrost melted. Relatively few of these lakes now remain. Lacustrine deposits are found in the Ya Ya Lake region but not at the Taglu site. Soils on old lake beds are generally heavy (silt and clay) and relief is flat to gently rolling, hence these areas are poorly drained. High-centered polygons, pingos and meadows of sedges or cotton grass are indicators of these deposits.

3.2.1.2.3 Marine

Much of Richards Island was covered by sea water and has emerged only recently. The sea level relative to land has been constant for 8,000 years (Mackay, 1963). Estuarine sediments in northern Richards Island are sandy, relief is gently to steeply sloping and drainage is moderate. These are rare in the vicinity of Taglu or Ya Ya Lake. Vegetation on marine deposits is dominated by heaths and dwarf willow and birch.

3.2.1.2.4 Moraine

Glacial till was deposited as a thin, irregular layer over most of the study region. This overburden is generally stony clay, hence drainage may be impeded, but slopes are relatively well drained. Much of the permafrost has a high ice content so thermokarst topography is common.

3.2.1.2.5 Pleistocene River

Water-sorted materials from Pleistocene glaciers have been deposited as eskers, kames and deltas in many areas on Richards Island. The Ya Ya Lake gravels are found in this deposit. There are more in the Taglu area. The material ranges from sand to gravel, and is usually very well drained.

3.2.1.3 Soils in Vegetation Mapping Units

In Vol. 3 of Slaney, 1974, Part 5 and Appendices 2, 3, 4, and 18 provide information on soils of the region. Figures 1 - 4 inclusive show soil and vegetation relationships. Mapping units describe the project area relative to vegetation structure, plant species composition and landform. They are shown in Map 2A and 2B in this report and are described in detail within the section on flora (3.4). They also serve as a partial basis for describing the habitat of terrestrial fauna (Section 3.5).

3.2.1.4 Landform in the Project Area

3.2.1.4.1 Taglu Site

Unconsolidated silts and silty fine sands exceed 300 feet in depth. The active layer is generally 15 to 20 inches thick. The region is characterized by extensive areas of low-centered polygons which cover about 30 percent of the area (Vol. 3, Table 3-4 Slaney, 1974).

Along the river channels levees have been built to seven feet above low-water level. Bank instability is evident along the various channels. The river is simultaneously aggrading bars and undercutting banks along the edges of the channels, causing slumping and erosion in the latter case (Vol. 3 Photo 3-23).

Remnants of till plain over ice-rich estuary sediments form a ridge between C-42 and the drill site. The slopes of the ridge are moderately steep (18^o) and show evidence of active slumping. Several old slumps have been stabilized and are now vegetated with alder. An escarpment two miles east of C-42 marks the boundary of the modern river Delta.

3.2.1.4.2 Ya Ya Lake Gravel Site

Gravel is being excavated from an esker-kame complex. The area consists of gravel-sand hills and sandy river deposits. The gravel-sand hills include eskers and other glaciofluvial deposits as well as river terraces and moraines. Many of the gravel deposits occur in the conspicuous rounded edges or mounds.

High-centered polygons 20 to 30 feet in diameter have developed in many low-lying areas near Ya Ya Lake. The fissures delineating the polygons tend to be one to two feet deep and 12 to 18 inches wide. The high centres are vegetated with Carex aquatilis and willow; the fissures support mosses.

Ground ice conditions vary between the well-drained hills and the poorly-drained depressions. In the low-lying thermokarst areas, a hummocky topography has often developed as a result of subsidence and erosion where frozen sediments of ground ice has melted.

Both low-centered and high-centered polygons, varying in size up to 30 feet in diameter, occur in the corridor.

Most of the hills have gentle side slopes which appear to be stable. Most of the low-lying areas, although heavily affected by frost action, show little signs of instability. Instability is evident along some shorelines, river banks and sidehills which have moderate to steep slopes, where minor slumping and shoreline erosion occur, occasionally with a surface veneer of debris which also indicates instability.

3.2.1.5 Heavy Metals and Sulphur in Soils

Samples of soil, plants and animals were analyzed to establish indicative values for four metals and sulphur. Soil samples were collected at two sites on Richards Island; at Denis Lagoon and Taglu G-33 (Vol. 7, Map &-3). Six samples were collected in each area from the fibric organic soil layer. Methods used in collection and analysis are presented in Vol. 7, Appendices 7-13 inclusive of Slaney, 1974. Results are presented in Appendices 25, 29 and 33 of the same volume.

3.2.2 Probable Effects of the Project Upon Terrain

The proposed development will not have an extensive influence on landform. The preservation of stable slopes, control of erosion and avoidance of subsidence are all concerns of both the environmentalist and the engineer. The proposed development plan reflects this joint concern and has been contrived to prevent terrain instability. Some provisions have been made to circumvent potentially troublesome landscapes and a later phase of design should accomplish that to a further degree. Provision has been made to survey development sites to detect and prevent disturbance of unstable terrain. As far as can be determined at this point in time, the development will not initiate serious erosion, slope instability or thermokarst.

3.2.2.1 Transportation

3.2.2.1.1 Summer Road Construction

All-weather roads on the Taglu floodplain will cover approximately 10 acres of level land. Minor thaw depressions were observed at the toes of the gravel pads at drill sites. At the edge of the pads where the thaw depression was deepest, surface water in mid-summer was six to eight inches deep at D-55 but did not accumulate at G-33. In extreme cases, effects of the thaw depressions were seen 20 to 30 feet from the pads. A similar thaw depression may develop at the toe of road beds and other pads in the plant area.

The connecting roads at the Taglu gas plant will act as dikes that will somewhat alter flood patterns. Floodwaters moving around the edges of the dikes, and therefore, the amount of silt deposited annually in the protected area, will be both reduced. The area that may be involved is relatively small.

3.2.2.1.2 Winter Vehicle Travel

There will be no new winter roads associated with this project. However, winter vehicle travel associated with camp activity and construction of the Taglu gas plant and related facilities will affect a few acres of both high-centered polygons and low-centered polygons within the project area, shown on Map 1A.

Terrain characteristic of the Taglu floodplain is generally resistant to permanent damage from winter vehicle use, even after two winters' use (Bliss and Wein, 1972). The very wet soils freeze to form a solid substrate and, although surface vegetation may be killed by traffic, regeneration from the dense rhizome mat is usually rapid.

Gravel has been hauled from a Ya Ya Lake pit for the last several years. A short road leads to the lake edge from which point travel is via the channel. It is assumed that no new summer or winter roads are required to further exploit gravels for the gas plant.

3.2.2.1.3 Airstrip Construction

The airstrip at Taglu will intercept floodwaters in the manner described for summer roads. Although more acres will be involved, terrain effects are expected to be minor.

3.2.2.2 Well Clusters

3.2.2.2.1 Staging Site Construction

A dock and storage facilities will be built in the Taglu area. The Taglu site will cover mostly low-centered and high-centered polygons. The storage facility will cover approximately five acres. Effects on terrain will result from covering the landscape with gravel. Unacceptable complications involving landform and vegetation are not expected.

3.2.2.2.2 Cluster Pad Construction

In the Taglu area, the clusters will cover approximately 15 acres of low and high-centered polygons. Effects other than removing these acreages from vegetative production are not anticipated.

3.2.2.2.3 Drilling Sumps

Development plans for construction, maintenance and use of drilling sumps will be designed so that the facility will inflict minimal damage to terrain under normal circumstances.

3.2.2.3 Gathering Systems

Clearing Right-of-Way

Modification of slope or extensive removal of vegetation within the field gathering system right-of-way will not occur. At Taglu, the line from clusters to plant will be short and above ground.

3.2.2.3.1 Pile Placement

Machinery required for installation of support piles is similar to that used for seismic surveys. Consequently, the impact of this phase of development on the environment is expected to be similar to that of activities of seismic survey crews. It will be localized within the approximate 350-acre development area.

3.2.2.3.2 Field Gathering Pipeline Construction

Heavy equipment will be responsible for some destruction of surface vegetation on the field gathering facility right-of-way during winter operations. Regeneration of plants will be initiated the first summer and little or no thermal erosion should result. However, most heavy equipment will operate from an adjacent gravel area.

Recent reports on terrain degradation resulting from winter surveys suggest that permanent or progressive damage can easily be avoided during winter operations (Kerfoot, 1972; Lambert, 1972; Radforth, 1972). The summary development plan outlines precautions to prevent terrain damage.

Winter operation of heavy vehicles on tundra has been associated with exploratory drilling in the Taglu area. Some sites of intensive use can easily be seen from aircraft but many cannot. Ground inspection reveals substantial regeneration (20 to 30 percent ground cover) and no evidence of surface subsidence.

3.2.2.4 Processing Plant

3.2.2.4.1 Gas Plant Pad Construction

The gas plant facilities will remove from production about 15 acres of vegetation. Thermal erosion or major changes in drainage are not anticipated.

The Taglu gas plant will be located over low-centered polygons. A thaw depression along the toe of the gravel pad will increase water depth in a small area which will, in turn, have a small effect on willows. Proposed precautions against transmitting heat through the pad to underlying permafrost should be adequate.

3.2.2.4.2 Gaseous Emissions

Vegetation damage from gaseous emissions is not expected (see Section 3.4 in this report). Terrain damage is, therefore, not likely to occur.

3.2.2.5 Wastes and Effluents

3.2.2.5.1 Garbage and Wastes Disposal

Prospective landfills to receive ashes and cinders from the incinerator have not been identified, nor have the logistics involved in transporting ashes to the site. Environmental assessment of the impact of these activities must be postponed until the details are known. Cinders, ashes, etc. in the landfill will gradually be incorporated into the soil and may even improve some of the soil characteristics.

3.2.2.6 Gravel Excavation

Continued gravel extraction from esker-kame ridges near Ya Ya Lake will enlarge the existing pit to an undetermined degree. Additional pits may be required. Slumping, soil erosion and siltation could occur if ice lenses are encountered and pits are allowed to drain downslope.

3.2.3 Mitigation

3.2.3.1 Site Restoration

Removal of Gravel during Restoration

After perennial use by large machinery, gravel structures will have become highly compacted. If the gravel is not removed from the site, the surface will likely remain bare for many years.

If the gravel is removed in summer, the heavy equipment used would operate over adjacent terrain, compacting the soil and destroying the vegetation. Permafrost, which will have developed well into the gravel, will be exposed. Furthermore, the weight of the gravel over the ground will have compressed the soil so that the surface will likely remain bare for many years.

3.2.3.1.1 Grading

Grading abandoned development sites could result in the destruction of adjacent vegetation with the possible consequence of initiating thermal erosion. Restoration of development sites will be accomplished with minimum use of heavy equipment and no large scale movement of earth materials. Landfills and sumps will be filled with material from borrow areas if feasible, rather than grading adjacent earth.

3.2.3.1.2 Re-Seeding and Fertilization

Re-seeding disturbed areas with native grasses and amending the soil with fertilizers will increase the rate of re-vegetation in some areas. This procedure will be employed not only at the termination of the project, but also as a preventative measure on unstable slopes traversed by the field gathering system or by roads.

3.3 Hydrology

3.3.1 Existing Conditions in the Mackenzie Delta Region

The Mackenzie River is second in length only to the Mississippi River in North America. It has numerous important tributaries and an extensive drainage area covering 711,000 square miles of the Northwest Territories, the Yukon, British Columbia, Alberta and Saskatchewan (Map 2-3, Vol. 2). Point Separation marks the beginning of the Mackenzie Delta where the Mackenzie River separates into three main channels; Peel Channel, Middle Channel and East Channel. Before emptying into the Beaufort Sea these silt-laden channels further sub-divide into an intricate network of low-relief channels and lakes, characteristic of the Mackenzie Delta.

The seasonal hydrologic regime of the Mackenzie Delta is complicated by an intricate maze of channels, lakes and streams which redistribute its waters. The physical state of the moisture-laden surface is important for local wildlife, especially birds. In summer, river fluctuations flood extensive land areas and in winter the thickness and duration of the heavy ice cover affect transportation and availability of water to aquatic life.

Hydrologic data was collected for channels in the Taglu and Richards Island region of the Mackenzie Delta in 1972-73. Objectives and methods employed during this study program are discussed in Sections 1.3 and 1.4, respectively, of Volume 2, Slaney, 1974.

3.3.1.1 Physical Features

3.3.1.1.1 Channels

There are a number of channel types in the Mackenzie Delta as detailed by Mackay (1963).

Channel cross-sections are varied in shape and somewhat dependent on the channel type. Bottom profiles of reversing channels, tidal channels and many of the smaller channels from 100 to 200 feet across are smooth and broadly U-shaped. Larger channels, especially West Channel, have irregular bottoms.

3.3.1.1.2 Lakes

Delta lakes are usually shallow. Few exceed ten feet in depth when measured at low water. Depths at high water are much greater, and can be estimated by noting the high water marks on lakeshore willows.

The Delta lakes have been classified into five general groups by Mackay (1963).

Those lakes which flood yearly are either connected with channels or have low closures and receive yearly additions of silty flood water from the Mackenzie and Peel Rivers. Some seaward inundation from storm surges occurs along the distal edge of the Delta. In early summer, following break-up those lakes which have been flooded are easily recognized by their muddy waters which contrast with the unflooded clear lakes whose suspended sediment has had at least one winter in which to settle out.

A simplified system of lake classification is presented in Volume 6 (Slaney, 1974). Briefly, upland lakes are those located on sand and gravel formations and that are characterized by gravel shorelines and the high topographical relief of the surrounding terrain. Upland lakes are subdivided into three types: shallow lakes (isolated from channels and less than ten feet deep), deep lakes (clear water with transparency greater than 200 cm. and usually deeper than 20 feet), and channel lakes (two basins, one with upland lake characteristics and the other with floodplain lake characteristics). Floodplain lakes are located on clay-silt deposits and are subject to seasonal and storm surge flooding. The three types of floodplain lakes are: shallow lakes (isolated from channels and less than ten feet deep), salt lakes (occasionally flooded by the Beaufort Sea), and channel lakes (usually linked by river to channels and with turbid water).

3.3.1.1.3 Streams

The few streams in the region of interest are usually shallow (six feet or less in depth) and narrow (less than 50 feet wide). As a result, most freeze solid in late winter. They usually contain clear flowing water, and are bounded on one end by river channels or other streams, and on the other by a source region other than channels, e.g. lakes, other streams. Streams also differ from channels in that stream flow is normally one way, and is not usually affected by summer storm surges or high tides.

3.3.1.1.4 Watersheds

Map 2-4 (Vol. 2, Slaney, 1974) shows the present drainage pattern of lakes, streams and channels of the outer Delta. Boundaries delineate areas with similar drainage. In some cases a relief of a few feet can completely reverse the direction of drainage.

3.3.1.2 Freeze-up

With the approach of fall, river flow decreases and waters become more transparent. Freeze-up, usually defined as the time the river freezes over and the ice stops moving, begins on the Delta in early October when air temperatures stay consistently below 0^{o} C. Ice cover progresses fairly regularly upstream from the Delta to Great Slave Lake and appears to be more orderly than break-up (Mackay, 1963).

Mean freeze-up dates for Mackenzie River Stations are shown in Table 2-3 (Vol. 2). The yearly variation in freeze-up dates is much larger than that for break-up (± 2 weeks).

Freeze-up on the Delta is systematic. Shallow enclosed lakes are the first to freeze, then deeper lakes, followed finally by channels whose waters are well mixed and whose temperatures are dependent on atmospheric conditions upstream.

Ice Summaries and Analysis (Dept. of Transport 1964-69) showed that freeze-up in Mackenzie Bay first begins in areas around Northern

Richards Island in mid-October and gradually extends into Kugmallit Bay and Shallow Bay by early November.

Freeze-up, 1973 is described in Vol. 2, Part 3.4, Slaney, 1974.

3.3.1.3 Winter Conditions

After freeze-up, both ice thickness and physical characteristics become functions of temperature, snow cover, channel depth, mixing and other factors (Anderson and Mackay, 1973). In the southwest sector of the Delta where levees are higher, where vegetation is tall and dense, and where snowfall is relatively heavy, ice thicknesses are somewhat less than those measured on Richards Island (Anderson and Mackay, 1973).

Winter, 1972-73 is described in Vol. 2, Part 3.1, Slaney, 1974.
Winter, 1973-74 is described in Winter Supplement, Slaney, 1974.

3.3.1.4 Break-up

Break-up, or the first movement of heavy ice winter cover, on the Mackenzie River usually begins at its headwaters but does not necessarily progress continuously or sequentially downstream to the mouth (Mackay, 1963). The time of break-up at each river station is approximately the same each year with only about a one week variation. This variability is dependent on fluctuations of spring air temperatures from the norm. Table 2-1 (Vol. 2) shows adjusted mean break-up times for the ten year period 1946-55 (Mackay, 1963).

Mackenzie Delta break-up is complicated because the southwestern part is controlled by the break-up of the Peel River (not Peel Channel) and mountain rivers (e.g. Rat River), which flow into Husky Channel (Mackay, 1963). Peel River floodwaters are released about ten days before those of the Mackenzie River in the latitude of Fort McPherson. The sequence of break-up which occurs over several days is: Fort McPherson; Lang Trading Post; Aklavik; then Reindeer Station (Mackay, 1963). Table 2-2 (Vol. 2) shows break-up times for Inuvik Research Station since 1964.

Break-up, 1973 is described in detail in Vol. 2, Part 3.2, Slaney, 1974.

3.3.1.5 <u>Summer Conditions</u>

The Arctic summer is very short. Mean number of frost-free days range from only 50 to 70 days across Richards Island.

3.3.1.5.1 <u>Summer, 1972</u>

Few data were collected in the summer of 1972 and only in the vicinity of Taglu G-33. A depth sounding was made of the channel at right angles to the banks from a point about 200 meters downstream from the dock at Taglu G-33 (Appendix 2-1, Vol. 2). The deepest point, 6.5 meters (21 feet) was found about 30 meters offshore from the Taglu G-33 bank.

Preliminary short-term water level measurements were made of oscillations in Harry Channel level. Figure 2-3 (Vol. 2) shows the results for a week's period. Two types of variation were evident.

There was a general decrease of channel level (probably associated with either a reduction in Mackenzie River run-off or large scale wind effects) and superimposed over the average trend was a planetary tidal oscillation (25 hour period). The peak amplitude of the tidal oscillation was about 12 cm. (5 inches).

3.3.1.5.2 Summer, 1973

A more comprehensive observation program was established in summer 1973 and is described in Vol. 2, Part 3.3, Slaney, 1974. Figure 2-2 (Vol. 2) shows time series plots of water temperatures and water-levels at Harry Channel.

Water Flow and Discharge Rates

Sectional channel flow measurements were taken at two particular times in the summer of 1973. The first measurements were in early July after spring flooding and the second in early October just before freeze-up. The most pertinent locations were Harry Channel (1.5 km. upstream from F-43).

Table 2-7 (Vol. 2) illustrates the measured differences in total volume discharges between stations for both sessions.

Storm Surges

Figure 2-6 (Vol. 2), a large-scale representation of a surge on Middle Channel, illustrates the typical nature of most surges in the Richards Island region. First there is a rapid increase of the water level caused by the back-up of wind-driven waters from the Beaufort Sea; then, as the winds subside, a fairly rapid decrease of water level to the original bank levels, followed by a gradual decrease of water level over the next day or so to the original pre-surge level. The latter is gradual because flooded areas do not drain efficiently.

3.3.1.6 Water Quality

Spot sampling of certain surface waters and laboratory analysis of same was undertaken. Samples were collected during August and September, 1972; May and September, 1973; and January and April, 1974 at sites indicated on Map 7-2, Vol. 7, Winter Study Supplement (Supp.), Slaney, 1974. Standard water analysis tests plus organic carbon and ether extractible hydrocarbon tests were conducted. Volume 7 outlines analytical methods, collection procedures and chemical constituents.

3.3.2 Possible Effects of the Project

3.3.2.1 Transportation

3.3.2.1.1 Drainage Disruption

A depression may develop along skirts of roads and other gravel-based facilities which will affect local drainage patterns.

Depressions have already been observed around the gravel pads at Taglu G-33 and D-55. Under summer conditions, seven to eight inches of water accumulated as a moat around D-55 in a perimeter of about 20 to 30 feet around the outside edge of the pad.

This depression along the edge of the Taglu sites will divert some drainage parallel to roadways and edges, especially during spring flooding and storm surges when channels overflow.

The positioning of the support roads and the new airstrip will partially dam areas to the northern and eastern sides of the gas plant site from early spring flooding, however culverts will be used where practical.

The gas plant and camp area will cover about 15 acres of land and because of the thick gravel layer, may create a subsidence area along the outer perimeter. Major changes in drainage are not anticipated but there will probably be accumulations of water along the outer edges because of subsidence. Addition of insulation to the edge of the pads may alleviate this problem.

3.3.2.2 Gravel Excavation

3.3.2.2.1 Yaya Lake Area

Minor silting of the lake has resulted from the road and dock at the site of gravel operations. However, the natural sediment increase resulting from the channel breakthrough into the lower basin of Yaya Lake vastly predominates and appears to be the major source of Yaya Lake siltation (Vol. 6, Part 8). Continued or expanded usage of the gravel area will provide some potential for further siltation unless special measures are implemented.

3.3.2.2.2 Dredging

Channel dredging will create increases in local suspended sediments. However, increases will be generally overshadowed by naturally high sediment loads in all but late summer or fall. The seriousness of the hydrological impact will be in general determined by the amount of materials to be removed, the type of dredging process applied, and the timing and actual period of operation.

3.3.2.3 Processing Plant and Cluster Facilities

3.3.2.3.1 Water Supply

Water supply for the Taglu Plant will come from Kuluarpak Channel. Approximately 9,000 gallons per day will normally be required. Trim cooling in summer may require an additional 40,000 gallons per minute. Its removal will have no effect on channel levels or the local water table.

Winter studies indicate that Harry Channel flow stops by mid-winter beyond the junction of Kuluarpak, but that Kuluarpak flow is maintained (current readings of at least 0.2 knots in January, 1974 and in April, 1974). This would indicate a bountiful supply of water to the plant from the typically 20 to 30 feet deep channel.

3.3.2.3.2 Wastes and Effluents

Sewage treatment facilities and processes is covered in Section 2.3.8.10.

The emission of low B.O.D. effluent with reduced nutrient concentrations should not cause excessive eutrophication or reduced oxygen concentrations if ejected into the channels.

3.3.2.3.3 Emergencies

Failure of the gas production facility or a major part of it is remote. To a very large degree, proper design and construction will preclude major happenings of that nature. But experience has shown that emergency conditions are a feature of complex developments, however infrequent.

Contingency plans for blow-outs, sump failures, pipeline leaks and liquid storage failures are described in Section 2.4.3 of this application.

3.4 Flora

3.4.1 Existing Conditions

3.4.1.1 Arctic Plant Strategies

Arctic plants are adapted to their environment because their life histories, physiologies and growth forms enable them to take advantage of favourable conditions and avoid damage during adverse times. The major stresses on plants in these latitudes are drought and the short growing season. Mineral nutrition may also become restrictive on plant development. This is a discussion of plant biology as it relates to plant responses in an arctic environment.

3.4.1.1.1 Reproduction

Reproduction in arctic plants is primarily asexual by means of rhizomes, runners, etc. (Bliss, 1971). In many arctic environments seedlings are rare because of the low seed production (Mosquin, 1966), stringent environmental controls of seed germination (Amen, 1966) and high seedling mortality (Bonde, 1968). In the project region seedlings of sedges and grasses are common, but seedlings of woody plants were rare.

3.4.1.1.2 Plant Growth

During the short growing season, arctic vegetation produces between 40 and 130 grams plant material per square meter (0.01 to 0.03 pounds per square foot) (Bliss, 1962). Generally the plants have attained their maximum growth (height, number of leaves, flowers, etc.) within four weeks of snow melt (Johnson, 1969).

In the Delta, plant growth is greatly influenced by soil temperature. Cold soils reduce the efficiency of a root system to take up water and minerals and retard the plants' ability to incorporate the minerals into protoplasm (Dadykin, 1955). Permafrost impedes drainage and reduces the volume of soil available for root systems to exploit.

Light compensation point, light intensity (langleys per minute) necessary for net photosynthesis, is low for arctic plants. Daytime light levels seldom fall below these values during the summer (Volume 1, Meteorology and Climate).

Cold injury to plants is caused by desiccation and by mechanical damage when ice crystals form in the tissues as temperatures fluctuate across the freezing point. Even a thin layer of snow is effective in moderating these stresses. Consequently, the height of woody vegetation in the region often corresponds to the depth of winter snow accumulation.

3.4.1.1.3 Water Relations

Plants are exposed to dry conditions in the Delta even though most of the soils are imperfectly drained. This is due, in part, to the inability of roots to take up water in cold soils. Water stress becomes most acute in spring when leaf temperatures are high, but while the soil is still frozen. Snow cover alleviates this stress, and certain evergreens (e.g. *Cassiope tetragona*) can grow only where snow cover persists well into summer (Lambert, 1972). On sites which are blown free of snow for much of the winter, and where water availability is limited in the summer, plants often have a compact growth form (cushion plants) which generally increases resistance to water loss.

3.4.1.1.4 Nutrient Budget

In most arctic soils, nitrogen is the nutrient most limiting to plant growth (Babb, 1972; Haag, 1972). Although the atmosphere is 80 percent nitrogen, only a relatively few specialized organisms can utilize (fix) atmospheric nitrogen and make it available to other plants. Nitrogen-fixation is accomplished in arctic ecosystems by lichens, primarily, *Peltigera aphthosa* (Alexander and Schell, 1973), soil algae (Alexander and Schell, 1973) and soil bacteria (Stutz, 1973). There are several legumes in the region (Family Legumenosae, Vol. 3, Appendix 3-1) which presumably fix nitrogen although root nodules were not observed in this study. Alder has been shown to fix nitrogen (Zavitkovski and Newton, 1968) as well as species of *Dryas* (Lawrence *et al*, 1967).

Nitrogen may accumulate in soils. A measure of the nitrogen regime of soil is the ratio between organic carbon and nitrogen (C/N). In the study region the ratio is generally wide (greater than 50), indicating nitrogen-poor soils. In some soils, however, the ratio is well below ten (Vol. 3, Part 4.4 and Appendix 3-3; Slaney, 1974).

3.4.1.1.5 Plant Succession

The entire Delta became covered with ice during the last ice advance of approximately 44,000 years ago. Immediately prior, vegetation was similar to the present day (Terasmae, 1959). During the ice retreat, the land was vegetated from two refugia; the Richardson Mountains and the northern tip of Tuktoyaktuk Peninsula (Mackay, 1963). Up to about 6,000 years ago, the region was vegetated by a closed canopy spruce forest (Ritchie and Hare, 1971). Since then, the tree line has retreated so that closed canopy forest does not occur north of about 68° N. latitude. A detailed description of plant succession in the study region is given in Vol. 3, Part 4.5, Slaney, 1974.

3.4.1.1.6 Revegetation

There has been considerable information gathered on natural revegetation of disturbed sites on the tundra, the degree to which species invade and the rate at which revegetation occurs. When disturbance is restricted to the above-ground level, revegetation occurs fairly rapidly from roots and rhizomes. When the rooting systems are destroyed and revegetation cannot occur vegetatively, plants are able to colonize the bare ground via seeds.

Any major disturbance which destroys plant rooting systems over a large area inhibits natural recovery by vegetative means. In the tundra, when seeds are required for the establishment of colonizing species, the recovery rate is slow. Well-planned seeding programs can likely enhance the rate of recovery and, to date, some success has occurred in seeding trials (Vol. 3, Part 4.6, Slaney, 1974).

Plant regeneration in northern regions is generally slow because of low soil nutrition, low soil temperatures and short growing seasons. The rate at which vegetation recovers depends on the type and extent of the disturbance and the type of vegetation originally on the site. Most sites which have not been excessively disturbed will be revegetated within a few years without assistance (Hernandez, 1972). In areas where mineral soil has been exposed, where thermokarst has been initiated, or where slope stability is threatened, natural revegetation may be too slow to prevent accelerating damage. In these instances, artificial revegetation techniques may be important.

3.4.1.2 Vegetation Mapping Units

Mapping units delineate the vegetation of the region in terms of vegetation structure, species composition and landform. Maps 2A and 2B show the vegetative units around the plant site and at Yaya Lake. A detailed description of each mapping unit is contained in Vol. 3, Part 5, Slaney, 1974.

3.4.1.3 Vegetation in the Project Area

3.4.1.3.1 Taglu Site

The Taglu project site is at drill site F-43 (Map 2A). Vegetation in this area is described and compared to vegetation near other Taglu drill sites. Vegetation at G-33 and F-43 sites is similar.

G-33 is located on a gravel pad about five feet high and 12 acres in extent. The pad was constructed over sedge-willow and low-centered polygon mapping units (Vol. 3, Appendix 3-7). The vegetation immediately around the pad does not appear different from the vegetation 750 yards from the pad.

Vegetation north and west of G-33 is primarily sedge-willow and sedge-herb. East and south of G-33 the landscape is marked with low-centered polygons, much of it supporting peat mounds. Table 3-6, Vol. 3, compares vegetation in low-centered polygons with other mapping units near G-33. Polygon centers are vegetated with sedge-herb and the rims with sedge-willow vegetation.

F-43 and P-03 centers are located in low-centered polygon areas which are similar to the low-centered polygons near G-33. The land surrounding these polygon areas has been typed as a complex of sedge-willow and sedge-herb (Ws-Sh) for mapping purposes. These areas are primarily sedge-willow units with vegetation similar to sedge-willow near G-33, but there are many pockets of sedge-herb type vegetation scattered through the area.

Along the river channels, levees have been built to seven feet above low-water level. These are vegetated with willow-herb vegetation dominated by willow (32 percent cover) and several forbs (20 percent cover). The forbs are primarily Astragalus Williamsii and Equisetum arvense.

C-42 center is located on an abandoned channel meander which is vegetated with a sedge-herb vegetation similar to that found near G-33. The surrounding area is a mosaic of willow-sedge and sedge-herb as described for F-43 and P-03 areas.

Remnants of till plain over ice-rich estuary sediments form a ridge between drill site C-42 and the proposed plant site. The slopes of the ridge are moderately steep (18^0) and show evidence of active slumping. Several old slumps have been stabilized and are now vegetated with alder. Table 3-5, Vol. 3, lists cover percent of major species in the alder mapping unit on this ridge.

An escarpment two miles east of C-42 marks the boundary of the modern river delta. The escarpment is vegetated with alder. The morainal deposits forming the escarpment is vegetated with alder and dwarf shrub-heath. Table 3-7, Vol. 3, gives cover values of major species found in the dwarf shrub-heath mapping unit in this area.

3.4.1.3.2 Yaya Lake Gravel Site

Gravel is being excavated from an esker-kame complex. Xeric gravel vegetation on the crest of this landform is composed mostly of small lichen thalli. The most abundant vascular plants include Selaginella densa, Arctostaphylos alpina and Antennaria monocephala. Total vegetative cover is 41 percent. The active layer is in excess of 36 inches.

Dwarf shrub-heath (which develops on glacial and glaciofluvial material) and Eriophorum tussock (on glacial till) are the most common mapping units. Table 3-9, Vol. 3, compares the species composition of dwarf shrub-heath vegetation on both landforms.

Eriophorum tussock occurs in a drainage-directed mosaic pattern with dwarf shrub-heath. Co-dominant with Eriophorum vaginatum in many areas will be slow, and will not begin until after the facilities have been abandoned. The rate at which these areas become useful to birds and mammals will be determined by the availability of water and the addition of soil amendments.

3.4.2.1 Transportation

3.4.2.1.1 Road Construction

All-weather roads on the Taglu floodplain will cover approximately 10 acres of vegetation, of which 5 acres will be low-centered polygons, 1 acre willow-sedge and sedge-herb complex.

Vegetation on the floodplain is dominated by willow and sedges with forbs and horsetail associated in varying degrees. The relative abundance of willow and sedge is determined by the amount of siltation deposited by spring floods and the depth of water on the surface of the ground. Willows are relatively intolerant of standing water while water sedge requires it to some degree. These preferences are reflected in that willows grow on the rims of low-centered polygons and sedges in the centers.

Thaw depressions developed at the toe of gravel pads at drill sites G-33 and D-55. At the edge of the pads where the thaw depression was deepest, surface water in mid-summer was six to eight inches deep at D-55 but did not accumulate at G-33. In extreme cases, effects of the thaw depressions were seen 20 to 30 feet from the pads. A similar thaw depression may develop at the toe of the road bed that will encourage the growth of sedges but retard or eliminate willow. However, the vegetation around the pad at Taglu G-33 was not different from the vegetation 750 yards away.

Roads connecting the clusters with the Taglu gas plant will act as dikes that will alter flood patterns over a few acres. The amount of floodwaters moving around the edges of the dikes and the amount of silt deposited annually will be reduced. With reduced siltation, mosses, primarily Drepanocladus spp. will become a more important constituent of the vegetation. As the moss layer develops, the insulative properties of the surface will improve and a shallower active layer will result. The combined effects of an organic soil and a shallower active layer will be seen in a decline in abundance of willows and Carex aquatilis and an increased occurrence of Eriophorum angustifolium and forbs (Vol. 3, Part 5).

3.4.2.1.2 Travel

Most vegetation subjected to winter vehicle use will die. Sedges will regenerate each summer from rhizomes. Willows will recover, but less rapidly (Vol. 3, Part 4).

Off-road travel associated with construction of the Taglu gas plant and associated facilities will affect a few acres of floodplain vegetation. Most vehicle travel, however, will be on specially constructed all-weather roads.

Vegetation and terrain characteristics of the Taglu floodplain are generally resistant to permanent damage from winter roads, even after two winters' use. The very wet soils freeze to form a solid substrate and, although surface vegetation is killed by traffic, regeneration from the dense rhizome mat is usually rapid (Bliss and Wein, 1972).

3.4.2.1.3 Airstrip Construction

The Taglu airstrip and associated storage pads will cover about 15 acres of floodplain vegetation, consisting mainly of low-centered polygon units. The airstrip will intercept flood waters and produce long term changes in plant composition over a small acreage to the north and east (see Section 3.4.2.1.1).

3.4.2.2 Well Clusters

3.4.2.2.1 Staging Site Construction

A dock and storage facilities will be built in the Taglu area. The Taglu site will cover approximately 5.0 acres of willow-sedge vegetation. The effects on vegetation will result from covering the landscape with gravel. Complications involving landform and vegetation are not expected.

3.4.2.2.2 Cluster Pad Construction

In the Taglu area the clusters will cover some 11 acres of a complex of willow-sedge and sedge-herb and about 3 acres of low-centered polygons with peat mounds.

Effects other than removing these acreages from production are not anticipated.

3.4.2.2.3 Drilling at Clusters

If there were a blowout during drilling on a gas cluster, most of the gas would be vented to the atmosphere, while water, mud and condensates would be deposited on or near the drilling pad. Damage to vegetation and water bodies is expected but effects should be localized.

If the blowout was accompanied by a fire, vegetation over a large area could be affected along with local ice and snow cover.

An oil blowout could have far reaching consequences if escapement was great. Contingency plans for development drilling are being prepared and systems readied.

3.4.2.2.4 Drilling Sumps

Development plans for construction, maintenance and use of drilling sumps are designed so that the facility will inflict no damage to vegetation under normal circumstances.

Drilling sumps may contain materials potentially harmful to vegetation. If these materials are spilled onto tundra, the vegetation within a certain distance would be destroyed. For example, the drilling sump of an exploratory wellsite on the Taglu floodplain was inundated by a storm surge in 1972, sedges were killed in an area approximately ten acres in size. After one season, revegetation had begun from rhizomes. The toxic materials were presumed to have been washed away, diluted, or decomposed. A change in depth of the active layer was not detected (Environmental Impact Assessment, Appendix 4).

3.4.2.3 <u>Gathering System</u>

3.4.2.3.1 <u>Clearing Right-of-Way</u>

Slope modification or extensive removal of vegetation for the short field gathering system right-of-way at Taglu will not be required.

3.4.2.3.2 <u>Pile Placement</u>

Machinery required for installation of support piles is similar to that used for seismic surveys. Consequently, the impact of this phase of development on the environment is expected to be similar to that of activities of seismic survey crews.

Recent reports on terrain degradation resulting from winter surveys suggest that permanent or progressive damage can easily be avoided during winter operations. Pile placement may be through gravel pads in summer.

3.4.2.3.3 <u>Pipeline Construction</u>

In the Taglu area the short field gathering system right-of-way will parallel an all-weather road from plant to clusters. The road will be used by pipe-laying vehicles. However, some off-road damage to vegetation will occur.

Regeneration of plants will be initiated on the first summer and little or no thermal erosion should result (Vol. 3, Part 4, Slaney, 1974).

Winter operation of heavy vehicles on tundra has been associated with exploratory drilling in the Taglu area. Some sites of intensive use can easily be seen from aircraft, but many cannot. Ground inspection reveals substantial regeneration (20 to 30 percent ground cover) and no evidence of surface subsidence.

3.4.2.3.4 Pipeline Leaks

The effects on vegetation of exposure to natural gas for a short period would be minimal. Most of the gas would be vented into the air. If fire were associated with a pipeline failure, tundra immediately around the break would be damaged. The vegetation at Taglu is not highly combustible.

3.4.2.4 Processing Plants

3.4.2.4.1 Gas Plant Pad Construction

The gas plant, camp and fire stack will remove from production about 20 acres of vegetation. Thermal erosion or major changes in drainage are not anticipated.

The Taglu gas plant will be located over low-centered polygons. A thaw depression along the toe of the gravel pad will increase water depth in a small area which will, in turn, have a small effect on willows. Proposed precautions against transmitting heat through the pad to underlying permafrost should be adequate.

3.4.2.4.2 Water Vapor Emission

Vegetation is not expected to be seriously affected by water vapor emitted during normal plant operations. Parameters considered in this judgment include a possible change in relative humidity, production of limited hoar frost, and reduction of net radiation during the growing season.

Relative humidity in the area of the gas plant is high during the summer, seldom dropping below 85 percent (Vol. 1, Part 2). During stable atmospheric conditions, the only period when moisture from the gas plant may have opportunity to accumulate, the relative humidity is normally 100 percent and cannot be increased.

Incidence of hoar frost may increase within a small radius of the gas plant. The length of the radius depends on the duration of stable atmospheric conditions, but will not likely exceed two miles around Taglu. These extreme conditions will be observed only in mid-winter. Accumulation of hoar frost has not been shown to detrimentally affect plants. Its weight is never sufficient to break limbs, and it disappears rapidly when exposed to wind or sunshine.

Vapor emission will tend to stay near the gas plant during stable atmospheric conditions and may lead to the formation of fog. Inversions are common in winter and less common during the growing season. Since fog normally develops during an inversion at any rate, gas plant emissions are not expected to significantly increase its frequency of occurrence.

Ice crystals may accumulate on the ground near Taglu gas plant during winter operations, requiring a longer thaw period to clear the area of snow. If soil thaw were dependent entirely on temperature and insulation, the growing season could be delayed as much as two weeks. However, spring floods of the Mackenzie River usually remove final traces of snow on the floodplain and will largely negate the effects of this impact (Vol. 2, Part 3).

3.4.2.4.3 Other Gaseous Emissions

The devastating effects of air pollution on vegetation around large urban and industrial centers has long been recognized (Grindon, 1859). While damage was initially attributed to smoke and particulate matter, the several components of smoke have only recently been evaluated separately to determine the role of each phytotoxicity. Oxides of nitrogen have been discounted as major problems because toxic levels (over 2 ppm for several hours) are above any known ambient levels (Brandt and Heck, 1968). The photochemical smog complex, which involves nitrogen oxides, contains phytotoxins, primarily ozone and PAN (peroxyacyl nitrates). All available evidence from laboratory and field studies demonstrates that the principal air pollutant affecting vegetation is sulphur dioxide (SO_2).

Sulphur exists in fuels that may be imported from the south for use in some machinery. It has not been confirmed in Taglu gas or condensate. Lichens are not a conspicuous element of vegetation within three miles of the gas plant. No serious problem is expected.

Consideration of the potential effects of sulphur compounds on sensitive arctic plants is discussed in more detail in the Environmental Impact Assessment volume (pages 192-196).

3.4.2.5 Wastes and Effluents

3.4.2.5.1 Garbage and Waste Disposal

Prospective landfills to receive ashes and cinders from the incinerator have not been identified, nor have the logistics involved in transporting ashes to the site. Environmental assessment of the impact of these activities must be postponed until the details are known. Cinders, ashes, etc., in the landfill will gradually be incorporated into the soil and may even improve some of the soil's growing characteristics.

3.4.2.6 Gravel Excavation

Gravel extraction from esker ridges near Yaya Lake will destroy xeric gravel vegetation which has limited extent in the development area. Natural revegetation on gravel sites will be extremely slow.

Xeric gravel vegetation is composed of plant species which are typical of high arctic and alpine environments but are locally restricted within the development area. There are an estimated 400 acres of this vegetation type on Richards Island, almost all of which is in the Yaya Lake region. The gravel source identified by the proposal is already being exploited (D.I.A.N.D., 1974). Greater demands may be made concurrently by exploration programs, and further gravel sources may be required.

Severe drought conditions of esker terrain and poor nutrient status gravel soils will tend to retard natural revegetation. Snowdrifts may accumulate in some locales which will temper the environment to some degree. Abandoned gravel quarries in the vicinity are sparsely vegetated with legumes and grasses after nine years. Cushion plants have not become established yet, and only a few crustose thalli represent the lichen flora.

3.4.3 Mitigation

3.4.3.1 Site Restoration

3.4.3.1.1 Removal of Gravel During Restoration

After perennial use by large machinery, gravel structures will have become highly compacted. If the gravel is not removed from the site, the surface will likely remain bare for many years.

If the gravel is removed in summer, the heavy equipment used would operate over adjacent terrain, compacting the soil and destroying the vegetation. Permafrost which will have developed well into the gravel will be exposed. Furthermore, the weight of the gravel over the ground will have compressed the soil so that the surface will likely remain bare for many years.

3.4.3.1.2 Grading

Grading abandoned development sites could result in the destruction of adjacent vegetation with the possible consequence of initiating thermal erosion. Restoration of development sites will be accomplished with minimum use of heavy equipment and no large scale movement of earth materials. Landfills and sumps will be filled with material from borrow areas if feasible, rather than grading adjacent earth.

3.4.3.1.3 Reseeding and Fertilization

Reseeding distrubed areas with native grasses and amending the soil with fertilizers will increase the rate of revegetation in some areas. This procedure will be employed not only at the termination of the project, but also as a preventative measure on unstable slopes.

3.5 Fauna

3.5.1 Mammals

3.5.1.1 Status of Mammals in the Delta

Five mammalian orders are present within the project area: Insectivora, Lagomorpha, Rodentia, Carnivora, and Artiodactyla. These five orders were represented by a total of 17 species that occur regularly. A number of other species occur less regularly.

The main components of the mammalian fauna are typical of the arctic tundra. Nearly all the regularly occurring species are found in tundra habitats of both Eurasia and North America.

Because of the nearness of the tree line, the lynx, moose and other boreal species occassionally find their way into the project area.

Mammal studies were undertaken in the Delta in 1972 and 1973 as part of the environment study related to proposed gas development systems and are reported in Vol. 5, Slaney, 1974, and in Winter Supplement, Slaney, 1974.

3.5.1.1.1 Reindeer and Caribou

On Richards Island, 55 reindeer were seen in 1972 and 70 in 1973 (Appendix 5-6, Vol. 5). In addition, a few reindeer were observed in 1972 on Hooper and Garry Islands. Some individuals may have been recounted while others were missed, but total numbers probably do not exceed 150. Conversely, the managed herd number about 5,100 at the 1973 round-up (Stevens, pers. comm.).

Reindeer sighted on Richards Island during the summer were usually feeding in sedge-meadow or sedge-willow vegetation types or in low-centered polygons where sedges and willows are abundant. An examination of some of the areas in which reindeer were feeding showed that sedges and the young, tender parts of willows were eaten. Summer forage on Richards Island has been lightly grazed for the approximately 10 years since the main herd was moved to Tuktoyaktuk Peninsula, and appears abundant. Most of the reindeer seen in the study region during summer were within a few miles of Mackenzie Bay where reliable onshore winds offer relief from insects and heat.

In winter, the few animals present on Richards Island appear to make use of windswept hilltops for foraging and frozen lakes for loafing. In the winter of 1971 - 1972, most of the reindeer seen were resting on frozen lakes, while an aerial survey on April 29, 1973, found reindeer feeding on hilltops on the northern part of the Island.

Ground observations on the hilltops revealed that lichens and shrubs had been eaten; the most common lichen eaten was Cetraria cucullata. (See supplement volume for further information on winter food habits).

Winter Movements

On Richards Island, two herds of reindeer were seen on May 2, 1974. Both were near the east shore of Mallik Bay (Supplement, Map S-7). One was composed of 11 animals and the other had approximately 80, about 15 of which were calves. On the same date, tracks and feeding craters of one to two dozen reindeer were observed five miles east of Mallik Bay and the tracks and feeding craters of up to one dozen reindeer were located six miles south of Mallik Bay. Because it had been at least three weeks since the last snow or wind storm, both feeding areas could have been used by the same animals. The number of reindeer occupying Richards is probably less than 100. By May 13 the larger herd had moved about four miles south-south-east of their previous location, and on May 22, tracks indicated that at least some reindeer were dispersing northwards, west of Hansen Harbour.

Except for the few animals seen on Hooper Island in March, 1972, there is no indication of the reindeer of Richards Island using areas other than the North Head south of Grassy Lake for wintering. Winter feeding areas were widely spaced during each successive winter. Considering the few animals present and the large area involved, range conditions will probably remain adequate for many years. However, should the number of reindeer increase dramatically, other wintering areas would be required.

Disturbance Reactions of Reindeer

The Winter Study Supplement (Supp. Slaney, 1974) reports in detail upon reindeer reaction to disturbance by man.

3.5.1.1.2 Barren-Ground Grizzly Bears

It was estimated that at least 13 grizzly bears inhabited the region studied during 1972. An estimated 23 frequented the Richards Island region studied in 1973 (Vol. 5, Appendix 5-7).

It is believed that the bears on Richards Island are not part of an isolated population. Some movement may occur between areas, Richards Island and the Tuktoyaktuk Peninsula, for example. In 1972, two bears were seen on Kendall Island which is about one-half mile offshore. River channels do not constitute major barriers to travel.

By using radio-telemetry to track radio-tagged grizzly bears in southwestern Yukon Territory, Pearson (1972) found minimum home-range sizes to be about 27 square miles for females and about 114 square miles for males. As Richards Island and adjacent islands to the west have an area of approximately 800 square miles, it seems likely that some bears reside there permanently.

Most active dens were found on upland soils of Richards Island, where soil texture and landform are most suitable (Vol. 5, Map 5-5 and Figure 5-2).

Habitat Preference

Bears appeared to make use of different habitats during different parts of the year. In June and July, bears were seen in areas characterized by the interspersion of fluvial lowlands, meadows, and uplands, which would be expected to provide an abundance of sedges, herbs and moulting or nesting waterfowl. Most bears seen in August were in the hills around Ya Ya Lake or on low hills on the northeast side of Richards Island. In both regions, ground squirrels and berries are abundant.

Number of Bears Denning in the Study Area, Winter 1973 - 1974

On Richards Island, 10 bears were captured and tagged; and an eleventh bear was seen and photographed which was not subsequently tagged. Seven recently occupied dens were located and bears associated with three of these dens were identified (Supp. Map S-8). Details on captured bears and dens sites located in the study region are contained in Winter Study Supplement Part 8.4, Slaney, 1974.

Disturbance Reactions of Grizzly Bears

On Richards Island and the Tuktoyaktuk Peninsula in the spring of 1974, 14 bears were seen a total of 27 times (Supp. Table S-22). Because most bears were tagged, positive re-identification was possible. Although these bears demonstrated inconsistency in their reactions to aircraft disturbance, some trends became apparent.

Tagging, which is probably as severe a psychological disturbance as could be inflicted on a grizzly bear, appeared to have no effect on the bears' subsequent movements other than fleeing or hiding from aircraft when sighted. Most bears remained within a few miles of where they were tagged, and none had left Richards Island by the time the study was terminated.

3.5.1.1.3 Foxes

Colored foxes were seen commonly year-round in upland habitat throughout most of the region. Winter surveys indicated that they were associated with shrubby areas inhabited by ptarmigan (Vol. 5, Table 5-6). Arctic foxes were most common during winter near the coast, on floodplain habitats and on barrier islands (Vol. 5, Appendix 5-10). In summer, they were seen mainly in upland areas near the coast as well as the nearby islands.

All dens located in 1973 probably belonged to coloured foxes, with two possible exceptions. Coloured foxes were seen at all but three of the dens judged to be active. One of the three had coloured fox hair attached to bushes at the den site. White hair was found near the remaining two dens, although the entrances were the size expected for coloured fox dens.

Two white foxes were seen near Mallik Bay and one of them ran into a den in spring 1974. A black fox was seen at Kumak C-58, and the den west of the north end of Ya Ya Lake appeared to be in use by coloured foxes. During April and May, 1974, nine coloured foxes were seen on Richards Island. Three were in the Swimming Point Ya Ya Lake region, one was seen near Taglu G-33 and five were on the North Head. Two occupied coloured fox dens were located, one near Swimming Point and one south of Hansen Harbour.

Fox tracks were abundant throughout lowland and upland areas which were frequented by ptarmigan, the feather of which were found at one of the fox dens. Tracks and feaces showed that virtually all muskrat pushups had been investigated by foxes. The remains of a muskrat was found among fox tracks. Fox scats examined contained remains of small mammals, feathers, muskrat fur, fox fur, fox claws, and paper.

3.5.1.1.4 Arctic Ground Squirrels

On Richards Island, active burrows of arctic ground squirrels were most abundant in areas of sandy or gravelly soil covered with xeric-gravel or short dwarf shrub-heath vegetation. In addition, ground squirrels sometimes dug burrows in pingos and in the banks of thermokarst lakes where sandy deposits are covered by only a thin mantle of marine. Only a few old, inactive dens were located there. Ground squirrels were not found in floodplain habitats.

3.5.1.1.5 Muskrats

Results of current surveys showed that muskrat pushup densities in the region ranged from nil to moderate in both 1972 and 1973 (Vol. 5, Table 5-2). Densities observed in 1972 were lower than in 1973, partly due to survey conditions.

Not all lakes in the region support muskrats and distribution is intermittent. Lakes with muskrats were most frequently observed in southern parts of the region. Similarly, densities were generally higher in floodplain lakes closest to the tree line.

Upland and floodplain lakes at least seven feet deep and with banks suitable for burrow construction had highest densities of pushups (Vol. 5, Table 5-3). Floodplain-channel, upland-channel and salt lakes had nil to very few pushups. Lake size appeared to be important. Lakes smaller than 100 acres had densities of less than one-third those of larger lakes (Vol. 5, Table 5.4).

Floodplain lakes on the south end of Richards Island appeared to provide the best muskrat habitat, provided that they were not directly connected to river channels and were of a suitable depth (Vol. 5, Table 5-3 and Map 5-7).

Results of Spring Pushup Census and Ground Surveys, 1974

Muskrat pushups densities were roughly twice as high in 1974 as they were in 1973. This increase was fairly constant throughout the areas sampled, except that densities in lowland lakes of the Taglu Corridor increased approximately five-fold. For further details, see Winter Supplement, Part 8.5, Slaney, 1974.

3.5.1.1.6 Voles and Lemmings

Compared with other tundra areas, current small mammal densities in the Delta region are low. Krebs (1964) reported trap indices as high as 27 and 14 for brown and collared lemmings, respectively, in the tundra near Baker Lake, N.W.T. Highest trap indices for brown and collared lemmings in this study were 0.09 and 0.23 in 1973 and 0.78 and 0.66 in 1972.

In the region, the highest trap indices for red-backed voles, the most common small rodent surveyed, were 5.36 in 1972 and 3.46 in 1973. The highest trap index for meadow voles was 2.0.

Numbers of small rodents may be reduced to approximately the same low level each winter by the severity of the environment, regardless of fall populations. However, maximum numbers in the summer can vary. Martell found 1973 summer populations of red-backed voles in the Delta to be roughly twice those of 1971 and 1972 (Martell, pers. comm.).

Red-backed voles appear to be the most numerous small mammal in the uplands of the region, particularly the alder mapping unit (Vol. 5, Figures 5-4, 5-5, 5-6, and 5-7).

3.5.1.1.7 Beaver

Very few beaver live on Richards Island. No beaver colonies were found on Richards Island in 1972, although old cuttings were seen at Ya Ya Lake. Local trappers reported some recent beaver activity at Ya Ya and other lakes. Dennington et al (1973) rates Richards Island as Class 4, "insignificant beaver habitat".

3.5.1.1.8 Moose

Several moose were recorded in the Delta region during the course of study. On May 28, 1973, an adult antlerless moose was observed standing in several feet of water on an island seven miles northwest of Tununuk Point, and a large bull was observed 10 miles west of Parsons N-10. Winter moose pellets and evidence of moose browsing on willow were found south of Parsons N-10. A Canadian Wildlife Service habitat survey (Prescott et al, 1973) lists most of the study region as Class 4 moose habitat; "insignificant or nil moose wintering habitat - may be used in summer". A small area on both sides of the East Channel near Swimming Point, Holmes Creek and Petes Creek were listed as Class 3; "poor wintering habitat".

3.5.1.1.9 Muskoxen

The former range of muskoxen is given by Anderson (1938) as extending west to about Cape Bathurst and on the North Slope of Alaska. Hall and Kelson (1959) show their former range as extending along the coast of the Beaufort Sea, and Lent (1971a) shows the present range as including Richards Island and the Tuktoyaktuk Peninsula. However, no muskoxen were seen or reported in the study region.

3.5.1.1.10 Polar Bears

Polar bears were seen occasionally during this study, but only twice within the region. In March, 1972, investigators saw two polar bears approximately 60 miles north of Cape Dalhousie near open leads frequented by seals. Also in March, 1972, an occupied winter den was located on Hooper Island. An adult was flushed by seismic activity. On March 20, 1973, field personnel observed an adult polar bear several times on the ice between Rae and Hooper Islands. The bear made several threatening gestures, prompting the crew to take refuge in a truck. On March 22, 1973, a polar bear attacked two men, one fatally, at an exploration camp on Kendall Island. The bear, which had waited beneath a trailer, was found to be an old male in an advanced state of emaciation (Boles, pers. comm.).

During the late winter of 1974, four sightings of polar bears were reported near the Delta. On April 1, a large polar bear was seen about one-half mile north of Pelly Island. Two polar bears, a sow and a cub, were seen 12 miles east of Pullen Island on April 17, and one was seen three miles north of Pullen Island on April 21. On April 19, one polar bear was seen six miles south of Garry Island. A pilot reported that polar bears are seen frequently in open leads about 30 miles north of Pullen Island.

Records show that out of the quota of 17 polar bears killed by natives of Tuktoyaktuk in 1974, only one was taken near the Delta. This was a 600-pound male shot at Hendrickson Island. One bear was shot at Atkinson Point, four at Cape Dalhousie, one at Pelly Bay and ten at Baillie Island.

3.5.1.1.11 Black Bears

Although black bears have not been reported in the outer Delta, they are present around Inuvik in timbered areas. Black bear tracks were observed 58 miles south of Tununuk Point, where a trapper reported that a black bear had destroyed his fish nets.

A trapper from Tuktoyaktuk recalled seeing black bears at Anderson River, approximately 125 miles east of Parsons Lake. Barry (1967) mentioned a report of a black bear in the vicinity of Reindeer Station in 1959.

Jonkel and Miller (1970) state that, "Recent records suggest that black bears are extending their range northward" and that "the extension of the range of the black bear onto the tundra could be expected as a response to a general decline in the numbers of barren-ground grizzlies". In view of the above, black bears could occur in the study area if the grizzly population declined.

3.5.1.1.12 Wolves

Wolves, formerly scarce, were attracted to the east side of the Delta with the introduction of reindeer in 1935 (Porsild, 1945).

In 1972, a wolf was seen near Taglu P-03 and a wolf allegedly killed two reindeer on Pelly Island. In 1973, only two sets of tracks were seen, both south of Parsons Lake. Constant vigilance by the herders and local residents has reduced the number of wolves in the reindeer area according to Jacobsen (pers. comm.).

3.5.1.1.13 Coyotes

No coyotes were seen in the region during the regular 1972 - 1973 study period, although they may rarely occur. Tracks were seen near the reindeer herd on February 23, and the skull was collected from a coyote shot by herders. There have been no other published reports of coyotes in this area since 1927 (Porsild, 1945).

3.5.1.1.14 Lynx

No lynx are known to have been trapped in the outer Delta although two were sighted during the 1973 season. One was seen in winter between Taglu G-33 and Tununuk Point, and another was observed one mile south of F-36 on June 29. They occur more frequently south of the tree line.

In April and May, lynx tracks were seen south of Swimming Point and south of Ya Ya Lake. In both areas, tracks were in willow-dominated lowlands.

3.5.1.1.15 Weasels

Both the least weasel and the ermine (short-tailed weasel) occur in the Delta region, although the former is quite rare.

Two adult short-tailed weasels were seen. One was in an active fox den near Taglu F-43 and the other on the gravel pad at Taglu G-33. Four weasel tracks were seen in April and May. One was crossing the river near Swimming Point, one was in an alder mapping unit west of Swimming Point, and two were near Pullen Lake in hills covered with dwarf shrub-heath vegetation. The size of the tracks indicated short-tailed weasels.

3.5.1.1.16 Mink

Mink have long been an important furbearer in the Mackenzie Delta, with from 30 to 3,500 taken annually (Hawley, 1968). Most of the harvest, however, is taken outside the region of interest.

No mink were seen during the current study. The only evidence of their existence was a scat collected during the 1972 field season on Richards Island. Low small mammal and muskrat populations, scarcity of hares and seasonal unavailability of ground-dwelling birds perhaps combine to make the study region marginal habitat for mink.

3.5.1.1.17 Marten

Marten have not been recorded in this study, although they are trapped regularly in the treed portions of the Mackenzie Delta, Anderson River and Horton River. Although their normal range does not extend beyond the tree limit, they may be occasional visitors to the study region.

3.5.1.1.18 Wolverine

Wolverines occur throughout most of the taiga and tundra although their numbers are nowhere great. Barry (1967) saw a wolverine on Richards Island near Taglu G-33 and Kucera (1973) observed one southeast of Parsons Lake (67° 35'N, 132° 25'W). None were observed during this study.

3.5.1.1.19 Otter

In 1970 - 1971, an otter was sold at Tuktoyaktuk, and in 1971 - 1972 one was sold at Inuvik. There are no current records of otters in the outer Delta.

3.5.1.1.20 Fisher

There are no known records of fisher in or near the outer Delta.

3.5.1.1.21 Hares

In the summer of 1972, remains of two snowshoe hares were found on Richards Island, and in late April, 1973, snowshoe hare tracks were seen at Ya Ya Lake. Martell (pers. comm.) found snowshoe hares very abundant in the winter of 1971 - 1972, but very few in the winter of 1972 - 1973. He felt that the snowshoe hare population had crashed throughout the Delta region, and a scarcity of hares in the spring of 1972 was confirmed by a trapper from Aklavik. Snowshoe hare populations are well known to fluctuate dramatically in approximately ten-year cycles.

In April and May, snowshoe hare tracks were common in the willow-dominated riparian zones and lowlands around Ya Ya Lake, Richards Island.

3.5.1.1.22 Shrews

A single arctic shrew was collected from a wet polygon complex on Richards Island in 1972. Six shrews were trapped in 1973; five were arctic shrews and one was a masked shrew. All but one were caught in dwarf shrub-heat or alder mapping units.

3.5.1.1.23 Seals

Field investigators saw several seals during the study. In 1972, a bearded seal was seen in a channel near Taglu F-43 and Taglu G-33, and a harbour seal was seen near Taglu G-33. A trapper from Aklavik reported having seen a large seal, (probably a bearded seal), on a sand bar upriver from Aklavik. All identifications are tentative.

Ringed seals are the most common seal in the region of interest, ranging all along the Yukon coast, east to Banks Island, and beyond (Porsild, 1945; Hall and Kelson, 1959). They often ascend river channels in the Mackenzie Delta (Currie, 1964).

3.5.1.1.24 White Whales

Large numbers of beluga frequent the mouth of East Channel in summer. Their distribution and abundance are discussed in Vol. 5, Slaney, 1974.

3.5.1.1.25 Heavy Metal Content of Mammalian Tissues

Samples of mammal tissue were collected and analyzed for certain heavy metals. Methods are in Volume 7, Slaney, 1974. Results are presented in Appendices 18, 19, 27, 31 and 35 of that volume.

3.5.1.2 Mammals in the Project Area

3.5.1.2.1 Taglu Gas Plant

The Taglu Gas Plant is within the part of Richards Island used by the small herd of feral reindeer during the summer insect season. Reindeer use the lowland areas for feeding. The most heavily used areas are probably those near upland areas to the north and east.

The managed herd of several thousand reindeer, if again brought to Richards Island, can be expected to range in summer near the Taglu site. Two adult grizzlies, probably a breeding pair, were seen within two miles of the site of the Taglu gas plant in 1973. A sub-adult was also observed in the area and another sub-adult was seen to the west. The lowlands comprising the Taglu gas plant area are unsuitable for ground squirrels. The area also contains poor habitat for muskrats (Vol. 5, Map 5-7). Meadow voles can be expected to be locally common in lowland mapping units containing abundant sedges. Other small mammals are less common.

The Taglu gas plant area is mostly floodplain and not suitable for denning by foxes (Vol. 5, Map 5-8). However, in winter, both fox species hunt ptarmigan in lowland willow mapping units.

3.5.1.2.2 Ya Ya Lake Gravel Site

The Ya Ya Lake gravel site area is not used extensively by reindeer but would be made use of by the managed herd in summer. Grizzlies may be seen in this area after emergence and just prior to denning.

They also den in the region (Map 4B). Bears feed on ground squirrels and berries in this area in late summer. Several bears, both single and sow groups, were observed to the south and west, and tracks were measured nearby.

Ground squirrels are abundant in the Pleistocene glaciofluvial deposits of the Ya Ya Lake gravel site (Vol. 5, Map 5-6). The medium-sized upland lakes near the Ya Ya Lake gravel site provide moderately suitable habitat for muskrats (Vol. 5, Map 5-7). Ya Ya Lake itself offers poor muskrat habitat.

Red-backed voles are most common in high-centered polygon and alder mapping units with smaller numbers occurring in dwarf shrub heath (Vol. 5, Figure 5-6). Meadow voles are relatively common in willow-sedge mapping units (Vol. 5, Figure 5-7).

The Ya Ya Lake area during summer coloured foxes hunt in the upland areas which predominate. In winter, foxes of both species hunt ptarmigan.

Suitable for denning sites are found in the Pleistocene glaciofluvial deposits of the region (Vol. 5, Map 5-8). Numerous foxes and fox dens were seen a short distance to the north and northwest of the gravel site (Map 4B).

3.5.1.3 Effects of the Project on Mammals

3.5.1.3.1 Transportation

All-Weather Roads

In some years, managed reindeer will be on Richards Island but they will be there probably during the summer and usually near the coast.

Experience in Scandinavia and Alaska suggests that usual reactions of reindeer and caribou to roads which are raised above the surrounding terrain is to move along and try to circumvent them or to adopt them as travel routes (Klein, 1971; Child, 1973; Child and Lent, 1973).

Roads are short and close to cluster and plant facilities so will have little effect on reindeer movement. Any effect will be masked by the general effect caused by the presence of the plant and associated facilities.

Grizzly bears can be expected to feed close to the gas plant roads during poor light. Although they avoid being seen by people, grizzlies may sometimes cross moderately travelled highways (Pearson pers. comm.). For example, a radio-tagged female and cub frequently crossed the Alaskan Highway in the southern Yukon.

All-weather roads will make a small amount of land unavailable to voles and lemmings. Voles and lemmings probably will be reluctant to cross roads, especially in winter, but this effect should be no greater than on winter roads and seismic trails.

Winter Road Construction and Use

Winter roads along frozen channels will be used in association with the Taglu development. Most of the mileage will be the same as currently in use.

Winter gravel haul from Ya Ya Lake will not conflict with the few feral reindeer on Richards Island. At any rate, reindeer will probably habituate to vehicular traffic. They are accustomed to being closely approached by snowmobiles used during herding operations. They showed no concern in response to winter road traffic a half-mile away or to the approach of a Bombardier to within about 200 feet in February, 1974. Scandinavian experience also indicates that there should be no undue effect of traffic except for the remote possibility of animal-vehicle collisions in the darkness (Klein, 1971).

In winter, grizzlies will den in rough terrain and be generally unaffected by the Ya Ya Lake gravel haul. It is possible, however, that one or two could den near the southern portion of the route, and be later disturbed.

Bears are perhaps more easily disturbed while in their dens than is generally thought. Dormant bears are not truly hibernating; their body temperatures drop only a few degrees below normal (Folk et al, 1972). While bears at this time are lethargic, there is evidence that they are active within the den. While bears have been known to survive on the delta after emerging in February, animals roused in early or mid-winter could suffer privation and possibly die (Environmental Impact Assessment, page 247).

In summary, the possible fate of winter disturbed bears cannot be precisely predicted. However, there is concern that their welfare may be seriously affected. The Mackenzie Delta grizzly is of unclear taxonomic status, but few in number and valued as a resource. Special efforts to protect it are justifiable.

Airstrip Construction

Construction of airstrips will remove a small amount of land from production. During construction, there will be some noise produced by machinery; disturbance from this source will be similar to that of road traffic.

The main effect on reindeer will be the creation of an obstacle to movement. Only during summer will reindeer make use of Richards Island, and they will be usually concentrated along the coast. Only during episodes of southerly winds in the insect season (Late June to early August) would the reindeer come into contact with the airstrip. Any deflection of movement would be of no significance at any rate, masked by the effect of facilities and pipelines.

Other mammals are not expected to be adversely affected beyond the removal of a small amount of land from production.

Airstrip Use

The following discussion assumes that fixed-wing aircraft will fly at 1,500 feet or more except while approaching or departing an airstrip. It is further assumed that aircraft will be above 1,000 feet beyond four miles of the airstrip.

It is unlikely that reindeer will be affected much by small, propeller-driven aircraft (e.g. Twin Otters) further than 500 feet away (Environmental Impact Assessment, Appendix 9). The animals may habituate to the regular presence of aircraft as experience is gained.

In the Taglu area where only small aircraft would operate, initial potential zone of disturbance around the strip would not be more than 1,000 acres. As reindeer would normally be along the coast, interaction with aircraft using the facility would be rare.

Grizzly bears probably will not be affected much by small aircraft (e.g. Twin Otters) beyond 1,000 feet (Environmental Impact Assessment, Appendix 10). The area affected in the Taglu area would approximate 2,000 acres.

Other mammals are likely to be affected by aircraft use of landing strips.

Fixed-Wing Aircraft Flights

In the following discussion, it is assumed that pilots obey guidelines of 1,500 feet minimum elevation except when approaching or departing landing fields and remain within flight corridors.

Reindeer are unlikely to be disturbed by aircraft flying at 1,500 feet or more (Environmental Impact Assessment, Appendix 9). Reactions were variable, but some reindeer approached as closely as 600 feet did not react adversely. Few reactions of caribou to aircraft flying above 1,000 feet have been reported (McCourt, et al, 1974).

Grizzly bears are unlikely to be affected by aircraft flying above 1,500 feet.

No observations on the reactions of the other mammals in our area are available, but it seems unlikely that they would be affected by regular fixed-wing aircraft flights.

Heliport Use

This discussion assumes that helicopters will fly at 1,500 feet or more until they are within one mile of the heliports associated with the clusters and plants.

It is unlikely that helicopters will have any serious disturbing effect at altitudes above approximately 500 feet. Therefore, the reindeer probably would not avoid more than 0.5 mile around each facility, and perhaps then only for a short, initial period.

In the Taglu area, approximately 2,000 acres might be initially affected; the same acreage discussed under fixed-wing aircraft. Interactions would be rare, and only from June through August.

It is unlikely that helicopters at an altitude of 1,000 feet or more will have serious effect on grizzly bears (McCourt et al, 1974). Therefore, no more than an area of 1 mile around each facility would be potentially affected.

Helicopter Flights

The following discussion assumes that helicopters will fly at 1,500 feet or higher until they are within one mile of their destination. It is unlikely that helicopters flying at 1,500 feet or higher will disturb reindeer. Any disturbance which does occur will probably diminish as reindeer become more familiar with helicopter traffic. Observations on the reaction of reindeer to helicopters were made on only a few occasions and with only small groups of reindeer. Helicopters as close as 700 - 800 feet caused no apparent effect (Supp. Part 8).

Helicopters operating in accordance with guidelines requiring 1,500 feet minimum altitude should not disturb grizzly bears. Although grizzly bears are generally thought to be very sensitive to helicopters (U.S.D.I. 1971), this may not be a universal response. Bears which have not had unpleasant, close-range experiences with helicopters (and other aircraft) are not frightened by them.

In the course of a 1974 program to tag bears on the Delta, naive bears were approached to within 150 - 300 feet before they reacted negatively (Supp., Part 8). In contrast, bears which had undergone the trauma of being chased by a helicopter and shot by a tranquilizer gun started to run from helicopters 700 - 1,000 feet distant.

Normal helicopter traffic is unlikely to disturb foxes. Four coloured foxes observed from an altitude of approximately 50 feet during a search for fox dens, fled or retreated inside their dens. All the dens at which these foxes were resident were later revisited, and none were abandoned. It seems unlikely that more distant helicopters would cause harmful reaction.

No observations are available on the reactions of other mammals in our area to helicopter traffic, but it seems unlikely that there would be effects from normal flights.

So long as aircraft are maintained within the corridors and at the prescribed altitudes or greater, wildlife harassment will be minimal. But often pilots "go down for a closer look". Grizzly bears and reindeer are often conspicuous and inviting to airborne personnel. Harassment of reindeer on calving grounds could cause calf mortality.

Water Borne Traffic

Boats may occasionally encounter reindeer or grizzlies swimming in inland waters and may come close to them near waterways (Environmental Impact Assessment, Appendix 8). Such encounters would be infrequent. No adverse effect is expected if the boats approach no closer than 500 feet.

3.5.1.3.2 Well Clusters and Processing Plants

Site Construction and Use

The main effects of plant, staging, dock and cluster site construction and use on most mammals will be the removal of small amounts of land from production through the construction of gravel pads and the loss of fox and grizzly bear denning habitat at Ya Ya Lake.

Facilities may be obstacles to travel for reindeer but will only deflect, not halt, unherded movements. Herded movements will not be prevented as herders can take animals on other routes.

No fox or bear dens have been located in the area proposed for plant construction. None are expected on floodplain sites, but a few could have been missed on upland sites.

The full extent and location of new gravel pits (or extension of the existing one) is not known. Bear dens could be affected but no active fox dens have been located in the immediate area.

Noise and the Presence of Man

Reindeer probably will not be seriously affected by compressor noise or equipment. It has been reported that reindeer in Scandinavia approach so closely to tree-felling operations, despite the noise of chain saws and other machinery, that many are killed by falling trees (Klein, 1971). Caribou, on the other hand, avoided coming closer than about 1/8 mile to devices which created noises similar to those of a gas compressor, and they may have used areas within 1/2 mile less extensively (McCourt et al, 1974).

Bears can be expected to avoid areas closer than 1,000 feet from gas compressors. Ground squirrels are little affected by noise. For example, ground squirrels were living near the runway at the base camp at Tununuk Point. Other mammals probably will not be seriously affected by the sound of gas compressors or the presence of man.

Foxes physically displaced from dens could suffer a higher mortality rate. Denning sites appear to be limiting to some fox populations but not in the project area. In the floodplain, fox den sites are scarce. None are threatened by the plant layout.

Ground squirrels are abundant in areas where gravel is the substrate. The areas from which gravel is taken will probably remain unusuable by ground squirrels for several years (Vol. 5, Part 3). An area south of Ya Ya Lake which had been used as a gravel source several years previously and since abandoned, showed no signs of use by ground squirrels although they were abundant in adjacent areas.

Ground squirrels are abundant in the Ya Ya Lake area from which gravel will be excavated. There will be a loss of ground squirrels according to the extent of gravel excavation operations, at a rate of approximately 2.8 dens per acre.

Feeding Wildlife

While most camps on the Delta are kept clean, elsewhere in the Arctic garbage has been accessible to gulls, ravens, foxes and wolves. Some camps on the Delta have had "camp foxes" which are fed by camp personnel. If camps associated with the gas production development are maintained in a manner similar to the major camps of the exploration program, problems will be slight.

Improper personnel behaviour such as the feeding of animals should be kept to a minimum for the following reasons:

Adverse effects of feeding wildlife are dual: it affects both the personnel and the wildlife. Having scavengers around camp will increase the possibility of personnel encountering rabid animals. It could also be an attraction to larger carnivores - grizzly and polar bears - which may encounter personnel and require removal.

Fox populations which are built up around camps are vulnerable to trapping pressures. Also, if the food supply is suddenly withdrawn, a large fox population would move or suffer starvation.

3.5.1.3.3 Field Gathering Systems

Clearing Right-of-Way (R.O.W.)

Clearing activities may remove some of the higher willows in the Taglu area. This is not expected to affect mammals.

Pile Placement and Line Assembly

Pile placement and line assembly will take place in winter and will disturb vegetation and the insulating layer of snow. The effect on snow will last only for the season during which construction occurs. Local noise and ground vibrations will also result from construction activities, particularly pile placement. No significant effect on reindeer is expected. Any reindeer in the vicinity of these construction activities would probably be little disturbed. In February, 1974, the main reindeer herd was within one mile of pile driving activities and showed no concern.

There are no ground squirrels in the Taglu area.

Pile placement and line construction activities will affect small rodents in local areas by destroying the insulating layer of snow (Vol. 5, Part 4). This will make limited areas uninhabitable for these animals.

3.5.1.3.4 Restoration

Grading

Damage to pioneering vegetation likely to result from grading of gravel pads upon abandonment will adversely affect mammals which will or could be using it.

Re-Seeding and Fertilization

Some mammals may be attracted to the possibly luxuriant and nutrient-rich vegetation which would result from re-seeding and fertilization of gravel pads and disturbed areas. Small mammals (voles and lemmings) and possible reindeer would be attracted in this context.

3.5.1.4 Mitigation

3.5.1.4.1 Harassment of Wildlife

Even with tight internal controls on personnel activities, some harassment of reindeer and grizzly bears can be expected. An educational program is planned to reduce consequences of that nature.

3.5.1.4.2 Disturbance of Reindeer

Irregular loud noises could frighten reindeer and will be avoided when animals are very near. Sump blasting, for example, should be appropriately timed. Conversely, static noises from plant facilities should have little effect upon the animals.

3.5 Fauna

3.5.2 Birds

Two distinct topographic types exist in the northeastern portion of the Delta region. These consist of low-lying floodplains directly influenced by river waters and surrounding uplands remote from the river's influence. The combination of river action, thermokarst and poor drainage in floodplain areas creates a physiographic-vegetational regime distinct from surrounding upland areas not exposed to the river's influence. The occurrence of various avian habitats is closely tied to these two regimes.

In 1972, 1973, and early 1974, bird studies were undertaken in the project area. They are reported in Volume 4 and the Winter Study Supplement, Slaney, 1974. Activities included aerial and ground survey of staging waterfowl in the spring, aerial survey of breeding waterfowl and other birds, post-nesting survey of waterfowl, fall aerial survey of staging waterfowl, small bird breeding census, bird utilization interviews, and opportunistic observations on bird-noise-aircraft interactions.

3.5.2.1 Birds of the Outer Mackenzie Delta

Compared to other vertebrate populations of the area the bird fauna is rich, a direct result of the seasonal influx of migratory species. Of 95 species observed during studies prerequisite to the preparation of this environmental statement, only three were permanent residents, the rest migratory in some degree (Vol. 4, Appendix 4-1). Species were observed that represented nine Orders and 21 Families, but only

52 species (eight Orders and 16 Families) were recorded breeding in the area. Loons, waterfowl, shorebirds and seed-eating passerines were the most common birds, making up over 70 percent of the total number of breeding species. Insectivorous passerines were not numerous and other bird families were poorly represented (Vol. 4, Table 4-1).

3.5.2.1.1 Description of Avian Habitats

Vegetation mapping units, useful in describing bird habitat relationships, are described as "habitat types" in Volume 4, Slaney, 1974. Several aquatic types are added. Photographs and diagrammatic sketches of the most important habitat types are presented in Vol. 4, Figure 4-1, along with lists of characteristic birds.

Maps 3A and 3B show the distribution of habitat types at 1:50,000 map scale in the project area and around the Yaya Lake gravel site. For purposes of mapping, habitats were grouped according to basic similarities. The two major groupings are floodplain and upland habitats, described in Vol. 4, Parts 2.1.1 and 2.2.2 (Slaney, 1974).

3.5.2.1.2 Avian Distribution and Status

Spring Migration

The distribution and abundance of birds within the region during spring migration is variable in time and is the result of a complex of factors. Some species pass through on their way to more northern nesting areas, stopping only briefly in the study region. Others arrive and spend a short time in non-nesting habitats until the season advances. Some species, particularly passerines, arrive and immediately disperse onto nesting territories. Species migrating in large flocks may utilize limited areas intensively for short periods of time while non-flocking species tend to use widespread areas less intensively. The combination of these behavioral traits and habitat availability resulting from weather conditions affect distribution of spring migrants on virtually a daily basis. Spring arrival of species, distribution and habitat usage are detailed in Vol. 4, Part 4 (Slaney, 1974).

Reproduction

Volume 4, Part 5 (Slaney, 1974) contains a review of the breeding biology of the more significant birds of the study region. Emphasis has been placed on distribution, abundance and nesting phenology. Population density indices are also given where available.

Moult

Moult occurs in all birds at least once each year. Waterfowl lose all flight feathers simultaneously and experience a period of flightlessness. The timing of moult in waterfowl is closely related to reproductive activities. Non-breeding birds tend to moult at much earlier dates than breeding birds. In the study area, pintail drakes were first observed moulting in both 1972 and 1973 by the first week of July. Other dabbling species were observed moulting shortly after this while diving ducks, geese and swans retained powers of flight several weeks beyond the first of July. By the third week of August, most geese and male diving ducks were again flying. Some female diving ducks did not complete moult until early September.

The distribution and abundance of the more significant bird species in the study region are detailed in Vol. 4, Part 6 (Slaney, 1974).

Staging and Departure

The term "staging" is used to describe the unusually large concentrations of birds which occur prior to migration. Not all species form such concentrations and among those that do only certain species do so conspicuously. Within the study region, the most spectacular concentrations are those of snow geese, and much of the autumn work was directed to monitoring this species staging and departure. To monitor the abundance of this species and other larger birds, transect surveys were flown over the study region on a regular basis. The departure of smaller species was determined from ground observations conducted regularly in the fall. Staging and fall migration patterns of the more significant species are detailed in Vol. 4, Part 7 (Slaney, 1974).

3.5.2.1.3 Birds of the Project Area

Taglu Gas Plant Site

Bird species characteristic of floodplain habitats (waterfowl and shorebirds) were common in the Taglu area. Loons, sandhill cranes, gulls, terns and shrub-nesting passerines were also common. A breeding census plot was located in the F-43 area and during 20 hours of observation in early June, a total of 31 bird species were recorded (Vol. 4, Appendix 4-14). Estimated numbers of certain species and species groups present during the breeding period are included in Table 4-12, Vol. 4.

The two large shorebird species, Hudsonian godwit and whimbrel, were present in the Taglu area. Because they were not easily observed during aerial surveys and too widely dispersed to register accurately on the breeding census plots, no estimate of numbers was made. However, additional ground observations showed at least several pairs of godwits and whimbrel in the general area during the summer of 1973.

Spring Migration

Large numbers of spring migrants were not observed in the Taglu area in 1973. In 1972, however, migrant geese (black brant and snow geese) were recorded during the last few days of May and until June 3. Flocks numbering up to 200 birds were observed feeding and resting in flooded willow-sedge and low-centered polygon habitats. This use of inland areas may have resulted from the late break-up in 1972 which left coastal habitats more heavily snow-covered than usual. Larger concentrations of migrant geese were, nevertheless, located just north of the Taglu area in both years (Vol. 4, Map 4-2; Slaney, 1974). Moderate numbers of shorebirds were recorded during spring migration in 1972 but not in 1973.

Breeding Period

In June, the combined index for all species recorded on aerial surveys in the Taglu group was only 9.8 birds/square mile (Vol. 4, Appendix 4-12; Slaney, 1974). This was the lowest density index, at this time of year, in any area surveyed. Low numbers continued through the year. Sandhill crane and glaucous gulls, however, were numerous at Taglu, considerably more so than in other wellsite areas.

Moulting Period

Large numbers of moulting birds were not observed during aerial surveys and overall densities during July and August were slightly lower than those recorded in other areas. The relatively large numbers of sandhill cranes present during nesting remained with their newly-hatched young. Glaucous gull numbers declined during the summer (Vol. 4, Appendix 4-13; Slaney, 1974).

Fall Migration

The Taglu area is too far inland from Mackenzie Bay to experience a large influx of migrant geese in the fall. Large numbers of geese, especially snow geese, however, did pass just north of the area on their way to Shallow Bay and the North Slope from the northeast.

Wintering Birds

Willow ptarmigan, rock ptarmigan and the common raven are permanent residents while snowy owls and snow buntings spend most of the winter in the Delta region. None of the species were numerous in the Taglu area. Wintering bird species are described in detail in Vol. 4, Part 8, Slaney, 1974.

The Yaya Lake Area

The area supported high numbers of summer resident birds, but was not used by staging waterfowl in spring or fall. Summer populations included relatively high numbers of arctic loons, arctic terns, small shorebirds and passerines (Vol. 4, Table 4-17; Slaney, 1974).

Spring Migration

No large movements of spring migrants was observed in this area.

Breeding Period

The index for all large species observed during aerial surveys in June was slightly more than 20 birds/square mile. The most observed species were arctic loon, greater scaup, oldsquaw and arctic tern. The latter species was found nesting in a small colony in high-centered polygon near the wellsite. Conspicuously absent during the breeding period were geese. The most common breeding shorebirds were northern phalarope and common snipe.

Brood Rearing and Moult

The combined index for large birds was the second lowest of all areas in July (Vol. 4, Appendix 4-13). Particularly noticeable compared to other areas was the low number of whistling swans. However, the index for arctic loons with young was the highest of any area. Arctic tern numbers were high, reflecting both the presence of the breeding colony as well as their use of channel areas for foraging. There was no indication that significant numbers of waterfowl moulted within the F-36 area.

Fall Migration

Staging or pre-migratory concentrations were not observed near F-36. Resident birds appeared to leave singly or in small flocks.

3.5.2.1.4 Heavy Metals in Bird Tissue

Samples of soil, plants and animals were analyzed to establish indicative values of four metals and sulphur. Tissue from randomly obtained birds, small mammals, fish and whales was collected and analyzed. Results are contained in Vol. 7, Part 4; Slaney, 1974.

3.5.2.2 Possible Effects of the Project on Birds

The proposed development will have effects upon birds arising from the destruction or creation of avian habitat and the prevention of habitat use through disturbance. Habitat destruction will arise directly from the building of roads, gravel pads, docks and airstrips over existing natural vegetation and extension of gravel excavation (direct effects) while the movement of men and equipment at these locations will prevent the use of habitat by frightening birds away (indirect effects). The extent of the former will be limited to the specific development sites while the latter may be relatively widespread.

Estimates of direct and indirect effects of developmental activities on birds were based on: 1) bird densities in the area to be affected, and 2) reactions of birds to similar activities associated with exploration (See Appendices 6 and 7, Vol. 4).

3.5.2.2.1 Taglu Gas Plant

Construction of a gas processing facility with related well clusters, roads, gathering systems, camp storage and staging areas and airstrip in the Taglu area will result in the direct loss of 61.6 acres of floodplain habitats composed of low-centered polygon, willow-sedge and sedge-herb vegetation.

3.5.2.2.2 High Use Areas

Development plans as outlined to date do not impinge on high use areas, and thus immediate major impacts are avoided. Some high use areas may have been more extensive in the past and in fact may have included areas now proposed for development. No historical evidence has been uncovered to substantiate this hypothesis but it cannot be completely discounted. Snow geese are known to have used Big Lake and the coastline north of it for brood-rearing purposes, although in the two years of study for this project, no such use was observed (Barry and Spencer. 1972).

3.5.2.2.3 Species Involvements

Loons

Two loon species occur in the region of interest. Arctic and red-throated loons are common throughout the area and are found in approximately equal numbers wherever adequate nesting lakes are present. Numbers of loons affected by development can be generally assumed to be made up of equal numbers of arctic and red-throated species.

Swans

Estimated impact figures present for swans refer to whistling swans, the only species observed in the area.

Geese

Included under this heading are four species: Canada geese, black brant, snow geese and white-fronted geese. White-fronts were the common breeding species in the development area and make up the bulk of the geese listed in tables. Canada geese were not numerous and black brant and snow geese occurred in areas distant from proposed development.

Ducks

Fifteen duck species were observed in the development area, divided into two groups: dabbling ducks and diving ducks. Most numerous of the dabblers were pintails, American wigeon and green-winged teal, along with moderate numbers of mallards and shovellers. Most numerous diving species were greater scaup, oldsquaw and white-winged scoter. Other species were not numerous.

Distribution and abundance of each species has been outlined elsewhere but generally dabbling ducks were most numerous in floodplain areas and slightly less so in uplands. Diving ducks were noticeably more numerous in upland habitats on deeper lakes.

Large Shorebirds

Whimbrels and Hudsonian godwits are the only two species included in this group. Whimbrels occurred throughout the outer Delta, while Hudsonian godwits were restricted to floodplain habitats. Anticipated numbers of large shorebirds affected by the Taglu facility include approximately equal numbers of both species. A few pairs of each may be involved. The Mackenzie Delta is one of the few reported breeding areas of the Hudsonian godwit. Godwits were present throughout floodplain areas but were nowhere numerous. An order of magnitude estimate of the population for approximately 300 square miles of habitat surveyed was only 50 birds. Although not surveyed, an estimated additional 600 to 800 square miles of apparently good habitat is present elsewhere in the Delta. The species is not currently on an "endangered" list, but has been designated as "depleted". Numbers were reduced by hunting. Now fully protected, increases have been recently recorded in its winter range (Holloway, 1970).

Birds observed in the field were not particularly disturbed by nearby human activity but neither did they closely approach camps or pads except during migration.

While some reproductive habitat will be directly lost as a result of development, this will be less than one percent of that available within two miles of the development site. It is anticipated that godwits will be able to accommodate to disturbance to some extent after establishment of the gas plant and transport routes.

Small Shorebirds

Included in this category were nine species including plovers, sandpipers and phalaropes. Most numerous of these were pectoral sandpipers, semipalmated sandpipers and northern phalaropes. Moderate numbers of lesser yellowlegs and stilt sandpipers were also present. Small shorebirds were most numerous in floodplain areas.

3.5.2.2.4 Sound Emissions

Noise levels during gas plant operation are not expected to be greater than 65 dBA at a distance of 750 feet outside the gas plant lease boundary, and they will be generally constant except for flaring. Levels are not expected to adversely affect birds in the vicinity of the plant beyond the range of avian disturbance expected from other sources. Most bird species were observed to adjust to constant noise levels arising from drilling operations.

Observations elsewhere, near airports and similar gas plants, indicate many birds can adjust to the noise from large jet landings and take-offs and from plant operations.

The snow goose nesting colony south of Kendall Island is located eight miles from the proposed Taglu gas plant site. Assuming even an extreme reaction on the part of the geese, the colony should be well outside the range at which gas plant sound emissions will disturb them.

Judging from the results of the North Slope gas simulator work, some deflections of migrant birds may result from sound emissions. If such occur, they are not expected to involve large numbers as the main flight path during fall migration is along the coast, five miles north of the Taglu gas plant location.

Increased levels of sound are anticipated during "flaring" which will take place at irregular intervals depending upon operational difficulties. The extent to which flaring will increase sound emissions is not known but the magnitude should be similar to the testing process at exploration wells. High intensity sound emissions over short periods at irregular intervals could have a disturbing effect on nesting geese near the plant.

Unexpected noises could cause birds to leave their nests resulting in incubation failure and/or increased egg predation by gulls and jaegers. A study of gas compressor noise on terrestrial nesting birds in the Yukon indicated no short term effects on nesting success in Lapland longspurs, the only species numerous enough in the control and test areas to allow the drawing of conclusions (Gunn and Livingston, 1974). Observations of other species (green-winged teal, willow ptarmigan and whimbrel), although too few to be conclusive, hinted that gas compressor noises had little effect on nesting success. Nesting geese, on the other hand, can be expected to avoid or leave the proximity of facilities that produce very loud intermittent sounds during the critical few weeks of May and June.

3.5.2.2.5 Personnel Activities

Any impact on birds arising from personnel activities is expected to be minor by employing policies similar to those in use during exploration (i.e. no guns in camps). Non-consumptive use of wildlife near campsites by workers (photography, observation, etc.) may cause the destruction of a few nests but because of the difficulty in travelling over the existing terrain, this will be restricted to small areas. On the whole, such interest in non-consumptive use may have a net positive effect in that it encourages awareness of environmental concerns and provides a recreational outlet. Continuing educational programs will keep personnel environmentally conscious of their responsibilities.

3.5.2.2.6 Cluster Sites

Preconstruction activities and pad construction phases will be carried out primarily during the winter months. Therefore, no disturbance to migratory birds will occur during this phase of operation.

Development drilling activities and establishment of permanent facilities will occur on a continuous basis until completion at each cluster site.

Subsequent normal operation without intense construction and drilling activities may lessen effects on birds, but work-over drilling will continue for some time, likely for the life of the cluster.

Drilling of production wells at cluster and gas plant locations is expected on a regular basis for a period of two years after initiation, and intermittently after that. The effects of such drilling will be similar to those of construction in kind and degree, but will maintain the effects over a longer time span (Impact Assessment, Part 5.5, Slaney, May, 1974).

All drilling wastes will be disposed of in sumps which will be integral parts of cluster pads. High capacity sumps with adequate diking to prevent overflow in emergency situations or, alternately, inflow of high floodwaters, should effectively prevent escape of sump contents and subsequent harmful effects on bird populations and habitats. Upon abandonment of cluster sites, sumps will be covered. Although there is a chance for channel erosion in floodplain areas to ultimately release the contents, release would be sporadic and over a long time period and would not likely cause immediate effects upon birds.

3.5.2.2.7 Staging Site Use

Use of staging sites will maintain the direct and indirect effects of their construction. Cessation of use will stop indirect effects, but direct effects will remain for an extended period - until revegetation occurs. Use of abandoned gravel staging sites as nesting locations may be undertaken by some species - sandpipers, gulls, terns and perhaps geese. Many species may use grit as a digestive aid and pads as loafing spots after abandonment. White-fronted geese were using the abandoned pad at Taglu G-33 during spring migration, 1974.

3.5.2.2.8 Small Boat Traffic

Boat traffic on main channels will have little or no effect upon birds as few use main channels during the ice-free season. Restriction of boat traffic in small tributary channels will reduce disturbance to moulting waterfowl using those areas. Regulations against travel to or through concentration areas could further safeguard against impact.

Recreational boat traffic in small channels and lakes may be a source of harassment for some birds. Several bird species utilize areas adjacent to small channels for nesting and moulting. During the moult, waterfowl are particularly vulnerable to disturbance. White-fronted geese, for example, would readily desert traditional moulting lakes and channels in the face of only limited recreational boating. The large construction camp at Taglu will provide a potential for interactions of that nature.

3.5.2.2.9 Barge Traffic

Barges, because of size, are limited to the larger channels. Little or no disturbance is expected from this source because of low bird use of main channels.

3.5.2.2.10 Airstrip Use

Low level approaches and take-offs could add an additional area of indirect impact on local birds due to audio and/or visual disturbance.

3.5.2.2.11 Fixed-Wing Aircraft Flights

Effects on birds near landing sites have been included in the use of airstrips. Effects along flight routes away from activity centers are difficult to assess but are not expected to be of serious consequence.

Loons were observed to react by diving to aircraft operating at altitudes in excess of 1,000 feet but only when the aircraft was directly over their location, or nearly so. The duration of such a disturbance is brief and its effect upon normal activities is not expected to constitute a hazard to the birds. Loons, in fact, were observed to adjust completely to heavy aircraft traffic on Shell Lake near Inuvik.

Swans, ducks, cranes and shorebirds were never observed to react by flying or diving to aircraft flying over 1,000 feet from the ground. Geese were the only group whose reactions indicated they might suffer from aircraft over-flights. Reaction was strongest when birds were migrating, both spring and fall. Observations of nesting geese reacting to aircraft over 1,000 feet indicated geese were disturbed by the craft's presence but not to the point of initiating an escape reaction. It is unlikely that properly conducted flights along predetermined flight lines which avoid areas of concentration will adversely affect nesting geese. Operational plans which reduce the chance of disturbance offer the best course for the prevention of impact.

So long as aircraft are maintained within the corridors as described, wildlife harassment will be minimal. But often pilots of charter aircraft and helicopters "go down for a closer look". Over the snow goose colony, a single incident of this sort could result in an inordinately high egg predation rate. Repeated harassment would cause desertion of traditional nesting, feeding and staging areas by large waterfowl. This threat is not new, of course. It exists in conjunction with ongoing commercial and private flights.

3.5.2.2.12 Helicopter Flights

Properly executed helicopter flights following predetermined flight lines away from areas of concentration are expected to have effects similar to those outlined for fixed-wing flights.

At landing sites, the helicopter's ability to make a steep descent should eliminate approach area effects. Descent, even under adverse conditions, should be well within the boundaries of secondary effects already outlined for plants, clusters and other facilities where landing pads are located.

In some situations, helicopters may create bird disturbance at greater ranges than fixed-wing craft (Barry and Spencer, 1972). Observations in the study area in 1972 and 1973 indicated that when there was a difference in reaction to the two kinds of craft it was small. For this reason anticipated effects of both types of aircraft are considered equal when estimating impact.

3.5.2.2.13 Surface Waste Disposal

Transportation of solid wastes after incineration to a suitable landfill site should have little effect upon birds. Gulls and ravens may be attracted if materials are not immediately covered.

The release of relatively small volumes of process water and of camp wastes, after sewage treatment, is not expected to adversely affect birds. Lake enrichment could induce higher rates of productivity and food availability, but the total input of this nature will be at best local, and of minor importance.

Open water near sewage outlets is a possibility, at least for a period in early fall. A few swans and other late migrating waterfowl may be induced to delay their departure. Late hatched young, and unhealthy birds would be affected. While survival of these birds could be low, total numbers involved would not be large, and the overall effect therefore quite limited.

3.5.2.2.14 Garbage and Debris Disposal

With the exception of gulls (largely glaucous gulls) and common ravens, no birds will be affected by garbage disposal. Even in situations where stringent controls on garbage collection and storage are in effect, gulls and ravens can be expected to frequent camps. Ravens may, in this way, be further encouraged to forage over tundra regions in winter.

3.5.2.2.15 Yaya Lake Gravel Site

Excavation for gravel is presently underway at the Yaya Lake pit. This operation has created direct and indirect effects over a small area. Future mining will increase the direct effects proportionately to the extra surface area mined but indirect effects will increase only fractionally over those already present.

Revegetation of these areas is expected to be slow and even after abandonment bird use will be slight. In terms of the total area affected and present bird use, the overall effect of future activities will be slight. Abandonment is not expected in the forseeable future as gravel sources in this area are being used for a number of sources other than the one addressed in this report.

3.5.2.3 Mitigation

3.5.2.3.1 High Use Areas

Development plans as outlined to date do not impinge on these high use areas, and thus immediate major impacts are avoided.

3.5.2.3.2 Personnel Activities

Any impact on birds arising from personnel activities is expected to be minor by employing policies similar to those in use during exploration (i.e. no guns in camps).

High density waterfowl and colonial nesting sites will be avoided in season, however, and undue harassment prevented by regulation, if necessary.

3.5.2.3.3 Cluster Sites

Preconstruction activities and pad construction phases will be carried out primarily during the winter months. Therefore, no disturbance to migratory birds will occur during this phase of operation.

Upon abandonment of cluster sites, sumps will be covered.

3.5.2.3.4 Small Boat Traffic

Restriction of boat traffic in small tributary channels will reduce disturbance to moulting waterfowl using those areas. Regulations against travel to or through concentration areas will further safeguard against impact.

3.5.2.3.5 Fixed-Wing Aircraft Flights

It is unlikely that properly conducted flights along predetermined flight lines which avoid areas of concentration will adversely affect nesting geese. Operational plans which reduce the chance of disturbance offer the best course for the prevention of impact.

3.5.2.3.6 Helicopter Flights

At landing sites, the helicopter's ability to make a steep descent should eliminate approach area effects.

3.5.2.3.7 Surface Waste Disposal

Transportation of solid wastes after incineration to a suitable landfill site should have little effect upon birds.

3.5.2.3.8 Grading During Restoration

Removal of development facilities and pad materials will have short term effects similar to those described for their placement. Long term effects will be limited to the areas defined under direct effects and will lessen in time as revegetation takes place.

3.5.2.3.9 Reseeding and Fertilization

Plans include reseeding with native plants and using fertilizers to speed re-growth on affected areas, if necessary. If successful, this will return affected areas to a condition close to their original form and carrying capacity within a time period as yet undetermined.

3.5 Fauna

3.5.3 Aquatic Fauna

The fish fauna of the lower Mackenzie Basin has been described on numerous occasions since the 19th century (Macoun, 1888; Gilbert, 1895; Preble, 1908; Bethune, 1937; McAllister, 1962; McPhail & Lindsey, 1970). Hatfield _et al_ (1972) sampled fishes in the middle and lower reaches of the Mackenzie drainage system as part of a systematic inventory carried on by Stein _et al_ (1973), and Jessop _et al_ (1974) and (1975).

Published information on the aquatic invertebrates and plankton of the Mackenzie Delta is limited. Hatfield _et al_ (1972) recorded invertebrate groups taken from fish stomachs, and Walker (1943 and 1951) described the Odonata of the Mackenzie Delta region.

As part of the environmental assessment of a Mackenzie Delta gas development system, studies were made over a two-year period to identify distribution and abundance of aquatic fauna populations in the study region, and their potential interaction with the proposed development. Methods and results are incorporated into Vol. 6 and Winter Study Supplement, Slaney, 1974.

3.5.3.1 Aquatic Resources in the Outer Delta

There are three distinct types of aquatic bodies in the outer delta: channels, lakes and estuaries, which contain aquatic fauna.

3.5.3.1.1 Channels

General Description of channels in this region is given in Part 3.3 of this report and Vol. 6, Part`3, Slaney, 1974.

Channel gill netting was conducted in 1972 and 1973 to identify fish species distribution and abundance. Vol. 6, Tables 6-1, 6-2, Slaney, 1974.

The predominant species netted was the broad whitefish with arctic cisco and humback whitefish next in abundance. Other species taken include: least cisco, inconnu, northern pike, burbot, longnose sucker, boreal smelt, ninespine stickleback, lake chub, spoonhead sculpin, slimy sculpin and Arctic lamprey. Arctic char, shum salmon and flathead chub occur in the lowest reaches of the Mackenzie but none were taken in the channels netting program.

The negative results of the 1972 dredging program indicate that benthic fauna are scarce in the heavily silted outer channels - at best limited to a few favourable areas. The water analyses (Vol. 6, Appendix 6-4) Slaney 1974, show that the water temperatures, pH, alkalinity, hardness and dissolved oxygen remain relatively constant throughout the open water period. Plankton production in these waters is probably low as turbidity remains high throughout the summer. The channel waters sampled do not appear to produce large amounts of fish forage during the open water season.

The 1972 and 1973 catch records suggest that the numbers of fish that reside in the channels that were sampled, or that use them for migration on the sampling dates, are low. However, major runs of whitefish along the East Channel and into Holmes Creek are reported during the open water period. The runs are large enough to support domestic and commercial fisheries.

Other reports of fish movement in channels in the region include Stein et al, 1973, and Jessop et al, 1974.

None of the whitefish or cisco taken in the channels contained food items. Perhaps these fish do not feed "normally" when in the channels. This would not be unexpected as most of the dredgings taken in 1972 from the channels did not contain bottom fauna and high turbidity of the channel waters would discourage plankton production. Of the stomachs examined from the 1972 channels catches, one pike and one inconnu contained fish remains and two burbot stomachs contained mysids and isopods. All the other stomachs examined from channel catches were empty.

It was not determined if any of the fish species taken in the channels spawn there. Several of the coregonids characteristically spawn on gravel substrates in clear rivers (Berg, 1948-49 and Alt, 1969), and it seems doubtful they would have much success in the silt bottomed Delta channels during the open-water period. At this time, the substrates of the major channels are largely unstable, and fish eggs would be swept away or covered with silt.

Northern pike trout perch, lake chub, slimy sculpin and spoonhead sculpin may spawn in quieter sections. It is not known if spawning occurs in the Mackenzie Delta channels after freeze-up but the burbot may do so, as it is a late-winter spawner (McPhail & Lindsey, 1970).

3.5.3.1.2 Lakes

A general description of lakes in this region is given in Part 3.3 of this report, Vol. 2 and Vol. 6, Part 5, Slaney, 1974.

In this report, only those lakes close to or likely to be affected by the development or personnel activities are considered. These are Big Lake, situated near the development; Ya Ya Lake, and Lake 50 site of the gravel pit operation; and lake trout lakes possibly utilized for recreation by camp personnel. The latter include Lake 48 (Old Trout Lake), Lake 52 (Pullen Lake), Lake 8 (Ya Ya Lake) and Lake 18 (Denis Lake). Lakes in the northeast portion of the island are remote from the development.

Maps 5A, 5B, and 5C show the type and locations of lakes addressed in this environmental statement.

Throughout the 1972 and 1973 lake surveys, information was collected on basic water chemistry, plankton and bottom fauna composition (Vol. 6, Part 5.4, Slaney, 1974). Additional winter information was collected in early 1974.

Considerable increases in alkalinity, hardness and conductivity were evident in the winter samples as compared to summer samples. These are probably caused by electrolyte and nutrient concentration increases in lake water as these substances are lost from the upper layers during crystallization (freezing).

During 1972, plankton hauls were taken in Ya Ya Lake and Denis Lake. Pennate diatoms were abundant in the former and rare in the latter (Vol. 6, Appendix 6-12, Slaney, 1974). Copepods were abundant in both lakes, and rotifers in Ya Ya Lake. Cladocera were common in Denis Lake.

Bottom samples were taken with an Ekman dredge. Bottom fauna categories, numbers and lake designations are shown in Vol. 6, Slaney, 1974, Appendices 6-13 and 6-18.

Fish species and distributions are identified in Vol. 6, Tables 6-4 and 6-5, and on Maps 6-3 to 6-6, Slaney, 1974. As can be expected in a region with a diversity of habitats, populations of fish species were not uniformly distributed throughout the region.

The numbers and presence of migratory fishes in lakes probably varies during the year because of the life history of the species. Populations of migratory fish (broad whitefish, humpback whitefish, inconnu and least cisco) were found in Lake 44. The outflowing stream did not seem to permit fish passage between the lake and the channel under normal conditions. However, passage would be possible during the spring flood and storm surges.

Ya Ya Lake and Lakes 48 and 50 contain populations of both migratory and non-migratory fish. Broad whitefish, inconnu and probably humpback whitefish are migratory, and lake trout, pike and least cisco are non-migratory. A population of migratory least cisco in Lake 56, which connects to Ya Ya Lake, must move through Ya Ya Lake to reach the channel.

Age and growth data on species collected in the region were compared to that found in other studies of arctic and temperate areas (Vol. 6, Part 5.8, Slaney, 1974). Generally fish exhibit slower growth rates, increased age of maturation, and decreased frequency of spawning at more northerly latitudes. This is a reflection of less favourable climatic conditions and decreased lake productivity (Ryder, 1965). However, individuals of some species may live longer and attain greater sizes in arctic regions than in temperate zones.

During 1972, a total of 185 stomachs were found to contain food items. A listing of those items is given in Vol. 6, Table 6-7, Slaney, 1974). The data are combined in Table 6-9 with 1973 information.

Most of the fish that were weighed, sexed and measured during the 1973 field program, were also subjected to stomach content analysis. Of 1,008 stomachs examined, a total of 573 contained recognizable food items. Vol. 6, Table 6-8, shows a list of fish species sampled and the occurrence of organisms found in the stomach contents.

Most of the fish netted in the lakes program are known to use lakes for spawning; these include least cisco, lake trout, northern pike, longnose sucker and burbot. Broad whitefish, boreal smelt and inconnu were also netted in lakes in the study region. However, these species generally spawn in streams. Humpback whitefish may spawn in either lakes or streams, depending upon the population. Suitable spawning sites for coregonids and lake trout exist in all five lakes except Big Lake. Pike could utilize shallow vegetated areas of Big Lake for spawning.

Three species of sport fish, lake trout, inconnu and northern pike, were taken in delta lakes. Populations do not appear to be large and annual production is low.

Abrahamson (1969) reports annual lake trout production in northern lakes to be 0.5 pounds per acre in northern lakes. Using this estimate, the delta lakes will not sustain a heavy sport fishery because of their low productivity and small size. The northern basin of Ya Ya Lake will produce 1,000 pounds or approximately 150 trout per year as trout average 6 to 7 pounds. Pullen Lake and Lake 48 will produce 850 and 750 pounds or approximately 150 and 135 lake trout per year, respectively. Lake 50 does not sustain sufficient lake trout for a sport fishery. Populations of lake trout in general are vulnerable to over-exploitation.

Small populations of pike and inconnu occur in numerous Delta lakes, many of which are turbid. The pike are generally less than 2 pounds while inconnu reach 15 - 20 pounds.

3.5.3.1.3 Estuary

Studies of the Mackenzie Delta estuary were initiated in 1972 and are presently on-going in relation to offshore exploration activity. Details of the area and aquatic fauna resources are contained in Vol. 6, Part 6, Slaney, 1974. No part of the estuary should be directly influenced by the proposed gas development system.

3.5.3.1.4 Fishes and Fish Habitat Near Project Area

Kuluarpak Channel

Kuluarpak Channel is 200 - 300 feet wide. There are no shoals within the area. The bank vegetation is primarily sedge-willow. Water temperatures reached 18°C in July. The river is turbid throughout the summer but clears somewhat during the period of ice cover. Water chemistry data are tabulated in Vol. 6, Part 8.1.3 (Slaney, 1974).

Three gill-netting stations in Kuluarpak Channel were netted eight times, a total of 800 feet of net, in July, August and September. A total of ten arctic cisco, three broad whitefish, one least cisco, and two longnose suckers were taken.

The physical difficulties in netting the channels at most locations may account for the low catches. Fish species may occur in the channels on a transitory basis because of their migratory patterns. It is possible that humpback whitefish, cisco, inconnu, boreal smelt and pike also utilize Kuluarpak Channel at some time during the year. With the exception of pike and boreal smelt, all species may undertake upstream migrations to spawning areas throughout the summer and downstream migrations to estuarine overwintering areas in late fall and early winter.

Harry Channel

Harry Channel is approximately 300 feet wide within the F-43 area. Shoal areas occur along the river banks. River currents varied from 2 feet per second in early July to 0.7 feet per second in October. The substrate is silt. The river bank is covered with sedge-willow and sedge-herb type vegetation. Water chemistry data are tabulated in Vol. 6, Part 8.1.3 (Slaney, 1974).

Big Lake (Lake 44)

The physical, chemical and biological characteristics of Big Lake are detailed in Vol. 6, Part 8.1.3.1 (Slaney, 1974).

Lake 48

The physical, chemical and biological characteristics of Lake 48 are detailed in Vol. 6, Part 8.1.1.2 (Slaney, 1974).

Pullen Lake (Lake 52)

Physical, chemical and biological characteristics of Pullen Lake are detailed in Vol. 6, Part 8.2.1.1 (Slaney, 1974).

Ya Ya Lake (Lake 8)

Physical, chemical and biological characteristics of Ya Ya Lake are detailed in Vol. 6, Part 8.2.4.1 (Slaney, 1974).

Lake 50

Physical, chemical and biological characteristics of Lake 50 are detailed in Vol. 6, Part 8.2.2.1 (Slaney, 1974).

3.5.3.2 Effects of the Project Upon Aquatic Fauna

3.5.3.2.1 Transportation

Roads

At the Taglu gas plant less than one mile of permanent roads will be built. Siltation should be minimal because of the flat terrain. The effects of any siltation on the aquatic ecosystems should be slight at any rate, as floodplain waters are generally very turbid throughout the summer. The expected small quantities of additional silt should not increase the turbidities and silt loads of these waters beyond the range expected from normal conditions.

In spring and summer months, small amounts of silt may be washed out of the road bed gravel and will enter some of the lakes and channels adjacent to the road. Slumping for any reason should not be a major source of silt in floodplain areas.

Airstrip Construction

The Taglu airstrip may be a minor sediment source during its construction but this will have no effect on the aquatic communities of the river.

Dredging

At the present time, there are no identified dredging requirements. Dredging channels to improve access or as a source of fill material would displace large volumes of bottom sediments which may be expected to affect the aquatic communities downstream of the dredged areas.

Some change in oxygen availability could result, and migrating fish might possibly be deterred by this or increased turbidity.

Major migrations of fish were not noted in Harry or Kuluarpak Channels, but may occur. Dredging would have least effects during spring peak flows when natural turbidity is high or in midsummer when limited populations of fish appear to inhabit the river.

Barge Traffic

Some siltation of river channels may occur from minor bank erosion caused by the "wakes" of barge traffic. However, this effect should not prove serious as the channel waters are normally very turbid throughout the summer months.

3.5.3.2.2 Well Clusters

Well clusters will be contained within the general plant site and connected to the plant by approximately 500 feet of pipeline. Sump pits alongside the well clusters will be diked to protect against flood or escapement of contents.

Blowout of a Production Well

The probability of a blowout is remote.

If there were a blowout, most of the gas would be vented to the atmosphere, while water, mud and condensates would be deposited on or near the drilling pad. Damage to water bodies is expected but effects would be localized since much of the material would be contained by perimeter dikes.

An oil blowout could have far reaching downstream consequences to aquatic organisms if escapement was great. Contingency plans for development drilling are being prepared and systems readied.

Sump Failure

Drilling sumps receive many materials considered toxic to aquatic organisms at various concentrations. Some of these include hydrocarbons and heavy metals. A sump failure could release them into the environment. Immediate effects could be siltation of water bodies. Long range effects could result from the accumulation of toxic materials in aquatic biota.

Sump failures at exploration rigs operating in the summer have been known to occur on the Delta. Accidental release of materials from production well sumps would seem less likely, but nevertheless could occur. Distribution of the materials would be localized where perimeter dikes are in good repair.

Not all offsite pipelines would be within perimeter dikes. In the event of escapement of hazardous liquids to channels some impact on aquatic biota could occur. However, in channels, volumes of water are high and the dilution effect would be correspondingly high.

3.5.3.2.3 Processing Plant

Pad Construction

Little siltation of channels, rivers and lakes is expected from pad construction.

Dock Construction and Use

Some erosion will occur when dock facilities are installed, however, a much greater silt input will occur if channel bank stability is reduced and bank slumpage occurs. Minor sedimentation of the river should have limited effect on the aquatic community as the receiving water body is large and naturally turbid.

Some spillage of pollutants may occur during loading and unloading. Depending upon the nature and volume of the pollutants there could be impact on the aquatic community of the river.

Water Supplies

Water for the Taglu plant will be drawn from a river channel with little effect upon its aquatic ecosystem. It will require approximately 9,000 gallons per day.

It is unlikely that removal of water for camps and clusters will have any effect on the local aquatic ecosystem.

Maximum number of personnel at the Taglu plant will be in the order of 500 during the peak construction phase. This will require approximately 36,000 gallons per day at the site. It should be possible to obtain this amount from the Taglu channels without depletion. Following construction and drilling, personnel requirements for this installation will drop to 50 at Taglu. There should be no difficulty in meeting the water requirements of the processing crews at this location.

Gaseous Emissions

Gaseous emissions such as NO_x will be released in relatively small amounts by the gas plant and no adverse effects upon aquatic systems are anticipated. There will be no sulphur emissions.

Material Storage

Normal storage procedures preclude spills and leaks into aquatic systems. There should be no adverse effects produced from normal operation.

Liquid Storage Failure

The frequency of a significant storage failure cannot be determined because it entails the simultaneous failure of the diked perimeter of the facility. Chances of simultaneous leaks of storage containers and ruptures in dike walls are remote.

There could be stored on site substantial quantities of materials considered highly toxic to organisms. These include in order of decreasing toxicity:

- hydrofluoric acid
- hydrocarbon fuels
- ammonia
- hydrochloric acid
- glycol
- propane
- methanol
- brine

The extent of environmental damage caused by a spill will depend in part on how far it is dispersed. Therefore, prevention of dispersal to waterways is of paramount importance.

Personnel Activities

Development activities will bring fisherman to the vicinity of unexploited or minimally exploited fish populations. Lake trout populations will not sustain a heavy sport fishery.

Angling pressure has drastically reduced the lake trout population of Great Bear Lake, a huge lake in comparison to the lakes of the study region (Folk, et al, 1973). The potential exists for decimation of lake trout populations by recreational fishing unless controls are instituted.

In order to ensure an attractive recreational resource available for long term use, it may be necessary to establish a policy whereby all fish must be released.

Sewage Disposal

Domestic sewage will be produced in large quantities at construction camps and in smaller quantities at permanent camps. Large volumes of nutrients could cause eutrophication or reduced oxygen concentrations within the normal systems in winter. However, treatment should produce a low B.O.D. effluent with reduced nutrient concentrations.

Site Restoration

Module removal, gravel removal and grading could cause some siltation of the channels. Replanting and fertilization of sites may cause a small and temporary increase in productivity within aquatic systems, as fertilizer would be washed or eventually leached into the channels.

3.5.3.2.5 Gravel Excavation

Gravel excavation has been underway at Ya Ya Lake for several years and further exploitation is anticipated. Minor siltation of Ya Ya Lake has occurred from the road between the pit and the dock. This siltation is minor in comparison to that created by the breakthrough of the Mackenzie River channel into the southern basin.

If additional gravel requirements are satisfied in the Lake 50 watershed, care is required to avoid erosion and subsequent siltation.

3.5.3.3 Mitigation

3.5.3.3.1 Well Clusters

Sump pit diking will be adequate to prevent pollution during floods and pit design should prevent leaking of contents.

3.5.3.3.2 Processing Plant

To reduce bank slumpage and consequent spillage of pollutants, docking facilities will continue inshore to the top of the channel bank, and storage pads of service areas will be located some distance back from the crest of the bank.

3.5.3.3.3 Gravel Excavation

If gravel excavation in the Lake 50 watershed is necessary, precautions will be taken to prevent siltation of the lake.

3.6 Public Participation

The Imperial Oil Limited application for the proposed gas development in the Taglu area of Richards Island is but one part of the total potential gas development in the Mackenzie Delta region of the Northwest Territories. At an early stage in the development planning, therefore, the three companies with indicated gas reserves in the Mackenzie Delta, namely, Gulf Oil Canada Limited, Imperial Oil Limited and Shell Canada Limited, recognized the advantages of a co-operative approach to environmental and socio-economic assessments. This approach included a combined comprehensive environmental impact assessment of the total envisaged facilities and activities referred to collectively as the Mackenzie Delta Gas Development System. The nine-volume report detailing the environmental program was informally presented to various government agencies in the Northwest Territories, native groups, news media and the general public in the Mackenzie Delta communities at meetings held during the weeks of January 13 and January 20, 1975. These meetings were held in Yellowknife, Inuvik, Aklavik, Tuktoyaktuk and Ft. McPherson with presentations by producer company representatives speaking on behalf of the Mackenzie Delta Gas Development System proponents.

The format of the meetings included a 20 - 30 minute talk by an industry official supplemented by slides illustrating some design concepts of the proposed development as well as some key environmental assessments. This was followed by a government representative explaining the review procedure that the government had set up for the producer application. Scale models of well clusters, plant sites and a typical gas plant were set up for each meeting. Following the formal presentations, all meetings were opened for general questions.

Attendance at the meetings was as follows:

Yellowknife, January 15, 1975

Three sessions:

(1) D.I.A.N.D. Group (15 people)
(2) Local news media and press conference
(3) Territorial Council and staff members of Territorial Government (Approximately 35 people)

Inuvik, January 16, 1975

Three sessions:

(1) Committee of Original Peoples' Entitlement (COPE) and Canadian Arctic Resources Committee (CARC) (Approximately 15 people)
(2) Inuvik Town Council (Approximately 10 people)
(3) Public meeting (Approximately 85 people)

Tuktoyaktuk, January 20, 1975

Two sessions:

(1) Tuktoyaktuk Council (9 attendees)
(2) Public meeting (Approximately 100 people)

Aklavik, January 21, 1975

Two sessions:

(1) Aklavik Town Council
(2) Public meeting (Approximately 60 people)

Ft. McPherson, January 22, 1975

Public meeting

Most of the questions which were asked following the private and public presentations related to the socio-economic impact of the proposed development. Environmental concerns were, however, implied in questions primarily from COPE and CARC representatives on further development such as: "How much more seismic and drilling?" "How many more gas plants?" "How about oil development?"

The environmental program reports on the Mackenzie Delta Gas Development System have been submitted to the Berger Commission and it is expected these will also be subject for discussion in the public enquiry.

Additionally, the Northwest Territorial Government has established a Mackenzie Delta Assessment Group which is receiving input from communities on socio-economic costs and benefits of the proposed development. Insofar as environmental impacts infringe on local use of renewable resources, the meetings provide a forum for discussion by communities of their environmental concerns.

3.7 Existing Land and Resource Use

Renewable resource use within the region has been described in appropriate volumes of the environmental report series. Volumes 3, 4, 5 and 6 (Slaney, 1974) contain such sections and the material is presented here in summary form.

3.7.1 Population Centers

The proposed project area directly involves the land and resources of a small portion of the Delta. To provide perspective, the human population of the outer Delta is described in detail in Impact Assessment, Part 4.1, Slaney, 1974.

3.7.2 Resource Allocation

The outer Delta lacks a large scale resource based industry or substantial commerce. Some activities covered by permit or lease are identified in the following sections.

3.7.2.1 Land and Soils

The project area is encompassed by Land Management Zone 2 and as such is subject to the Territorial Land Act. Under these and other federal statutes, exploratory permits for hydrocarbons have been granted to several companies. Land use permits have also been extended for the quarrying of gravel. Gravel quarrying sites are currently in use in a small area north of Tununuk Point and an esker-kame along the south shore of Yaya Lake. A survey of possible gravel sites has recently been undertaken (Dept. of Indian Affairs and Northern Development, 1974). Seismic surveys are also being carried out in conjunction with hydrocarbon exploration.

3.7.2.2 Water Resources

The Mackenzie River is the major water source for most Delta settlements. There is some available groundwater in the region but it is not used for domestic purposes. Heavy silting of the Mackenzie causes its water to remain turbid and unsuitable as a potable supply throughout the summer, unless treated. However, in the winter the Mackenzie provides an adequate source of drinking water in most reaches (Supp., Part 5). Inuvik supplements a lake reservoir with water pumped from the river in the winter. Tuktoyaktuk uses a lake for its summer water supply. The water in Tuktoyaktuk harbour is mostly fresh in winter and is used by the community. Other Delta settlements pump water from under the river ice (Cooper, 1967).

3.7.2.3 Game Reserves

The General Plan map outlines the boundary of the Kendall Island Bird Sanctuary. All of Richards Island is also within the Reindeer Grazing Preserve. This preserve was established by the government in 1933 and enlarged in 1952 to cover 17,900 square miles. Hunting of reindeer, except harvesting by the herder, is prohibited, and caribou and grizzly hunting therein is subject to some control (Vol. 5, Part 6). The Kendall Island Bird Sanctuary was established to protect migratory birds that use the region. All bird species are protected within the Sanctuary and disturbances that might affect waterfowl production and use, such as low flying aircraft, are controlled (Vol. 4, Part 9).

3.7.2.4 Native Trapping Areas

Group trapping areas are negotiated every five years at a meeting of the Mackenzie Delta Trappers Association. Each community has a Trappers Council which is represented at meetings. The region north of Tununuk to the offshore islands is a group area assigned primarily to Inuvik and Aklavik hunters (Delta Group). However, Tuktoyaktuk trappers had traditionally hunted the North Point area and the offshore islands and currently retain the right to do so.

No official records are available as to the number or origin of trappers that used the region in 1972 - 1974. However, trapping effort was at a very low level in both years. One Inuvik trapper has taken muskrats from the area north of Tununuk during the last two years, while several others have trapped Ellice Island for foxes and muskrats. Inuvik sales from that area are down from a few years ago. Some casual trapping of foxes takes place by people travelling through the outer Delta. In 1972 and 1973, small numbers of foxes were taken around mainland camps and rig sites by travelling Tuktoyaktuk people, while very few were killed on the barrier islands (Vol. 5, Part 6).

3.7.3 Birds

The project area is a nesting ground for large numbers of migratory and resident species (Vol. 4, Parts 3 and 9). Geese, ducks and ptarmigan are most commonly hunted. Hunting is prevented in the

Kendall Island Bird Sanctuary which encompasses the area between Middle Channel and Harry Channel and north to Kendall Island. This includes the Taglu plant site.

3.7.3.1 Ways In Which Birds Are Used

Sale of migratory game birds is prohibited. Bird hunting is a traditional source of feed for natives and a recreational activity to both natives and non-natives.

Utilization of Mackenzie Delta birds occurs as consumptive and non-consumptive elements. Consumptive demands are made by native (domestic) and non-native groups (recreation) both in the Delta region and along the various flyways used by the birds. Non-consumptive demands (viewing) are high in southern parts of flyways.

Information on local utilization of birds was obtained from interviews with hunters, game officers, R.C.M.P., and from observations in the field. From these sources it appears that the use of avian resources in the general area is largely consumptive, and carried out mostly by natives. Even though hunting returns are undoubtedly incomplete, they probably represent the relative degree to which species are harvested. If so, it is clear that native hunters in the lower Mackenzie Delta concentrate their hunting efforts on ptarmigan and geese. Geese appear to comprise a smaller proportion of the harvest by non-native hunters.

3.7.3.1.1 <u>Domestic Hunting</u>

Domestic hunting in the study region is described in detail in Impact Assessment, Part 4.3, Slaney, 1974.

3.7.3.2 Recreational Hunting

Recreational hunting is described in detail in Impact Assessment, Part 4.3, Slaney, 1974.

3.7.3.3 Non-Consumptive Use of Birds

There is little doubt most of the non-consumptive utilization, or appreciation, of Mackenzie Delta birds takes place well south of the project area. A major component of this utilization is made up of active naturalists and bird-watchers. It is now realized that this group is both more numerous and spends more recreational dollars than do hunters (Myres, 1968). Another and more numerous group is composed of passive appreciators of nature. They do not actively pursue outdoor hobbies but they derive some pleasure from conspicuous natural phenomena, such as the migration of geese.

The non-consumptive utilization of birds south of the Delta involves various activities. These include excursions to parks, refuges, and natural areas where Mackenzie Delta birds may be observed. The objectives of such excursions are varied but the presence of large numbers of migrant birds is often paramount. For millions of North Americans, these are important recreational activities.

In the lower Mackenzie Delta, non-consumptive uses of avian resources appear to be of minor importance. However, tourism is growing in the N.W.T. The annual number of tourists has increased from 600 in 1959 to over 20,000 in 1972. At present, tourism in the lower Mackenzie Delta is limited by access. There is no road link with southern Canada, thus all tourists must come by air or by boat down the Mackenzie River. In addition, there is little accommodation for tourists outside the main towns. However, it is possible for tourists to get a glimpse of the Delta by taking the cruise boat 'Norweta' to Tuktoyaktuk. At the present time, the opportunities for local non-consumptive utilization of birds appears to be limited.

3.7.4 Mammals

3.7.4.1 Commercial

Many natives rely on trapping for a portion of their income. Hunting in the Delta is primarily of an opportunistic nature. The reindeer herd is a source of income for only a few residents of Tuktoyaktuk. However, it is an important resource since it is a local source of fresh meat.

3.7.4.1.1 Reindeer

The reindeer herd is currently managed by one Eskimo. In the winter season he hires three or four herders, but at the summer roundup many more are hired and may be paid in cash or meat (Vol. 5, Part 6).

Management problems and other difficulties saw the herd reduced beyond harvestable levels by 1968. The Canadian Wildlife Service took over management of the herd until it was sold last year. There are currently several thousand animals under management.

Historically, the herd was summered on Richards Island but in the last number of years, they have roamed the Tuktoyaktuk Peninsula (Vol. 5, Part 3). They are currently wintered near Parsons Lake, but cannot be sustained there each winter because of range limitations. The herd manager may use Richards Island as summer range in future, but apparently not in 1974 (S. Kangegana, pers. comm.)

Caribou have in the past associated with the main herd producing generally unidentifiable offspring. Caribou-reindeer mixed herds may exist in the taiga south-east of Eskimo Lakes. A small remnant herd of 75 - 130 feral reindeer, or perhaps reindeer-caribou crosses, is resident on northern Richards Island, and appears to be increasing in numbers (Supp., Part 8).

Over its 38 year existence, the herd has not been a profit-making venture, but revenue generated by the herd could increase when larger harvests are feasible. Reindeer carcasses are currently selling for 75 cents per pound in the communities of the Delta. Increased tourism in the north could generate income from reindeer souvenir products (Stager, pers. comm.).

3.7.4.1.2 Trapping

Most trappers earn relatively little from trapping but a few, particularly in recent years of higher fur prices, do well by northern native standards. Trapping is generally used to supplement income from other sources. Details on trapping in the study region are contained in Impact Assessment, Part 4.4, Slaney, 1974.

3.7.4.1.3 Hunting

Polar bears are hunted on the sea ice near leads. When a sighting is reported close to land, a concentrated hunt takes place. They represent a valuable source of income to the hunter who is lucky enough to kill one.

The white bears are and have been important both economically and culturally to natives, especially those from Tuktoyaktuk: "In the Northwest Territories about 20 percent of the polar bear pelts are retained for personal use as sled robes, sleeping platform covers, and occasionally, trousers, boots, or mitts. Fragments of hide are also used in icing sled runners, and commercially for the production of fishing flies ... approximately half of the meat is consumed by the Eskimos, the remainder being used for dog food" (Harrington, 1964).

Caribou are an important source of meat and income for Delta hunters. They are hunted by people from all communities during the summer in the Richardson Mountains and by Tuktoyaktuk people in the Anderson River area in winter. Since caribou hunting is restricted in the Reindeer Preserve, few animals are taken in the study region. In 1971-72 approximately 1,160 caribou of the Porcupine Herd were taken by people from Inuvik, Aklavik and Tuktoyaktuk. In the same year, 440 caribou were sold for about $25,000 in the Inuvik region (Kwaterowsky, pers. comm.).

3.7.4.1.4 Domestic

Few natives depend entirely on the land for their domestic needs but many supplement their diets with wild game. The white whale hunt is an important cultural activity that still yields large harvests. The 1973 harvest was approximately 177 animals (Slaney, 1974). Whaling camps are run from late June to early August. Aklavik hunters camp to the west of Shallow Bay at West Whitefish Station, Bird Point or Shingle Point. Inuvik residents hunt in Kittigazuit and Kugmallit Bays from camps based at Kittigazuit, Indian Camp and Whitefish Station or in Mackenzie Bay from a Kendall Island camp. Hunters from Tuktoyaktuk and Inuvik took the largest percentage of the whale harvest in 1973 (Slaney, 1974).

The ringed seal is the most common seal on the coast between Herschel Island and Cape Bathurst. A camp located on Herschel Island in 1964-65 is reported to have harvested 855 of these animals (Smith, 1965). They usually are either netted or shot and harpooned. Seals are also taken in open leads during October and November. Although seals are present off Tuktoyaktuk, few are taken by hunters (Abrahamson, 1969). Virtually none are taken in the Mackenzie estuary. The market for seal skins has been unpredictable in the last twenty years and this has discouraged an intense harvesting of several species. There were few seal skins sold in Delta Communities in the early 1970's (Foote, 1971).

Grizzly bears are taken infrequently in the Delta. Seven were reported killed by Delta region natives in 1972, from an area including the Tuktoyaktuk Peninsula and the Richardson Mountains. Fewer were killed in 1973.

3.7.5 Fisheries

3.7.5.1 Commercial

A commercial fishery for broad whitefish has been financed by the federal government. Processing is done at the mouth of Holmes Creek. Fish are netted in the creek and in adjacent sections of East Channel. The fish are gutted, frozen and sold locally in Inuvik. A commercial fishery at Tuktoyaktuk is not feasible as the annual yield is consumed by the domestic fishery (Abrahamson, 1969).

3.7.5.2 Domestic

Fish form a high percentage of northern diets and are eaten raw, dried, and frozen as well as cooked. Fish are also used as a major source of dog food. Therefore, domestic fisheries play an important role on the Delta. Fish species most frequently netted in the 1973 season included broad whitefish, inconnu and some humpback whitefish.

Few fish are caught for any purpose in the area to be directly affected by the hydrocarbon development project. However, important fish species may migrate seasonally through the nearby Harry and Kuluarpak Channels.

3.7.6 Effects Upon Human Use of Resources

The possibility of induced change in resource use patterns is considered in this section.

3.7.6.1 Birds

3.7.6.1.1 Domestic Waterfowl Hunting

The taking of geese and other waterfowl by native peoples of the three Delta settlements will be essentially unaffected by the project as understood at this time. Traditional hunting areas are the coastline west of Tuktoyaktuk, mouth of East Channel, Kendall Island, Ellice Island, the coastline west of Shallow Bay, and the main Mackenzie River channels south of the development area; they will not be directly subject to staging areas, gas plants, clusters, or gathering systems.

Boat traffic in hunted regions, including East Channel, will occur essentially at non-conflicting times of the year, or will be of no greater magnitude or frequency than experienced at present.

Air traffic in designated corridors and at regulated heights will not disturb flocks normally pursued by native hunters. Unauthorized flights over hunted areas could cause local changes in feeding patterns, and in extreme cases of harassment, temporary abandonment of feeding areas. Hunters in the field would be inconvenienced. Unauthorized overflights and harassment (although contrary to the Migratory Bird Act) are expected to be more frequent than at present - in direct relation to the use of charter aircraft and private aircraft in the area. Company aircraft will be under control and should present little interference.

3.7.6.1.2 Domestic Ptarmigan Hunting

Willow ptarmigan are hunted in willow thickets near Tununuk Point and Yaya Lake during March and April. In 1973, hunters, probably from Tuktoyaktuk, harvested most of the birds. In 1974, most birds were taken incidentally by Inuvik trappers based at Yaya Lake. Such activities will not be seriously affected. More frequent channel ice road truck traffic is anticipated during construction years, but hunting has not been prevented by currently heavy exploration traffic. The birds are not likely to show a markedly different response at the new level of traffic.

3.7.6.1.3 Cultural Change

A second order, social effect of the hydrocarbon project, may have greater consequence to traditional bird hunting than any other factor. To the extent that local native people accept full-time employment opportunities with the project, subsistence hunting of birds will become less necessary and perhaps voluntarily reduced.

However, resistance to relinquishing in favor of jobs the excitement and fulfillment of spring bird hunting and summer whaling has been shown by many Tuktoyaktuk people. In recent years, the tendency has been for natives to seek jobs in the oil and gas exploration field only during non-hunting periods.

3.7.6.2 Mammals

3.7.6.2.1 Reindeer Herd Management

At Taglu, reindeer herd encounters with facilities should occur only in summer and should not require additional management effort. Animals will be scattered in summer and not closely herded.

3.7.6.2.2 Taking of Bears

The polar bear harvest will not be directly affected by normal operation of the project as harvest areas are sufficiently remote from activity centers.

Grizzly bears are taken infrequently in the project area. Seven were reported killed by Delta region natives in 1972, from an area including the Tuktoyaktuk Peninsula and the Richardson Mountains. Fewer were killed in 1973.

Several factors associated with the project are likely to provide greater opportunity for native killing of bears - disturbance of animals in winter dens, publication of denning areas located during this study, increased frequency of encounters in the field and the supportive nature of industry camps to travelling hunters. As with polar bears, the killing of grizzlies is partly opportunistic. Prior knowledge of a bear's location is often sufficient motivation for pursuit. Knowledge that shelter, food and gasoline are available on an emergency basis may tend to encourage the following up of leads.

3.7.6.2.3 Trapping

No destruction, loss, or removal of traps or cabins is anticipated.

There will be some loss of fur production potential on the scattered acres under development, but not sufficient to reflect in trapper returns. On the other hand, two factors could work to increase fur returns on at least a short term basis. Foxes will be attracted to camps despite adequate garbage disposal methods and will be more easily taken by trappers. Support received from camps will make long skidoo trips less hazardous and thus more frequent. However, both these factors are in play during the ongoing exploration program. The general effect of the production project should be no greater than experienced in the last two years.

3.7.6.2.4 Whales

Project development will not directly affect whale hunting. However, boat and barge traffic through the East Channel should be kept moderate during the whaling period - July 15 to August 10 (approximately). Air cushion vehicle use should be avoided in that region at that time.

To the extent that attractive industry jobs are taken by native whalers, their efforts at whaling could be reduced.

3.7.6.3 Fish

Domestic or commercial fisheries should not be affected by development, except possibly in Yaya Lake. Without regulation, large lake trout could be additionally over-exploited by the combined pressure of Inuvik and oil and gas company sport fishermen. If so, winter fishing in the lake, of large specimens, will become less productive.

Similarly, the potential for a recreational fisheries-based commercial endeavour at Yaya Lake would be lessened.

Adequate controls on fishing, if implemented early in the project, would eliminate the possibility of over-fishing while still allowing participation in the sport.

Lakes supporting lake trout on Richards Island are sensitive to even moderate levels of exploitation and require management.

3.7.6.4 Resource Use Options

No future opportunity for the use of existing renewable resources need be lost as a result of the development project.

3.7.6.5 Management of Resources

Existing and future government programs bearing upon renewable resource conservation and management will require adjustment in response to potential impact of the project. Most concerns can be handled as conditions of land use and other permits, but a few additional management activities may need consideration. Some are: protection of grizzly bears around den sites; control of the sale of grizzly bear hides; prevention of bird harassment in key bird habitats outside the Kendall Island Bird Sanctuary; and, special regulation of recreational fish harvests in certain water bodies.

Realization of potential harvests of fish, furbearers and large carnivores will be assisted by improved access, the infusion of workers with recreational time at their disposal, the attraction of foxes to camps, and the tacit support afforded to native trappers by the presence of year round facilities. Realization of previously unharvested potential is considered a proper goal in most areas by fish and wildlife resource managers.

3.8 Aesthetics, Recreation and Scientific Uses

Traditional use of the region's renewable resources for these purposes conveys value to them of a special kind that is difficult to measure or evaluate. The following constitutes an identification of scientific and aesthetic uses and values.

3.8.1 Scientific Values

Since the Delta visits by Porsild (1943) and Cowan (1947), the upper and middle Delta has been the subject of an increasing number of faunal inventories and research studies of varying kinds. Muskrats, beaver and reindeer have been the subjects of detailed population, habitat and range studies by Canadian Wildlife Service and university personnel. In recent years, Dr. D. Gill of the University of Alberta and R. Hill of the Inuvik Research Station have conducted or coordinated ecological studies. Most recently, pipeline oriented studies by private firms and government agencies have covered the Mackenzie River to Tununuk Point, and sometimes beyond.

The outer Delta and barrier islands until the last two years have been essentially overlooked by scientists. The most notable exception is Dr. J. R. Mackay, whose geographic monograph of 1963 ranks as a definitive work. Dr. Mackay has continued his studies primarily on Garry Island. Dr. T. W. Barry of the Canadian Wildlife Service and others have monitored waterfowl populations for up to 15 years. A. Martell has studied small mammals. Various university specialists, such as Dr. J. D. H. Lambert and Dr. L. C. Bliss have studied surficial processes and vegetation under the auspices of the Arctic Land Use Research Program and the Arctic Petroleum Operators Association. F. F. Slaney and Company Limited have completed several baseline and disturbance studies for oil and gas companies and Environment Canada in the last two years. Other Arctic Petroleum Operators Association (A.P.O.A.) and oil company research has been conducted into engineering considerations. Ongoing work by government agencies is being directed towards the outer Delta and the Beaufort Sea and covers a range of resource subjects from white whales to ocean currents.

An outcome of some of the more basic studies is that study sites, plots and even populations take on value as scientific reference points in the constantly changing regime of northern environmental conditions. None of these sites have been established as official reserves for scientific study, however, and indeed, may lose some of their value as a basis for assessing change were they to be isolated from disturbance.

The Delta system (and estuary) has an intrinsic research value - it represents the site at which the only major Canadian river draining middle latitudes empties into the Arctic Ocean.

Certain common birds, fishes and mammals were found north of previously established ranges during the current study. It may represent the northernmost occurrence of those species anywhere in North America, a function of the Mackenzie River's lifeline to the south, or of moderate climate.

Mammalian taxa have been first described from specimens collected on the Mackenzie Delta, a circumstance, perhaps fortuitous, which conveys special status to the area among taxonomists as a "type location". The small rodent Microtus pennsylvanicus arcticus was first identified on northern Richards Island.

Other species which occur on the Delta are rare or restricted in range. The barren-ground grizzly bear is considered a threatened animal and thus rates special attention. About 25-35 inhabit the outer Delta. The Hudsonian godwit is known to breed in only a few locations throughout the north. The several pairs near Taglu site may take on special scientific significance.

Research stimulated and in many instances sponsored by the oil and gas industry is adding scientific value to the region.

3.8.2 Aesthetics

The character of the region can be briefly described in subjective terms. Response to that character is a personal thing and will vary with the background of the person experiencing it.

At the head of the Delta there are evergreen forests; as one goes farther north, these give way, first to willows, then to gently rolling tundra. The flatness of the low delta, with its mosaic of river channels, islands, and lakes, is eased by the Caribou Hills on one side, and, on the other, by the Richardson Mountains which furnish a landmark for many miles.

Pleistocene deposits on Richards Island provide topographic relief on a small scale and feature varied shrub, lichen and tussock habitats which produce a variety of colours in autumn.

The floodplain is level and without major variation except for subtle features of erosion and sedimentation. Vegetative communities tend also to be monotypic.

To many people, the character of the Delta is one of remoteness and vast distance where faraway objects loom near and sounds travel further than expected.

During the very short period in June that days are long, the diverse bird population is made conspicuous by territorial defence, and the biting insects have not yet appeared in their customary abundance. Unfortunately, it is one of the two seasons of fog and low cloud.

The climate can only be termed relatively inhospitable except for short periods in the summer months.

The project area is wild but not wilderness in that the presence of man is evident at all seasons and has been in varying degrees for many years. Drilling rigs, aircraft, boats and trucks are often seen; and staging areas and camps occur along channels.

The use of aesthetic resource by non-residents has been minimal. A travel agency based in Hay River provides boat runs for tourists down the Mackenzie River to Tuktoyaktuk. The view from the deck of a boat on East Channel includes only a very small segment of the general region, and does not glimpse the project area.

Most of the immigrant workers on hydrocarbon exploration projects expressed little concern or curiosity about their arctic environment. What leisure time was afforded them was usually spent on indoor activities. The aspect of the environment most likely to evoke comment was sighting of a large wild animal.

3.8.3 Recreation

Geese and ducks are hunted in a limited fashion within the study region by non-native residents. Outsiders are not attracted to the Delta to hunt waterfowl. At the present time, migratory birds that nest in the study region are of greater recreational significance during their southern migration and winter layover in the southern climates.

Sport hunting for mammals is virtually non-existent within the boundary of the study area. The lakes of Richards Island are not used to any significant extent by sport fishermen. The exception is Yaya Lake which is fished regularly by Inuvik residents.

3.8.4 Possible Effects

3.8.4.1 Scientific Values

The development project should not eliminate scientific values on the Delta or seriously impinge upon ongoing research activities. In fact, oil and gas industry studies will continue to assist in the production of scientific knowledge from the area.

No ecological reserves, study plots or research sites will be directly involved as far as can be ascertained.

The pristine nature of the Delta environment will be further altered by the addition of low levels of contaminants and presence of facilities. Changes of this nature will be of the same kind as those already happening through oil and gas exploration.

3.8.4.2 Aesthetics

The development will result in large structures well above ground level that will be visible for many miles.

New structures will not be visible to travellers on East Channel, but existing staging areas will remain.

All-weather roads and overhead pipelines will be built in the outer Delta region for the first time. Use of roads will be heavy during the construction period.

Development of facilities will be localized to concentration point. Transportation facilities will also be localized and reduced after the construction period.

3.8.4.3 Recreation

Recreational hunting will not be detrimentally affected by the development. Firearms will not be permitted at development sites, so any increased hunting pressures by staff will not exist. Aircraft strips at the processing plant would be unavailable for use by fly-in hunters or naturalists. Recreational fisheries should not be affected by the development.

A concern does exist, however, in over-exploitation of lake trout in Yaya Lakes by resident fishermen.

3.8.4.4 Tourism

Tourism based on the non-consumptive use of wildlife may be encouraged on the outer Delta by the presence of facilities and the knowledge of bird distribution gained through completion of the field studies for this program of assessment. Similarly, scientific interest could be stimulated by some parts of study reports, perhaps leading to discoveries of a more fundamental nature.

3.8.4.5 Archaeological Resources

A preliminary archaeological investigation by G. J. Fedirchuk, M.A under the direction of Dr. James V. Millar, B.A.Sc., P.Eng., Head and Professor of Archaeology, University of Saskatchewan indicated that, in general, the location proposed for the Taglu facility was in a low priority area.

The proposed development site at Taglu was also inspected on the ground on August 25, 1975 by Roscoe Wilmeth, Chairman, Salvage Program, Archaeological Survey of Canada, who confirmed that there was little possibility of archaeological sites in the area to be disturbed.

3.9 Summary of Substantial Interactions

Several thousand possible interactions between features of the Mackenzie Delta environment and proposed gas development activities were examined. Most of those possible interactions were judged not likely to produce physical or biotic effects of substance. Others carried the possibility of producing substantial change in existing environmental conditions and therefore were subjected to further review.

The potential concerns identified and discussed are essentially those anticipated from normal operation of a project designed and constructed with due care for environmental matters, using current and feasible engineering practices. They are project and site specific. In addition, possible effects of two classes of deviation from operational procedure were considered; those digressions resulting directly from personnel activity or judgment, and those accidents which result from failure of design or materials.

3.9.1 Atmosphere

During calm cold sessions when temperatures are less than -35^{o} C., some localized ice fog will prevail along roads.

Particulate redeposition from roads onto the surrounding snow cover will lower surface albedo and thus increase the rate of snow melt in spring. The overall effect will be offset by snow piling and drifts along immediate sides of roads, but beyond the piles, the effect would be noticeable. Similar effects of a localized nature and short duration will occur around staging sites, gravel extraction areas, airstrips, and pads.

Only small amounts of hydrocarbon exhausts will be vented from barges and boats. Local air quality will not be affected to a degree measurable by standard techniques.

Wind scouring of particulate materials off barges will be minimal because of full container transport practices.

Warm water vapor from aircraft exhausts will cause localized ice fog during calm conditions when air temperatures are below -35^{o} C. on the strip. A combination of uplifted snow and ice particles from the ground surface of the airstrip plus the ice fog production will restrict visibility.

Cumulative water vapor emission and thus visibility effects would be reduced by restricting vehicular traffic near the airstrip when air temperatures are less than -35^{o} C.

There will be some disturbance of loose surface material and reduction of visibility during take-offs and landings at heliports as well as some additional, well-dispersed hydrocarbon exhausts.

The surface roughness effect of plant facilities will cause air turbulence in their wake.

Emission stacks will have to be designed high enough to avoid downdrafts in the module wakes so that exhaust fumes are not carried quickly to ground levels.

Change of heat capacity and albedo of the plant site will create an urban "heat island" effect.

Water vapor emissions from hydrocarbon burning at Taglu Plant will cause additional hoar frost, slight rises in relative humidity, additional fogging, some reduction of net radiation to the ground, high potential for local ice fog and increased deposition of ice crystals around the plant.

Taglu Plant will disseminate other gases into the local atmosphere from the burning of condensate fuels. The primary components of exhausts from the turbines will be: CO_2, H_2O, O_2, N_2 and NO_x (as NO_2). Sulphur will not be emitted unless new gas fields with H_2S become involved.

Plant noise will produce no atmospheric effect except to raise the ambient noise level in the atmosphere about each operation. Taglu Gas Plant will be designed to meet a noise level of 65 dBA at the plant lease boundary, which is assumed 750 feet outside the plant dike.

"Flaring" during emergency or start-up will produce high noise levels, and increased amounts of combustion products. No liquid hydrocarbons will be flared at any time. Gaseous hydrocarbon will be flared from time to time to prevent overpressuring a piece of equipment, or during plant start-up operations, but will be scrubbed of liquid hydrocarbons. Noise levels will be high but in a range similar to testing at exploration drill sites.

There will be some additional exhausts from rig engines and heaters at well clusters.

Compressors will be eventually established at clusters. Their turbines will burn condensate or gas showing no sulphur content.

There will be some ash and unburnt hydrocarbons dispersed from each solid refuse incinerator during fire-up.

3.9.2 Terrain

The connecting roads and airstrip at the Taglu Gas Plant will act as dikes that will somewhat alter flood patterns. Floodwaters moving around the edges of the dikes, and therefore the amount of silt deposited annually in the protected area, will be both reduced. Mosses will become predominant, the insulative capacity of the vegetation improved, and the active layer shallower.

It is assumed that no new summer or winter roads are required to further exploit gravels for the gas plant.

Docks and storage facilities will cover mostly low-centered polygons. Unacceptable complications involving landforms are not expected.

The clusters will cover approximately 13.8 acres of low-centered polygons. Effects other than removing these acreages from vegetative production are not anticipated.

Development plans for construction, maintenance and use of drilling sumps are designed so that the facility will inflict minimal damage to terrain under normal circumstances.

Slope modification or extensive removal of vegetation within the field gathering system right-of-way will not occur.

The impact of pile placement on the environment is expected to be similar to that of activities of seismic survey crews. It will be localized within the 350 acre development area.

Heavy equipment will be responsible for some destruction of surface vegetation on the field gathering facility right-of-way. Regeneration of plants will be initiated the first summer and little or no thermo-karst should result.

The gas plant plus connected facilities will remove from production about 15 acres of vegetation. Thermal erosion or major changes in drainage are not anticipated.

The Taglu Gas Plant will be located over low-centered polygons. A thaw depression along the toe of the gravel pad will increase water depth in a small area which will in turn have a small effect on willows. Proposed precautions against transmitting heat through the pad to underlying permafrost should be adequate.

Vegetation damage from gaseous emissions is not expected. Terrain damage is therefore not likely to occur.

Prospective landfills to receive ashes and cinders from the incin-erator have not been identified. Cinders, ashes, etc. in the land-fill will gradually be incorporated into the soil and may improve some of the soil characteristics.

Continued gravel extraction from esker-kame ridges near Yaya Lake will enlarge the existing pit to an undetermined degree. Additional pits may be required. Slumping, soil erosion, and siltation of lakes could occur if ice lenses are encountered and pits are allowed to drain downslope.

After perennial use by large machinery, gravel structures will have become highly compacted. If the gravel is not removed from the site, the surface will likely remain bare for many years. If, upon abandonment of pads, gravel is removed in summer, the heavy equipment used would operate over adjacent terrain, compacting the soil and destroying the vegetation. Permafrost which will have developed well into the gravel will be exposed.

Restoration of development sites should be accomplished with minimum use of heavy equipment and no large scale movement of earth materials. Grading abandoned development sites could result in the destruction of adjacent vegetation with the possible consequence of initiating thermal erosion.

Landfills and sumps should be filled with material from borrow areas if feasible, rather than grading adjacent earth. Reseeding disturbed areas with native grasses and amending the soil with fertilizers will increase the rate of revegetation in some areas. This procedure should be employed not only at the termination of the project, but also as a preventative measure on unstable slopes traversed by the field gathering system or by roads.

3.9.3 Hydrology

A depression may develop along skirts of roads and other gravel-based facilities which will affect local drainage patterns. The positioning of the support roads and the new airstrip will partially dam areas to the northern and eastern sides of the gas plant site from early spring flooding.

Adequate culverting will have to be designed to allow freer movement of these flood waters through to the northeast sections of the development site. Such culverting practices would help to minimize erosional effects near the northern and southern edges of the roads and airstrip where flows could become excessive during the spring flooding process.

The gas plant and camp area may have accumulations of water along their outer edges because of subsidence.

Continued or expanded usage of the gravel area at Yaya Lake will provide some potential for further siltation of the lake unless special measures are implemented.

Channel dredging would create increases in local suspended sediments.

Water supply for the Taglu Plant will come from Kuluarpak Channel. Approximately 9,000 gallons per day will be required during normal plant operations.

Liquid wastes will arise from washrooms, laundries and kitchens in the camp facility with discharge of 36,000 gpd during the construction period.

A gas well blowout would be vented to the atmosphere, while water, mud and condensates would be deposited on or near the drilling pad.

An oil blowout could have far reaching consequences if escapement was great.

A sump failure could release toxic materials into the aquatic environment.

Loss of gas condensate through pipe failure would reduce channel and lake water quality if materials were not contained.

Perimeter dikes and/or gravel pads must be built around the cluster facilities, the gas plant site, the storage areas and all sumps in a sufficient manner to contain all minor spills which might occur within the facilities. In addition, the diking must be designed to withstand the most extreme effects of storm surging and spring flooding expected near F-43 for the duration of the project.
The frequency of a significant storage failure cannot be determined because it entails the simultaneous failure of the diked perimeter of the facility. Chances of simultaneous leaks of storage containers and ruptures in dike walls are remote.

3.9.4 Flora

Facilities on the Taglu floodplain will cover approximately 150 acres of willow-sedge and sedge-herb, 20 acres of willow-sedge, 85 acres of low-centered polygons, and 95 acres of low-centered polygons with peat mounds.

With development will come increased chance of introducing exotic plant species, primarily weeds.

A thaw depression may develop at the toes of gravel pads that will encourage the growth of sedges but retard or eliminate willow in a narrow band around facilities.

The two roads and airstrip will act as dikes that will alter flood patterns over a few acres. With reduced siltation, mosses, primarily Drepanocladus spp. will become a more important constituent of the vegetation.

Damage to vegetation is expected from the unlikely prospect of a gas well blow-out but effects would be localized since much of the material would be contained by perimeter dikes.

If a blow-out were accompanied by a fire, vegetation over a larger area could be affected along with local ice and snow cover.

An oil blow-out could have far reaching consequences if escapement was great.

Development plans for construction, maintenance and use of drilling sumps are designed so that the facility will inflict no damage to vegetation under normal circumstances.

Drilling sumps may contain materials potentially harmful to vegetation. If these materials are spilled onto tundra, the vegetation within a certain distance would be damaged.

Slope modification or extensive removal of vegetation for the short field gathering system right-of-way at Taglu will not be required.

Machinery required for installation of support piles is similar to that used for seismic surveys. Consequently, the impact of this phase of development on vegetation is expected to be similar in type to that of activities of seismic survey crews, but localized in extent.

In the Taglu area the field gathering system right-of-way will parallel an all-weather road from plant to clusters. The road will be used by pipe-laying vehicles. However, some off-road damage to vegetation will occur.

The effects on vegetation of exposure to natural gas and condensate would be minimal. If fire were associated with a pipeline failure, tundra immediately around the break would be damaged.

Vegetation is not expected to be seriously affected by water vapor emitted during normal plant operations. Relative humidity in the area of the gas plant is normally high during the summer, seldom dropping below 85 percent. Accumulation of hoar frost will occur but has not been shown to detrimentally affect plants. Vapor emissions will tend to stay near the gas plant and may lead to the formation of fog. Inversions are not common during the growing season.

Oxides of nitrogen have been discounted as a major concern with respect to local vegetation because toxic levels should not occur.

The photochemical smog complex, which involves nitrogen oxides, contains phytotoxins, primarily ozone and PAN (peroxyacyl nitrates), but similarly should not occur at toxic levels around the Taglu plant.

Sulphur exists in fuels that may be imported from the south for use in some machinery. It has not been confirmed in Taglu gas or condensate. No problem is expected unless new gas fields with sulphur are located in future. At any rate, lichens are not a conspicuous element of vegetation within three miles of the gas plant.

Cinders, ashes, etc. in landfills will gradually be incorporated into the soil and may improve some of the soil growing characteristics.

Gravel extraction from esker ridges near Yaya Lake will destroy xeric gravel vegetation which has limited extent in the development area.

If gravel is removed in summer, the heavy equipment used would operate over adjacent terrain, compacting and destroying the vegetation. The weight of the gravel over the ground will have compressed the soil so that the surface will likely remain bare for many years.

Grading abandoned development sites could result in the destruction of adjacent vegetation.

Reseeding disturbed areas with native grasses and amending the soil with fertilizers will increase the rate of revegetation in some areas.

3.9.5 Birds

The proposed development will have effects upon birds arising from the destruction or creation of avian habitat and the prevention of habitat use through disturbance.

Construction of a gas processing facility with related well clusters, roads, gathering system, camp, storage and staging areas, and airstrip in the Taglu area will result in the direct loss of some 60 acres of floodplain habitats composed of low-centered polygon, willow-sedge and sedge-herb vegetation.

Preconstruction activities and pad construction phases will be carried out primarily during the winter months. Therefore, no disturbance to migratory birds will occur during this phase of operation.

Total numbers of nesting birds estimated to be subject to both direct and indirect effects of the gas plant layout are:

loons	10
swans	10
geese	35
ducks	240
large shorebirds	10
small shorebirds	210
sandhill cranes	5
passerines	140

Development plans as outlined to date do not impinge on high use areas, and thus immediate major impacts are avoided.

High density waterfowl and colonial nesting sites should be avoided in season, however, and undue harassment prevented by regulation, if necessary.

The Mackenzie Delta is one of the few reported breeding areas of the Hudsonian godwit. A few pairs will be affected.

Roads will be used by many species of birds as a source of digestive gravel.

Noise levels from normal gas plant operation are not expected to adversely affect birds in the vicinity of the plant beyond the range of avian disturbance expected from other sources.

High intensity sound emissions from "flaring" over short periods at irregular intervals could have a disturbing effect on nesting geese near the plant.

Any impact on birds arising from personnel activities around Taglu is expected to be minor if policies similar to those in use during exploration are kept in force (i.e. no guns in camps).

Interest in non-consumptive use of birds may have a net positive effect in that it encourages awareness of environmental concerns and provides a recreational outlet.

An oil blowout could have far reaching consequences to waterfowl and other birds if escapement was great. Impact would relate directly to distribution of spilled materials.

High capacity sumps with adequate diking to prevent overflow in emergency situations or, alternatively, inflow of high floodwaters, should effectively prevent escape of sump contents and subsequent harmful effects on bird populations and habitats. Accidental release of sump contents, if uncontained, could locally damage bird habitat. Upon abandonment of cluster sites, sumps will be covered.

There is a chance for channel erosion in floodplain areas to ultimately release the contents, but release would be sporadic and over a long time period and would not likely cause immediate effects upon birds.

Use of abandoned gravel staging sites as nesting locations may be undertaken by some species - sandpipers, gulls, terns and perhaps geese.

Boat traffic on main channels will have little or no effect upon birds as few use main channels during the ice-free season. Recreational boat traffic in small channels and lakes may be a source of harassment for some birds.

Restriction of boat traffic in small tributary channels will reduce disturbance to moulting waterfowl using those areas. Regulations against travel to or through concentration areas could further safeguard against impact.

Use of airstrips will have an indirect impact at either end of the runway because of low level approaches and take-offs.

Effects of aircraft along flight routes away from activity centers are not expected to be of serious consequence.

So long as aircraft are maintained within the corridors as described, wildlife harassment will be minimal. Over the snow goose colony, a single incident of harassment could result in an inordinately high egg predation rate.

It is unlikely that properly conducted flights along predetermined flight lines which avoid areas of concentration will adversely affect nesting geese. Operational plans which reduce the chance of disturbance offer the best course for the prevention of impact.

In some situations helicopters may create bird disturbance at greater ranges than fixed-wing craft, but observations indicated that when there was a difference in reaction to the two kinds of craft, it was small. Anticipated effects of both types of aircraft are considered equal when estimating impact.

At landing sites, the helicopter's ability to make a steep descent should eliminate approach area effects.

Transportation of solid wastes after incineration to a suitable landfill site should have little effect upon birds. Gulls and ravens may be attracted if materials are not immediately covered.

The release of relatively small volumes of process water and of camp wastes, after sewage treatment, is not expected to adversely affect birds.

Open water near sewage outlets is a possibility, at least for a period in early fall. A few swans and other late migrating waterfowl may be induced to delay their departure.

With the exception of gulls (largely glaucous gulls) and common ravens, no birds will be affected by garbage disposal.

Future mining at Yaya Lake will increase the direct effects on birds proportionately to the extra surface area mined.

Revegetation of these areas is expected to be slow, and even after abandonment bird use will be slight.

If reclamation on abandoned gravel pads is successful, affected areas will be returned to a condition close to their original form and carrying capacity.

Removal of development facilities and pad materials will have short term effects similar to those described for their placement. Long term effects will be limited to the areas defined under direct effects and will lessen in time as revegetation takes place.

3.9.6 Mammals

Roads are short and close to cluster and plant facilities so will have little effect on reindeer movement.

All-weather roads will make a small amount of land unavailable to voles and lemmings. Voles and lemmings probably will be reluctant to cross roads, especially in winter, but this effect should be no greater than on winter roads and seismic trails.

Winter gravel haul from Yaya Lake will not conflict with the few feral reindeer on Richards Island.

In winter, grizzlies will den in rough terrain and be generally unaffected by the Yaya Lake gravel haul. It is possible however, that one or two could den near the southern portion of the route, and later be disturbed.

Use of all-terrain vehicles and other activities contrary to land use permits and company policy, will be tempting to some personnel in off-duty periods. Results could include harassment of mammals, especially bears and reindeer. An effective educational program could reduce consequences of that nature.

It is unlikely that reindeer will be affected by small, propeller-driven aircraft at low levels near airstrips, if more than 500 feet away, or grizzlies more than 1,000 feet distant. The animals may habituate to the regular presence of aircraft as experience is gained. The area affected around Taglu would approximate 2,000 acres.

Reindeer are unlikely to be disturbed by aircraft flying 1,500 feet or more. Grizzly bears are unlikely to be affected by aircraft flying above 1,500 feet.

Helicopters operating in accordance with guidelines requiring 1,500 feet minimum altitude should not disturb reindeer or grizzly bears. Normal helicopter traffic is unlikely to disturb foxes.

So long as aircraft are maintained within the corridors and at the prescribed altitudes or greater, wildlife harassment will be minimal. Harassment of reindeer on calving grounds could cause calf mortality.

Boats may occasionally encounter reindeer or grizzlies swimming in inland waters and may come close to them near waterways. Such encounters would be infrequent. No adverse effect is expected if the boats approach no closer than 500 feet.

The main effect of plant, staging, dock and cluster site construction and use on most mammals will be the removal of small amounts of land from production through the construction of gravel pads.

Facilities may be obstacles to travel for reindeer but will only deflect, not halt, unherded movements.

No fox or bear dens have been located in the area proposed for plant construction.

The full extent and location of new gravel pits at Yaya Lake is not known. Bear dens could be affected but no active fox dens have been located in the immediate area.

Bears can be expected to avoid areas closer than 1,000 feet from gas compressors. Other mammals probably will not be seriously affected by the sound of gas compressors or the presence of man.

Ground squirrels are abundant in areas where gravel is the substrate. The areas from which gravel is taken will probably remain unusable by ground squirrels for several years. There will be a loss of ground squirrels according to the extent of gravel excavation operations, at a rate of approximately 2.8 dens per acre.

If camps associated with the gas production development are maintained in a manner similar to the major camps of the exploration program, problems associated with feeding animals will be slight. Improper personnel behavior such as the feeding of animals should be kept to a minimum.

Local noise and ground vibrations will result from construction activities, particularly pile placement. No significant effect on reindeer or other mammals is expected.

Irregular loud noises could frighten reindeer and should be avoided when animals are very near. Sump blasting, for example, should be appropriately timed. Conversely, static noises from plant facilities should have little effect upon the animals.

Pile placement and line construction activities will affect small rodents in local areas by destroying the insulating layer of snow. This will make limited areas uninhabitable for these mammals.

Reindeer will not likely come into contact with gathering lines north of the Taglu plant site.

Damage to pioneering vegetation, likely to result from grading of gravel pads upon abandonment, will adversely affect mammals which will or could be using it.

Some mammals may be attracted to the possibly luxuriant and nutrient-rich vegetation which would result from reseeding and fertilization of gravel pads and disturbed areas.

3.9.7 Aquatic Fauna

At the Taglu gas plant facility construction will produce minimal siltation because of the flat terrain. The effects of any siltation on the aquatic ecosystems should be slight at any rate, as channels and channel-connected waters are generally very turbid throughout the summer.

In spring and summer months, small amounts of silt may be washed out of the road bed gravel and will enter some of the casual waters adjacent to the road, of no consequence to aquatic fauna. Slumping, for any reason, should not be a major source of silt in floodplain areas.

Dredging channels to improve access would displace large volumes of bottom sediments which may be expected to affect the aquatic communities in and downstream of the dredged areas.

Some siltation of river channels may occur from minor bank erosion caused by the "wakes" of barge traffic. However, this effect should not prove serious as the channel waters are normally very turbid throughout the summer months.

The probability of a blowout is remote. If there were a blowout, most of the gas would be vented to the atmosphere, while water, mud and condensates would be deposited on or near the drilling pad. Damage to water bodies is expected but effects would be localized since much of the material would be contained by perimeter dikes.

An oil blowout could have far reaching downstream consequences to aquatic organisms if escapement was great. Contingency plans for development drilling are being prepared and systems readied.

Drilling sumps receive many materials considered toxic to aquatic organisms at various concentrations. A sump failure could release them into the environment. Accidental releases of materials from production well sumps would seem unlikely, but nevertheless could occur. Distribution of the materials would be localized where perimeter dikes are in good repair.

In the unlikely event of escapement of condensate to channels or lakes, some impact on aquatic biota could occur.

Some erosion will occur when dock facilities are installed, however, a much greater silt input will occur if channel bank stability is reduced and bank slumpage occurs. Minor sedimentation of the river should have limited effect on the aquatic community as the receiving water body is large and naturally turbid.

Some spillage of pollutants may occur during loading and unloading at docks. Depending upon the nature and volume of the pollutants there could be some impact on the aquatic community of the river.

Water for the Taglu plant will be drawn from a river channel with little effect upon its aquatic ecosystem.

It is also unlikely that removal of water for camps and clusters will have any effect on the local aquatic ecosystem.

Gaseous emissions such as NO_x will be released in relatively large amounts by the gas plant but no adverse effects upon aquatic systems are anticipated. There will be no sulphur emissions unless new fields with sulphur gas are added to the project at some future date. In that event, acidic precipitate could enter aquatic systems.

Normal storage procedures preclude spills and leaks into aquatic systems. There should be no adverse effects produced from normal operation.

A significant storage failure is unlikely because it entails the simultaneous failure of the diked perimeter of the facility. However, there could be stored on site substantial quantities of materials considered highly toxic to organisms. The extent of environmental damage caused by a spill will depend in part on how far it is dispersed.

Development activities will bring fishermen to the vicinity of unexploited or minimally exploited fish populations. Lake trout populations will not sustain a heavy sport fishery and could be damaged.

Domestic sewage will be produced in large quantities at construction camps and in smaller quantities at the permanent camp. Large volumes of nutrients could cause eutrophication or reduced oxygen concentrations within the channel system in winter. However, treatment as outlined should produce a low B.O.D. effluent with reduced nutrient concentrations.

Replanting and fertilization of sites may cause a small and temporary increase in productivity within aquatic systems, as fertilizer would be washed or eventually leach into the lake or channels.

Minor siltation of Yaya Lake has occurred from the road between the pit and the dock. This siltation is minor in comparison to that created by the breakthrough of the Mackenzie River channel into the southern basin. If additional gravel requirements are satisfied in the Lake 50 watershed, care is required to avoid erosion and its subsequent siltation.

3.9.8 Use of Land and Resources

The following concerns are based on consideration of normal project operation including spills and leaks of hydrocarbons and other toxic material. A major, uncontained oil blow-out during flood or storm surge, although remote, could moderate the predictions for at least the year of occurrence.

The taking of geese and other waterfowl by native peoples of the three Delta settlements will be essentially unaffected by the project as understood at this time.

Willow ptarmigan are hunted in willow thickets near Tununuk Point and Yaya Lake during March and April. Such activities will not be seriously affected.

To the extent that local native people accept full-time employment opportunities with the project, subsistence hunting of birds will become less necessary and perhaps voluntarily reduced.

Recreational hunting of waterfowl will not be detrimentally affected by the project. Additional workers during both construction and operational periods may mean increased hunting pressure and more intensive utilization of the resource.

The presence of facilities at Taglu should have little effect on any potential for tourism based on the area's wildlife resources.

At Taglu, reindeer encounters with facilities should occur only in summer and should not require additional management effort.

The polar bear harvest will not be directly affected by normal operation of the project as harvest areas are sufficiently remote from activity centers.

Several factors associated with the project are likely to provide greater opportunity for native killing of grizzly bears - disturbance of animals in winter dens, publication of denning areas located during this study, increased frequency of encounters in the field and the supportive nature of industry camps to travelling hunters.

No destruction, loss, or removal of traps or trapping cabins is anticipated.

There will be some loss of fur production potential on the scattered acres under development but not sufficient to reflect in trapper returns.

Two factors could work to increase fur returns on at least a short term basis. Foxes will be attracted to camps despite adequate garbage disposal methods and support received from camps will make long skidoo trips less hazardous and thus more frequent.

Project development will not directly affect whale hunting. However, boat and barge traffic through the East Channel should be kept moderate during the whaling period - July 15 to August 10. Air cushion vehicle use should be avoided in that region at that time.

To the extent that attractive industry jobs are taken by native whalers, their efforts at whaling could be reduced.

Domestic or commercial fisheries should not be affected by development except possibly in Yaya Lake. Without regulation, large lake trout could be additionally over-exploited by the combined pressure of Inuvik and oil and gas company sport fishermen.

Other lakes supporting lake trout on Richards Island are sensitive to even moderate levels of exploitation and require management.

No future opportunity for the use of existing renewable resources need be lost as a result of the development project.

Existing and future government programs bearing upon renewable resource conservation and management will require adjustment in response to potential impact of the project.

3.9.9 Aesthetics and Scientific Uses and Values

The development project should not eliminate scientific values on the Delta or seriously impinge upon ongoing research activities.

No ecological reserves, study plots or research sites will be directly involved as far as can be ascertained.

The pristine nature of the Delta environment will be further altered by the addition of low levels of contaminants and the presence of facilities. Changes of this nature will be of the same kind as those already happening through oil and gas exploration.

The development will result in large structures well above ground level that will be visible for many miles.

All-weather roads of substantial length and overhead pipelines will be built in the outer Delta region for the first time. Use of roads will be heavy during the construction period.

Tourism based on the non-consumptive use of wildlife may be encouraged on the outer Delta by the presence of facilities and the knowledge of bird distribution gained through completion of the field studies for this program of assessment. However, airstrips and camps will not be available to tourists.

Scientific interest could be stimulated by some parts of the study reports, perhaps leading to discoveries of a more fundamental nature.

3.9.10 Significant Environmental Effects

The following potential interactions are considered the most significant:

Gaseous emissions from several sources will add contaminants to the atmosphere.

Local climate will be modified around the gas plant during periods of extreme cold.

Disruption of flooding patterns and local surface drainage will take place along dikes, roads, airstrips and pads.

Water quality parameters will be affected where treated sewage from camps is added to surface runoff or escapement of liquid hydrocarbon or stored materials occurs.

Gravel excavation at Yaya Lake will result in an approximate doubling of the surface acres disturbed there to date.

The major adverse effect upon vegetation will be the expropriation of some 60 acres of floodplain vegetation types for facility development.

In total, approximately 70 acres of bird and mammal habitat over two small areas will be changed.

The presence of man and his machines in the gas plant area will render additional habitat close to roads and facilities unusable by the more wary and inflexible bird and mammal species.

Some harassment of colonial nesting birds, grizzlies and perhaps reindeer can be expected even with tight internal controls on personnel activities.

Destruction of fox or grizzly bear dens will not likely occur, but disturbance of bears while in dens is a possibility along the gravel haul route and in the Yaya Lake area.

A few reindeer in summer may initially avoid or be deflected in their seasonal movements by facilities and activity around the Taglu gas plant.

A potential exists for overharvesting of lake trout in several lakes on Richards Island, including Yaya Lake.

Some effects of the development project will bring benefits to inhabitants of the natural systems through the creation of new habitat upon abandonment.

Realization of potential harvest of fish, fur-bearers and large carnivores by native residents will be assisted by improved access.

Patterns of fur returns to trappers and waterfowl harvests by hunters from all three communities should not be negatively affected unless a major uncontrolled emergency, such as a well blow-out with massive oil escapement, were to occur.

No future opportunity for the use of existing renewable resources should be lost as a result of the development project.

The proposed development imposes perturbations only on very local segments of the terrestrial system. The construction and presence of the facilities should not upset any major ecological sub-system unless major escapement of toxic compounds were to occur.

Certain existing and future government programs bearing upon renewable resource conservation and management will require adjustment in response to potential impact of the project.

4. Important Environmental Impacts

Consequences of a normal operation will be to modify existing environmental conditions. Residual or unavoidable consequences are those that cannot be prevented by protection or mitigation efforts. While unavoidable, most are reversible or can be compensated.

4.1 Habitat Changes

The major adverse effect upon vegetation that is anticipated will be the expropriation of some 70 acres of floodplain and upland vegetation types for road and facility development. The impact will be largely short term (duration of the project) in that restoration will induce new vegetative growth, but the new communities will be different from those initially covered by pads.

Approximately 70 acres of bird and mammal habitat over a large area will be changed. Restoration at the end of the project will create new habitat. The presence of man and his machines will render additional habitat close to roads and facilities unusable by the more wary and inflexible species. Many species will be unaffected in this manner, while still others will adjust in varying degrees after initial responses. Most critical bird habitats are fortunately some distance from the scene of proposed construction and will remain unaffected. Several pairs of Hudsonian godwits and small numbers of white-fronted geese and swans are the most prominent groups to be displaced during the nesting season. The extent to which displaced nesting birds can be absorbed elsewhere in nesting habitat is unknown, but there is reason to assume that reproduction will not occur at the same rate during the first year after displacement.

Gaseous emissions from several sources will add contaminants to the atmosphere but in such small amounts that air quality parameters will not be pushed beyond acceptable thresholds. It is unlikely that federal standards will be exceeded, or even that present Inuvik maxima will be equalled at any of the planned facility sites. Ground concentrations of SO_2 and other toxic compounds potentially damaging to local vegetation should not be reached.

Local climate will be modified around gas plants during periods of extreme cold. Ice fogs could make the use of airstrips difficult on some winter days.

4.2 Disruption of Terrain

Gravel excavation for this project will result in further surface area disturbance at Yaya Lake.

4.3 Alteration of Water Regimes

Some minor effects on Mackenzie River hydrology are anticipated. While not serious impairments of any phase of the natural hydrologic cycle, disruption of flooding patterns and local surface drainage will take place along dikes, roads, airstrips and pads.

Adequate culverting and bridging will reduce the magnitude and importance of this kind of physical effect, but will not totally eliminate it.

The adverse consequences of unavoidable drainage modification will be slight. Some erosion in hilly areas near gravel pits may result, and if uncontrolled could lead to silting of lakes. Long term changes in vegetation community structure is possible in small portions of the floodplain through changes in silt deposition and occurrence of standing water.

Water quality parameters will be affected where treated sewage from camps is added to surface run-off. Federal effluent standards should not be exceeded.

A potential exists for overharvesting of lake trout in several lakes on Richards Island, including Yaya Lake. Avoidance depends upon intensive control measures by regulatory personnel.

4.4 Interference With Wildlife

Some harassment of colonial nesting birds, grizzlies and perhaps reindeer can be expected even with tight internal controls on personnel activities. An effective educational program could reduce consequences of that nature.

Human use of waterfowl, ptarmigan or other birds will not be adversely affected.

Destruction of fox or grizzly bear dens will not occur, as far as can be determined, but disuse of active bear dens or the disturbance of bears in dens is a possibility along the gravel haul route. One to two bears could be involved in that area, from a population of 25 - 35 animals.

4.5 Land Use Changes

Adverse effects upon trapping or trappers are not expected.

Reindeer in summer may initially avoid or be deflected in their seasonal movements by facilities and activity around the plant. Rapid adjustment is expected, however. The main herd will not be involved in winter.

5. SUMMARY

The Applicant has applied for land tenure and associated land use for a proposed gas processing plant and related facilities on a location called "Taglu" on the Delta floodplain on Richards Island. This gas is urgently required to alleviate Canada's shortfall in supply.

At the Taglu site, there would be two groups of production facilities, a gas plant and supporting facilities all concentrated in one location near the geographic centre of the Taglu gas field, just south of Big Lake. The location is considered optimum from the standpoint of both extraction of the resource and minimum environmental disruption. After processing, the gas would be fed to a Mackenzie Valley pipeline. Similar gas development facilities would likely be constructed at different locations in the Delta by other companies operating in the area.

Plant support facilities would include living quarters for about 100 men, a 2,500 foot airstrip, a helicopter pad and a dock facility. Personnel transportation would be by fixed-wing aircraft and helicopter. Maintenance supplies would be transported by barge in summer, snow and ice roads in winter, and by aircraft year-round.

The plant would not normally emit noxious gases other than NO_x. A minimum amount of waste effluents would be produced and these would be appropriately treated.

Contingency plans are being developed for accidental release of liquid pollutants, and for fires. The low ground gradient and slow water

currents would facilitate containment and clean-up of spills.

The proposed development would have some impact on the environment principally in relation to habitat changes, disruption of terrain, alteration of water regimes, interference with wildlife population and land use changes.

Habitat Changes

As a consequence of the development, bird and mammal habitat would be affected on some 350 acres in the Taglu area and a considerably smaller amount in the Ya Ya Lake area. The presence of man and his machines would render additional habitat close to roads and facilities unusable by the more wary and inflexible species. In laying out the overall development plan, the Applicant has made the facilities as compact as possible thus reducing the area of vegetation and hence the habitat which would be taken out of production. An impervious dyke surrounding the plant and liquid storage areas would protect the surrounding tundra in case of accidental spills. Restoration at the end of the project would create new habitat. Gravel extraction from esker ridges near Ya Ya Lake would destroy xeric gravel vegetation which has a limited extent in the development area. Natural re-vegetation on gravel sites would be extremely slow.

Gaseous emissions from several sources would add contaminants to the atmosphere but ground concentrations potentially damaging to vegetation would not be reached. The fog created by heat and vapour emissions could occasionally restrict visibility but should have no deleterious effect on surroundings.

Disruption of Terrain

Modification to terrain in the Taglu area would consist of gravel pads, roads, dock and airstrip covering some 60 acres of floodplain. Gravel removal from the pit at Ya Ya Lake would strip this area of surface material to an extent not yet determined. The gravel pads, augmented if necessary with insulation, would prevent degradation of ice-rich permafrost soils. Appropriate operational controls would be instituted to avoid offsite terrain degradation by vehicle travel. Present practices of restricting vehicle traffic in summer and using snow and ice roads in winter would be continued.

Alteration of Water Regimes

Minor disruption of flooding patterns and local surface drainage would take place along dykes, roads, airstrips and pads. Adequate culverting is planned to reduce the magnitude and importance of this effect. However, long-term changes in vegetation community structure is possible in several hundred acres of floodplain. The release of relatively small volumes of treated waste water and sewage from camps could lead to increase in biological productivity.

Some erosion would occur during construction but minor sedimentation of the river should have limited effect on the aquatic community as the receiving body is large and naturally turbid. Development activities would bring fishermen to the vicinity of unexploited or minimally exploited fish populations. Lake trout populations would not sustain a heavy sport fishery and could be damaged.

Upon completion of drilling at the cluster sites, sumps would be covered. There is a chance for channel erosion in floodplain areas to ultimately release the contents, but such a release would be sporadic and over a long time period and would not likely be deleterious to the environment.

Interference with Wildlife

The presence of the industrial activity along with associated noise would have some disturbing effect on birds and mammals. Fortunately, most critical bird habitats, however, are some distance from the scene of proposed construction and would remain unaffected. Some harassment by man of colonial nesting birds, grizzlies and perhaps, reindeer, could be expected but an educational program is planned which should reduce this interference.

To reduce noise levels in and around the plant to acceptable limits, sound attenuation devices would be installed on critical equipment.

Recreational boat traffic in small channels and lakes could be a source of harassment of some birds. Aircraft flight paths and altitudes would be designated so that wildlife harassment would be minimal.

Firearms would not be permitted in camps. An exception could be made for protection of personnel but such firearms would be under strict supervision.

Land Use Changes

The development area is within the boundaries of the Kendall Island Bird Sanctuary and the Reindeer Grazing Preserve. Other land use includes trapping and hunting by natives, recreational fishing, tourism and scientific investigations. Trapping effort was at a very low level in the area in 1972-1974 although no official records are available. Some casual trapping of foxes has taken place by people travelling through the area.

Willow ptarmigan are hunted by natives in the Ya Ya Lake area but these activities should not be affected by this development.

At present, tourism in the lower Mackenzie Delta is limited by access.

At Taglu, reindeer herd encounters with the proposed facilities should occur only in summer and should not require additional management effort.

Finally, no future opportunity for the use of existing renewable resources would be lost as a result of the development project.

TABLES

Table 1

TAGLU PROCESSING PLANT

Feed-Gas Analyses

Component	Taglu MOL %
Nitrogen	0.12
Carbon Dioxide	0.26
Methane	92.81
Ethane	3.63
Propane	1.13
Iso Butane	0.23
Normal Butane	0.27
Hexane	0.05
Heptane	0.07
Octane	0.11
Nonane	0.05
Decane	0.10
Undecane	0.08
Dodecane	0.27
Benzene	0.04
Toluene	0.11
Xylene	0.19
Aromatic "A"	0.04
Cyclo Hexane	0.07
Naphthene "A"	0.16
	100.00

TABLE II

MATERIAL BALANCE FOR TAGLU GAS PLANT

Inputs to TAGLU GAS PLANT:

- Feed Gas 1 BCF/Day
- Hydrocarbon Liquid 15085 BPD in feed gas
- Water 200 BPD in feed gas

Outputs from TAGLU GAS PLANT:

- Sales Gas .98 BCF/Day
- Water in Sales Gas 200 Lb/Day
- Pentanes Plus Liquids 11,885 BPD
- Waste Water 199.5 B/D

A sales gas burned with 100% excess air →

Pilot Light Gas	36 MCFD
CO_2	36 MCFD
H_2O	72 MCFD
O_2	72 MCFD
N_2	576 MCFD
Oxides of Nitrogen	7 lb. per day

Pentanes plus liquid burned with 200% excess air →

Plant Fuel	3200 B/D
CO_2	43 lbs/hr.
H_2O	4914 lbs/hr.
Particulates	11 lbs/hr.
Hydrocarbons	66 lbs/hr.
Oxides of Nitrogen	210 lbs/hr.

→

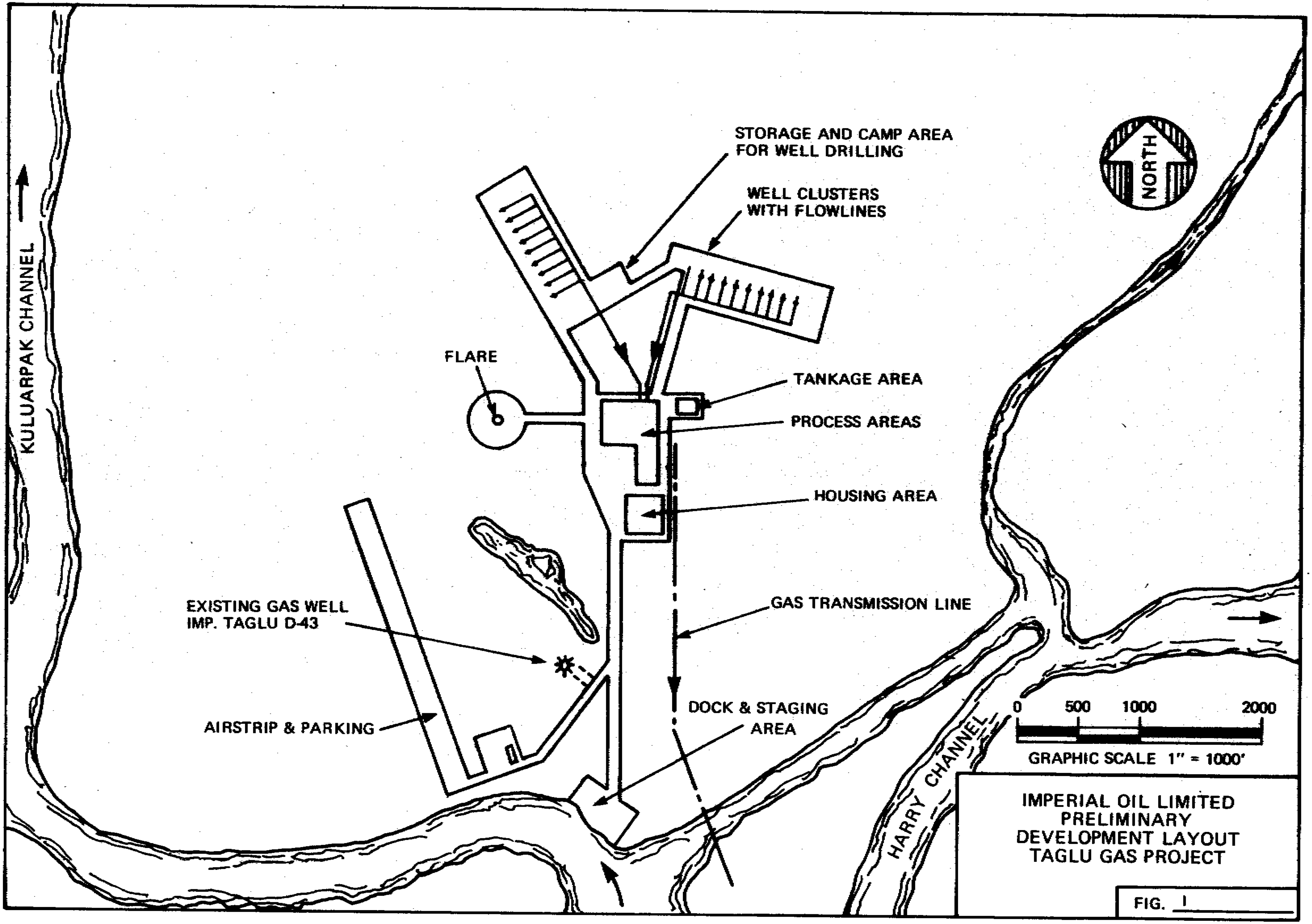
Power Generation Fuel	3.2 MMSCFD
CO_2	Nil
H_2O	13,000 lbs/hr.
Particulates	2 lbs/hr.
Hydrocarbons	3 lbs/hr.
Oxides of Nitrogen	105 lbs/hr.

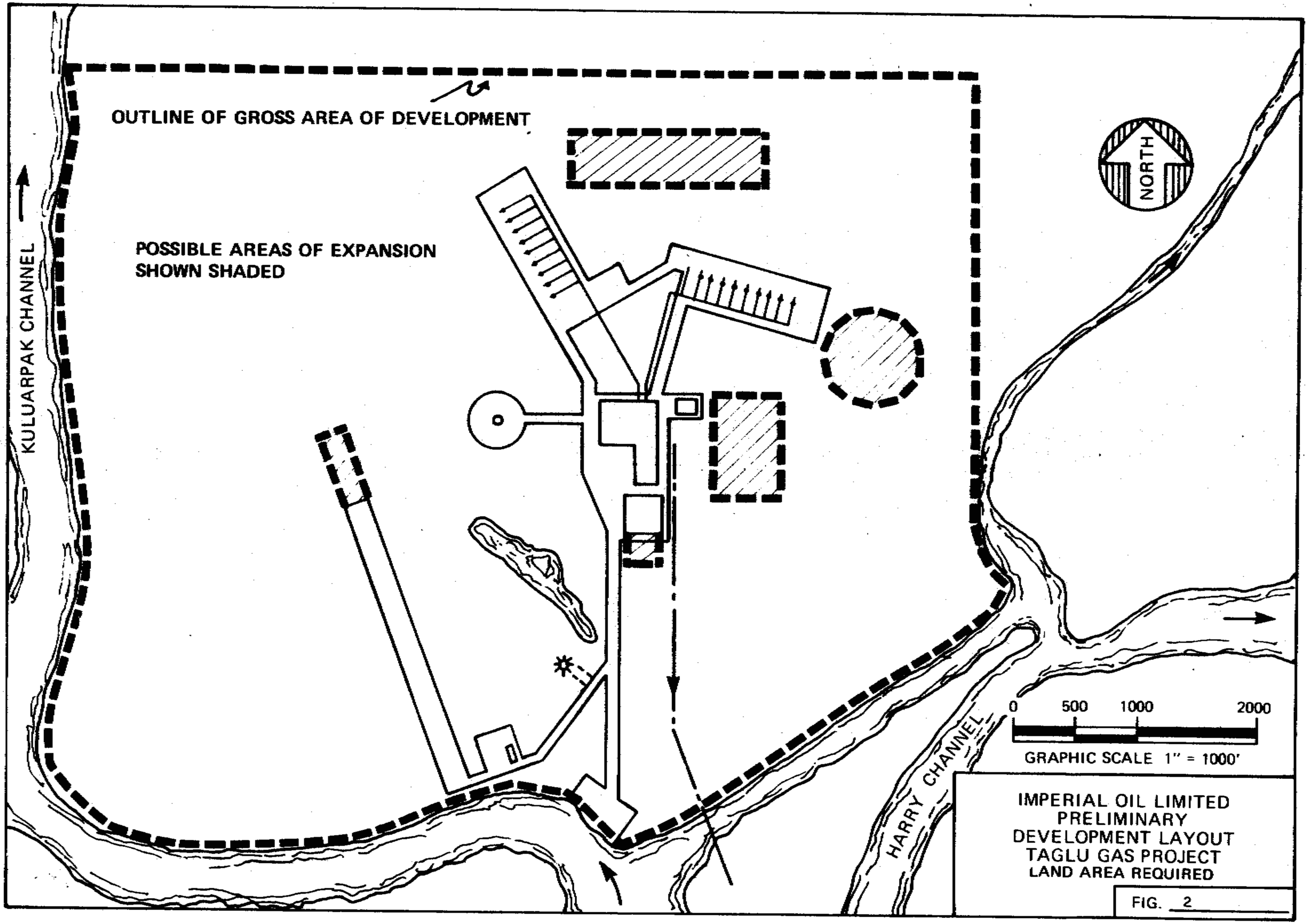
Plant gas burned with 100% excess air →

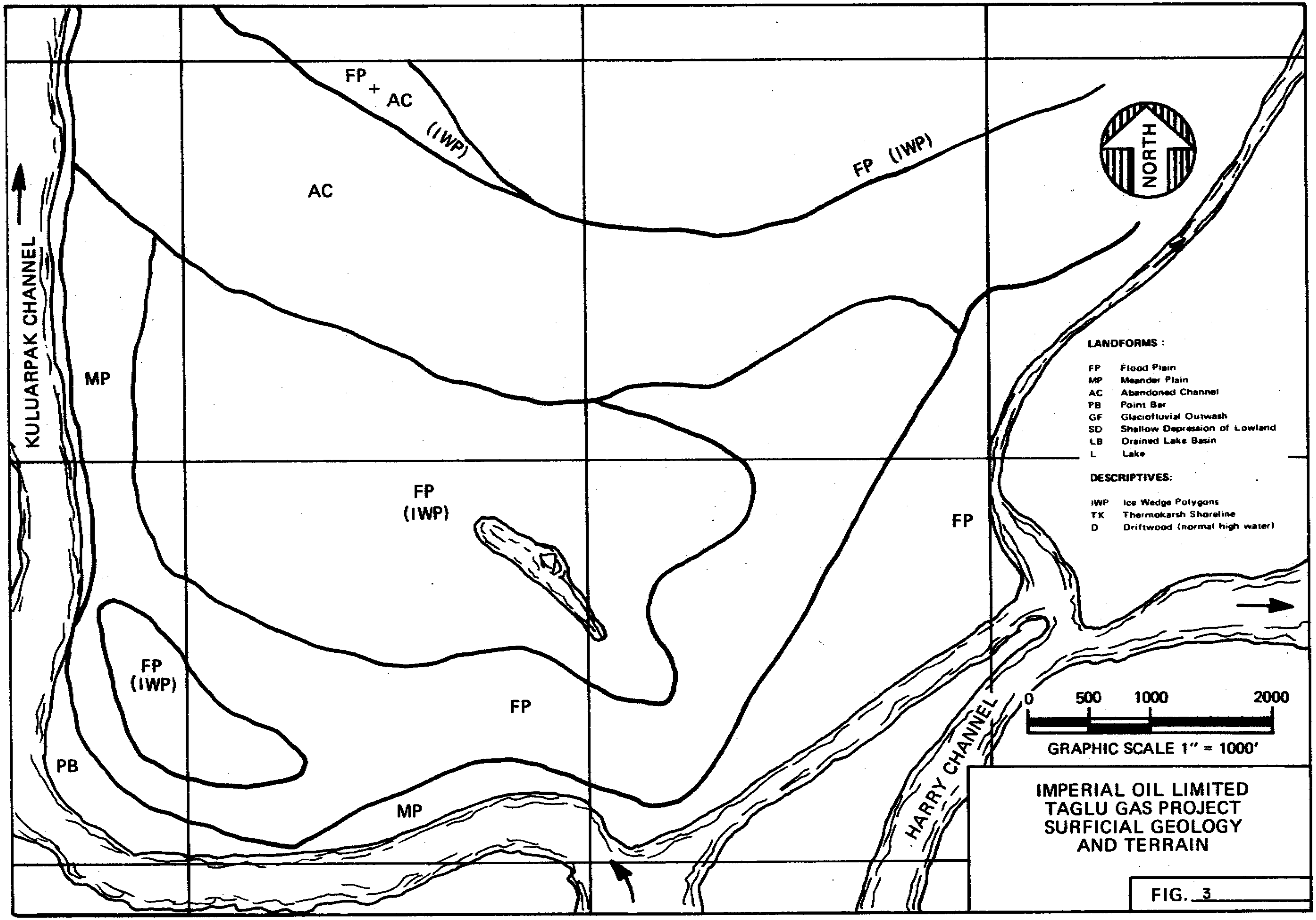
Maximum Emergency Flare	347 MCF per min.
CO_2	347 MCF per min.
H_2O	694 MCF per min.
O_2	694 MCF per min.
N_2	3560 MCF per min.
Oxides of Nitrogen	68 lb. per min.

All gas volumes are in standard cubic feet at 14.696 psia and 60°F

FIGURES


STORAGE AND CAMP AREA
FOR WELL DRILLING
WELL CLUSTERS
WITH FLOWLINES
NORTH
KULUARPAK CHANNEL
FLARE
TANKAGE AREA
PROCESS AREAS
HOUSING AREA
EXISTING GAS WELL
IMP. TAGLU D-43
GAS TRANSMISSION LINE
DOCK & STAGING
AREA
AIRSTRIP & PARKING
HARRY CHANNEL
0
500
1000
2000
GRAPHIC SCALE 1" = 1000'
IMPERIAL OIL LIMITED
PRELIMINARY
DEVELOPMENT LAYOUT
TAGLU GAS PROJECT
FIG. 1


OUTLINE OF GROSS AREA OF DEVELOPMENT
POSSIBLE AREAS OF EXPANSION
SHOWN SHADED
KULUARPAK CHANNEL
NORTH
HARRY CHANNEL
0 500 1000 2000
GRAPHIC SCALE 1" = 1000'
IMPERIAL OIL LIMITED
PRELIMINARY
DEVELOPMENT LAYOUT
TAGLU GAS PROJECT
LAND AREA REQUIRED
FIG. 2



IMPERIAL OIL LIMITED
TAGLU GAS PROJECT
SURFICIAL GEOLOGY
AND TERRAIN

FIG. 3

PROPOSED TAGLU WELL DESIGN

SEPT. 1975

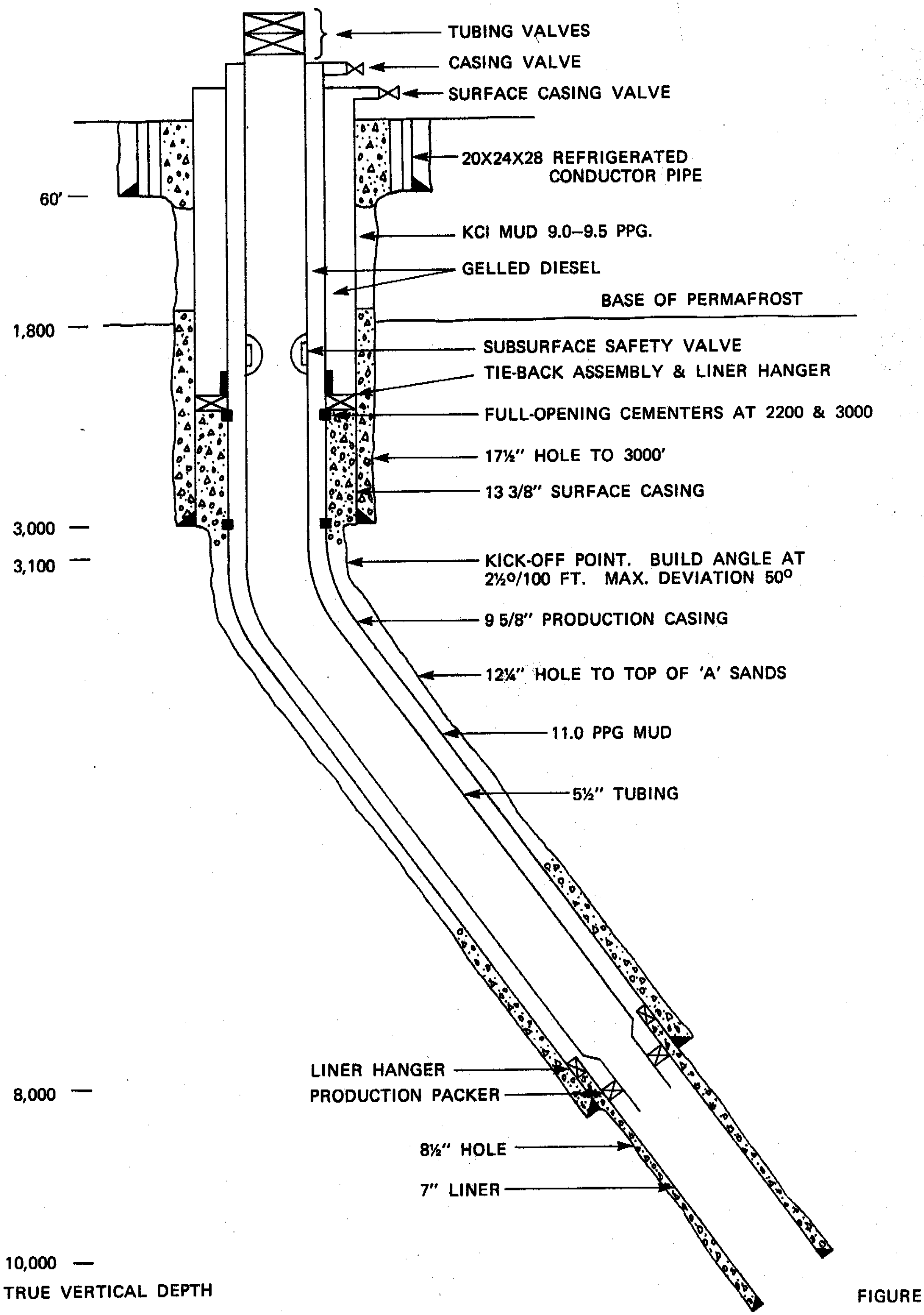


FIGURE 5

PRELIMINARY
DRILLING PAD LAYOUT

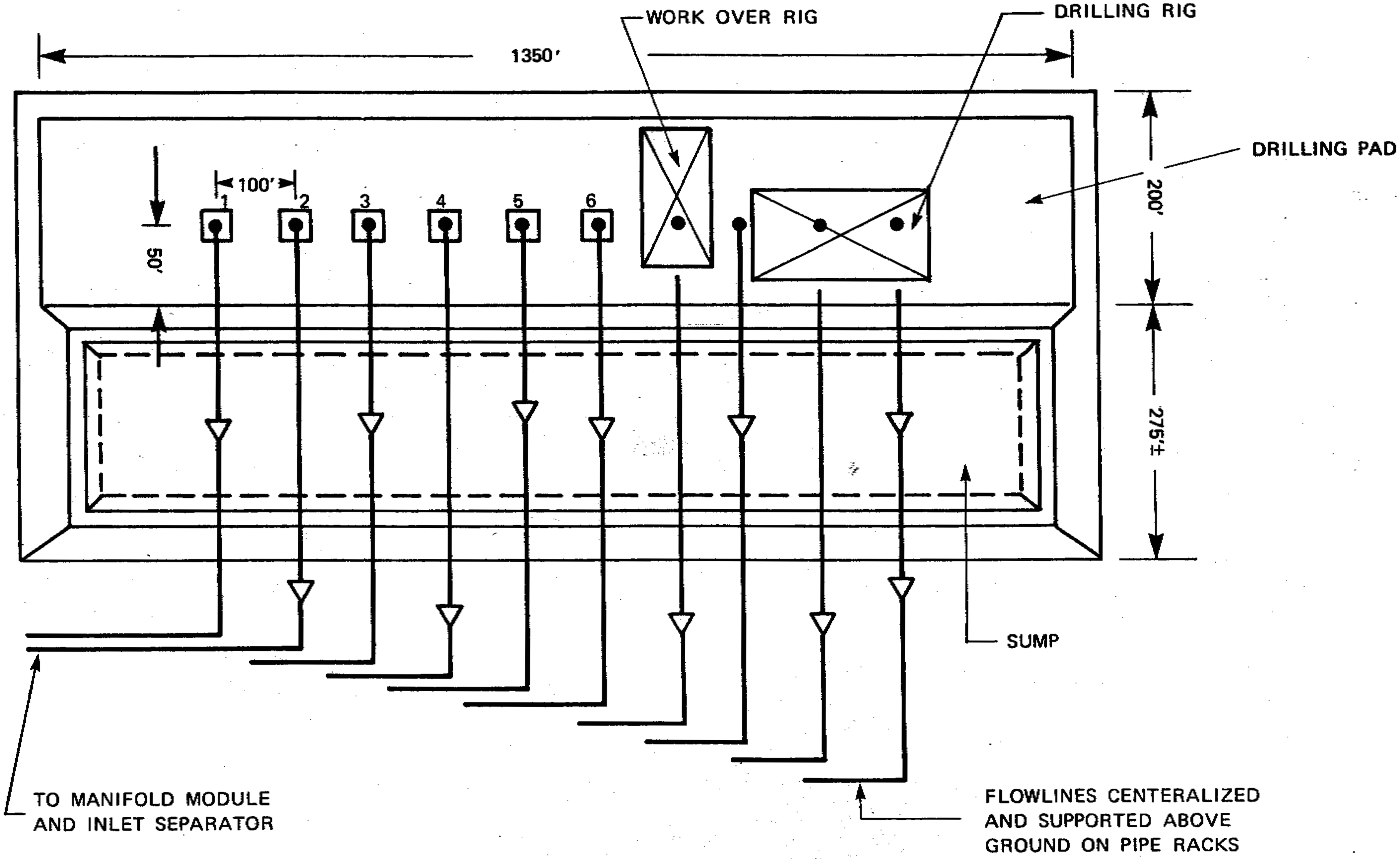


FIGURE 6

MAIN PROCESS FACILITIES TAGLU GAS PLANT

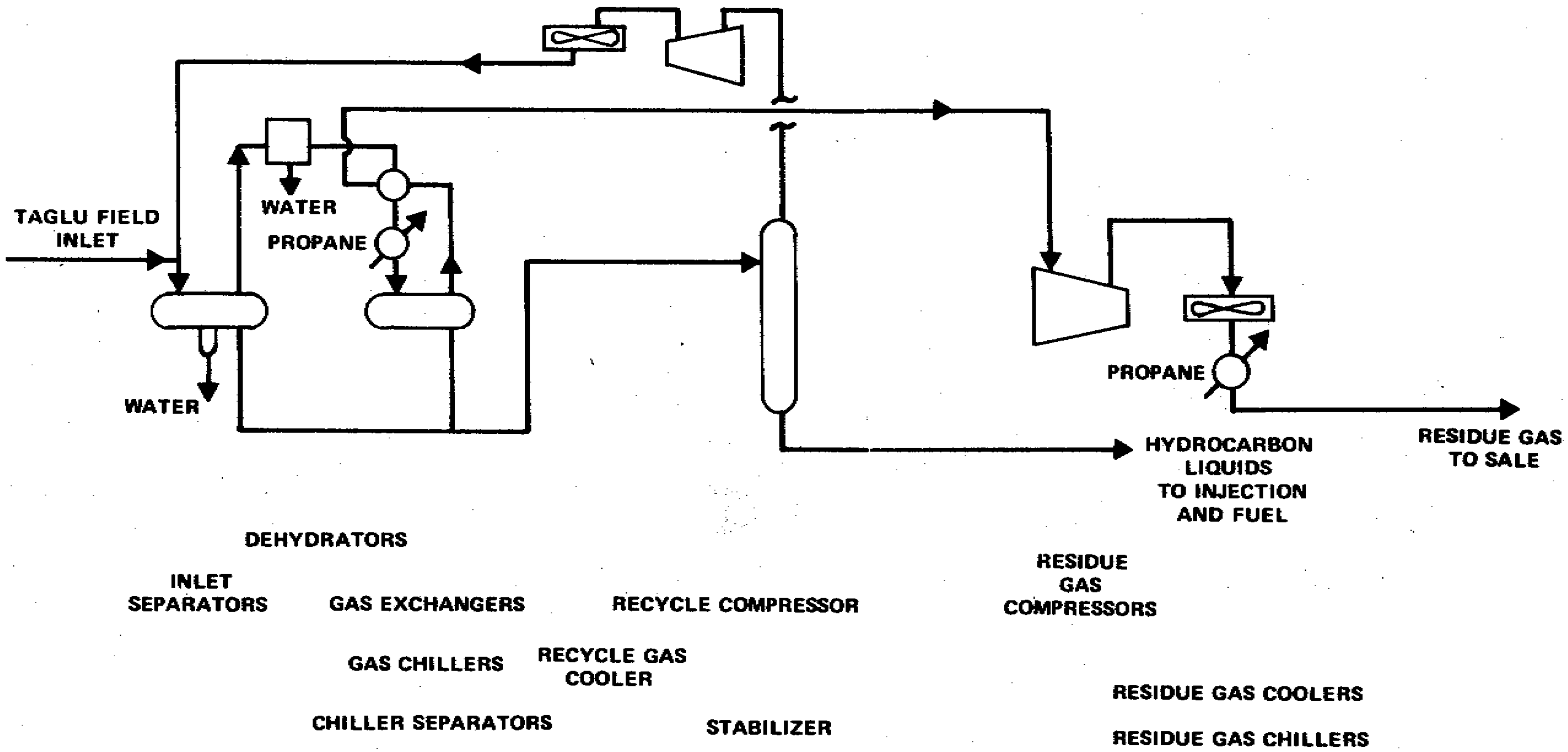


FIGURE 7

TYPICAL REFRIGERATION FACILITIES TAGLU GAS PLANT

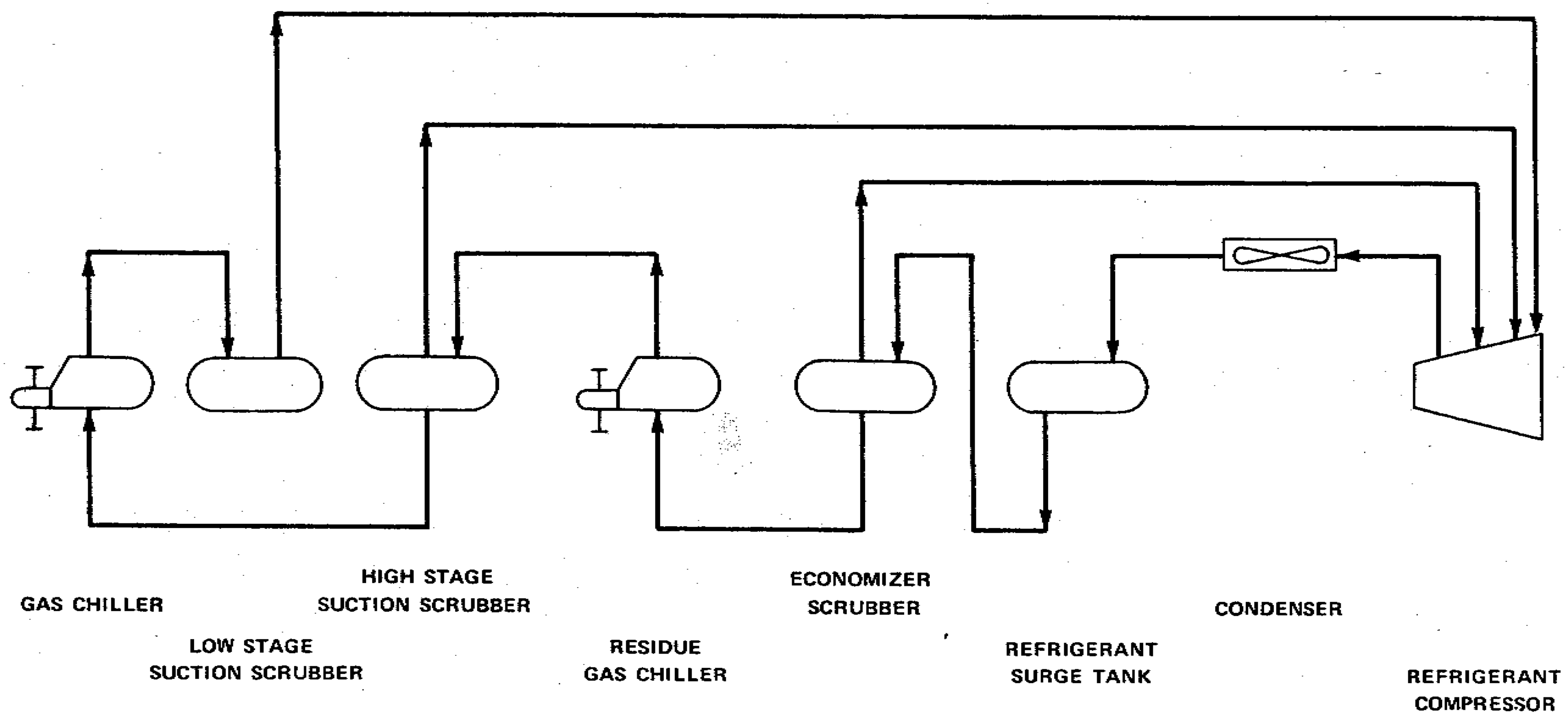


FIGURE 8

25-487

WORK CONDITIONS - MACKENZIE DELTA AREA

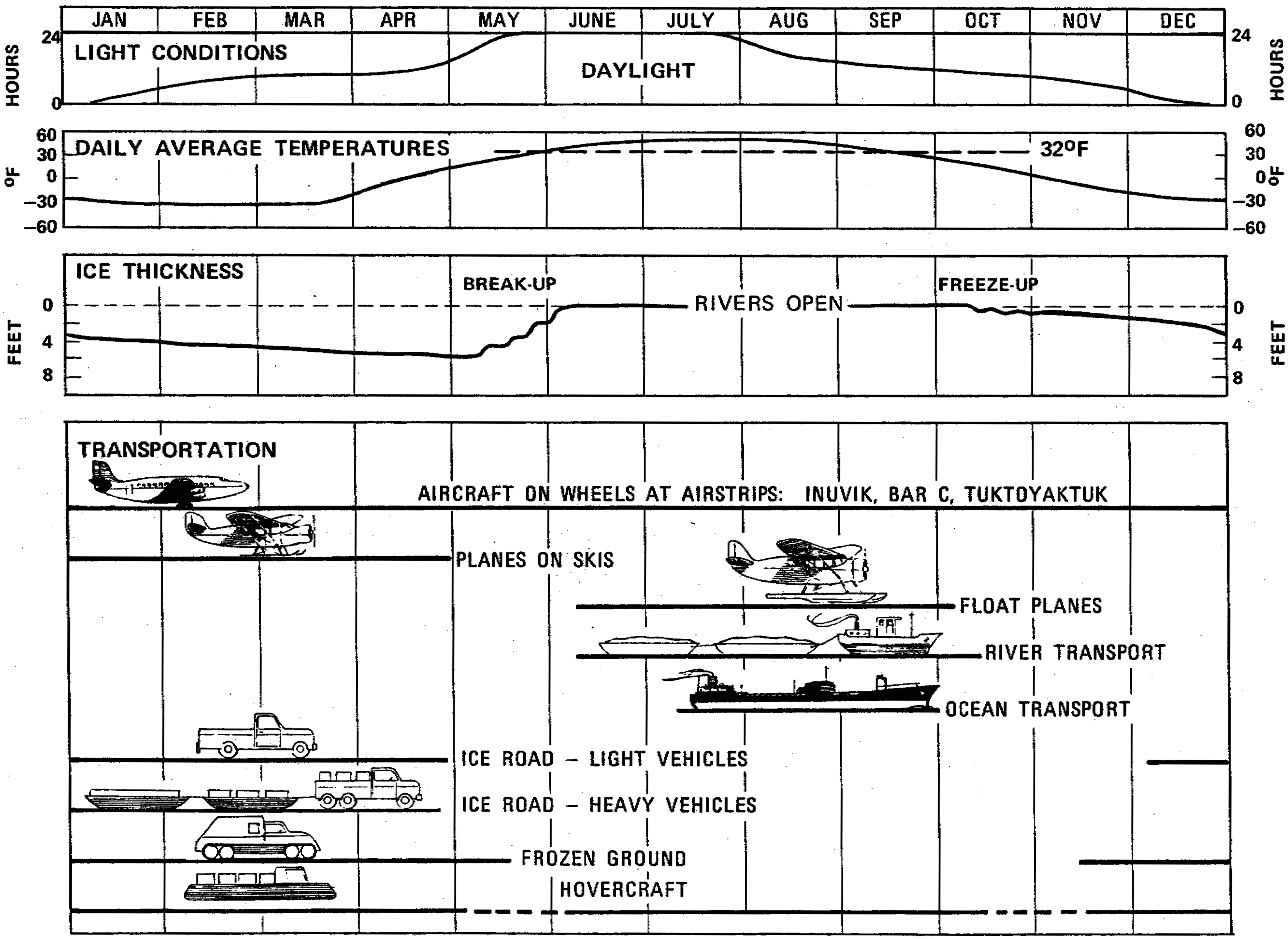


FIGURE 9

TAGLU GAS PLANT PROJECT SCHEDULE

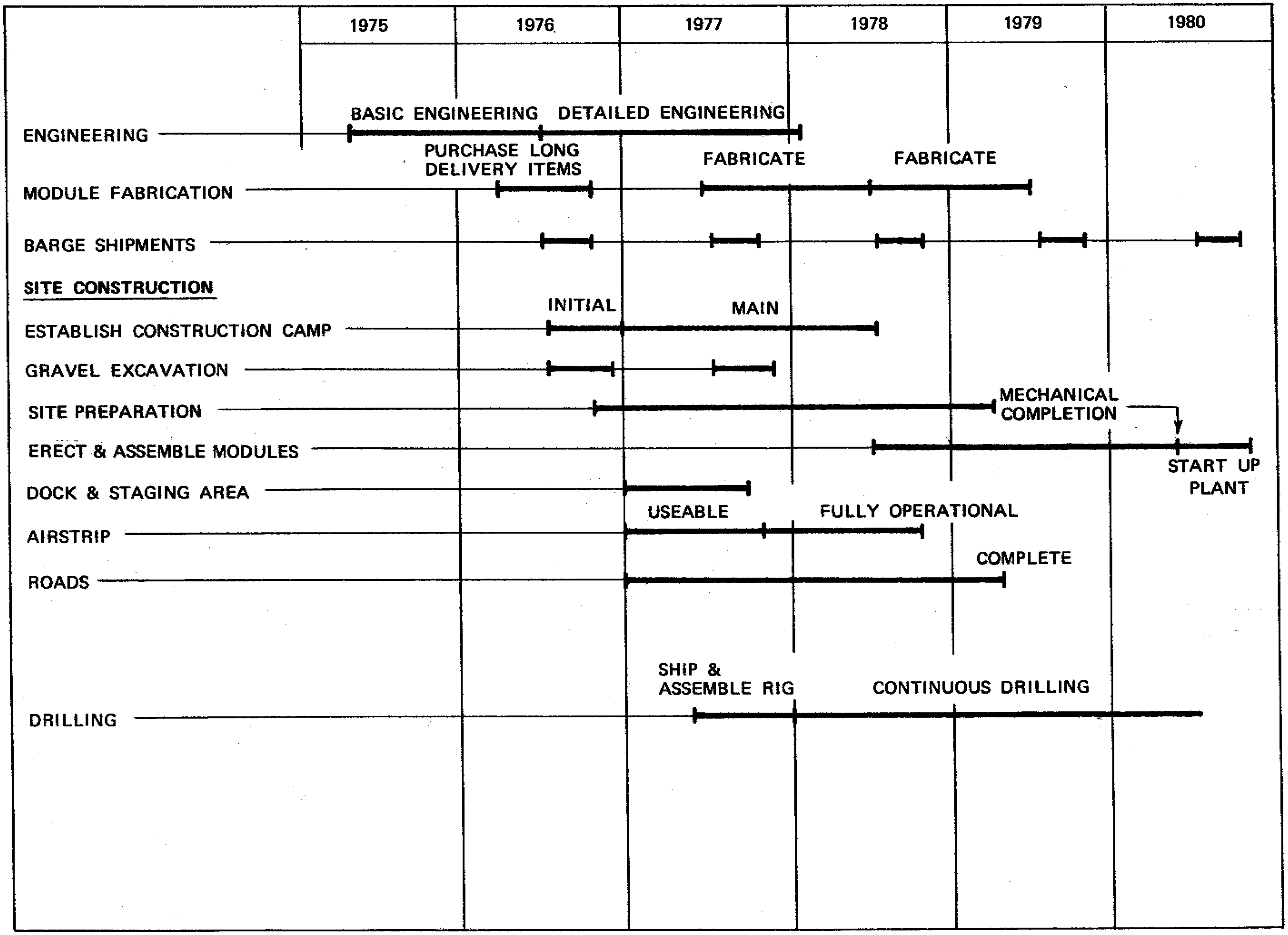
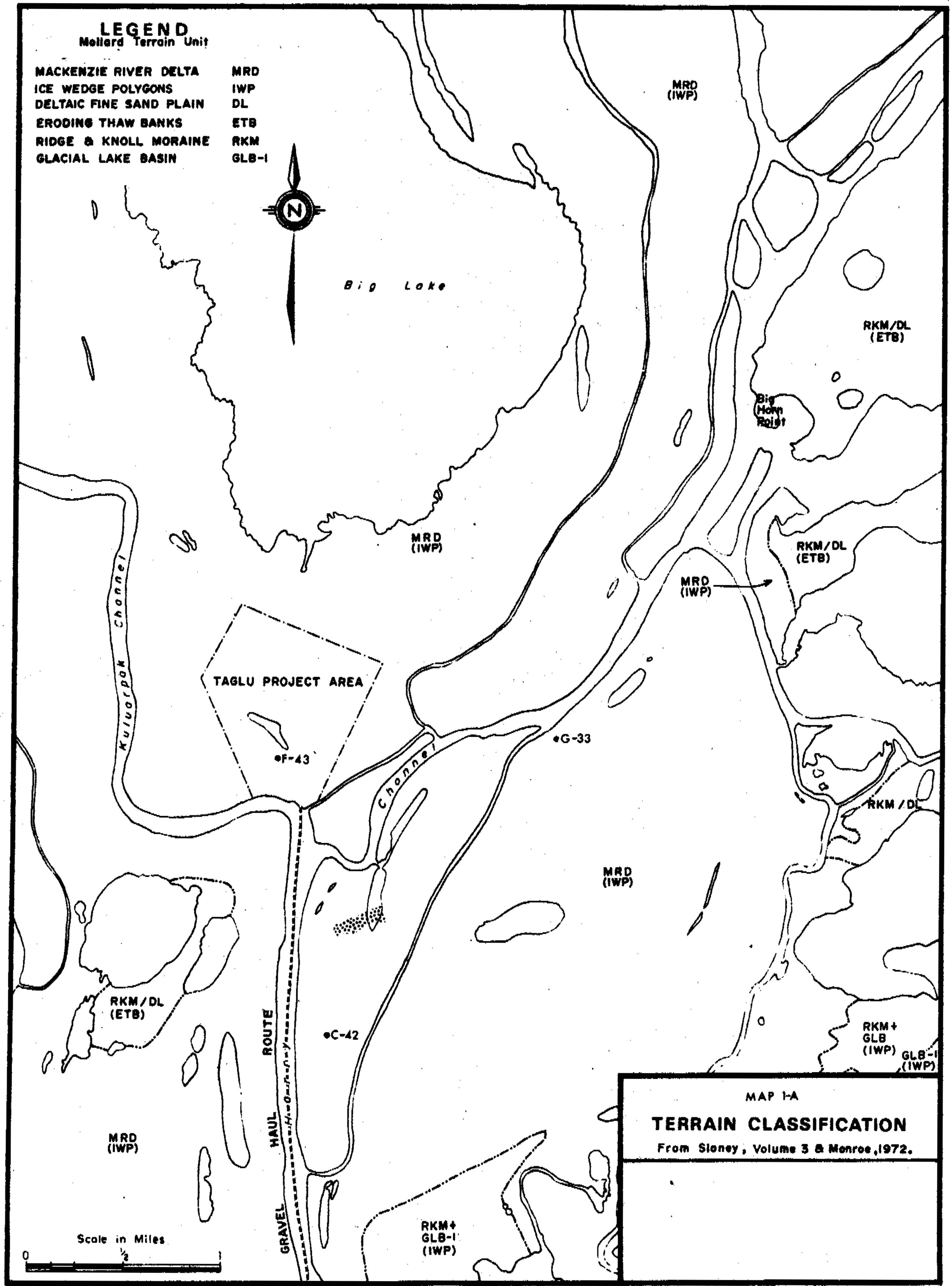


FIGURE 10

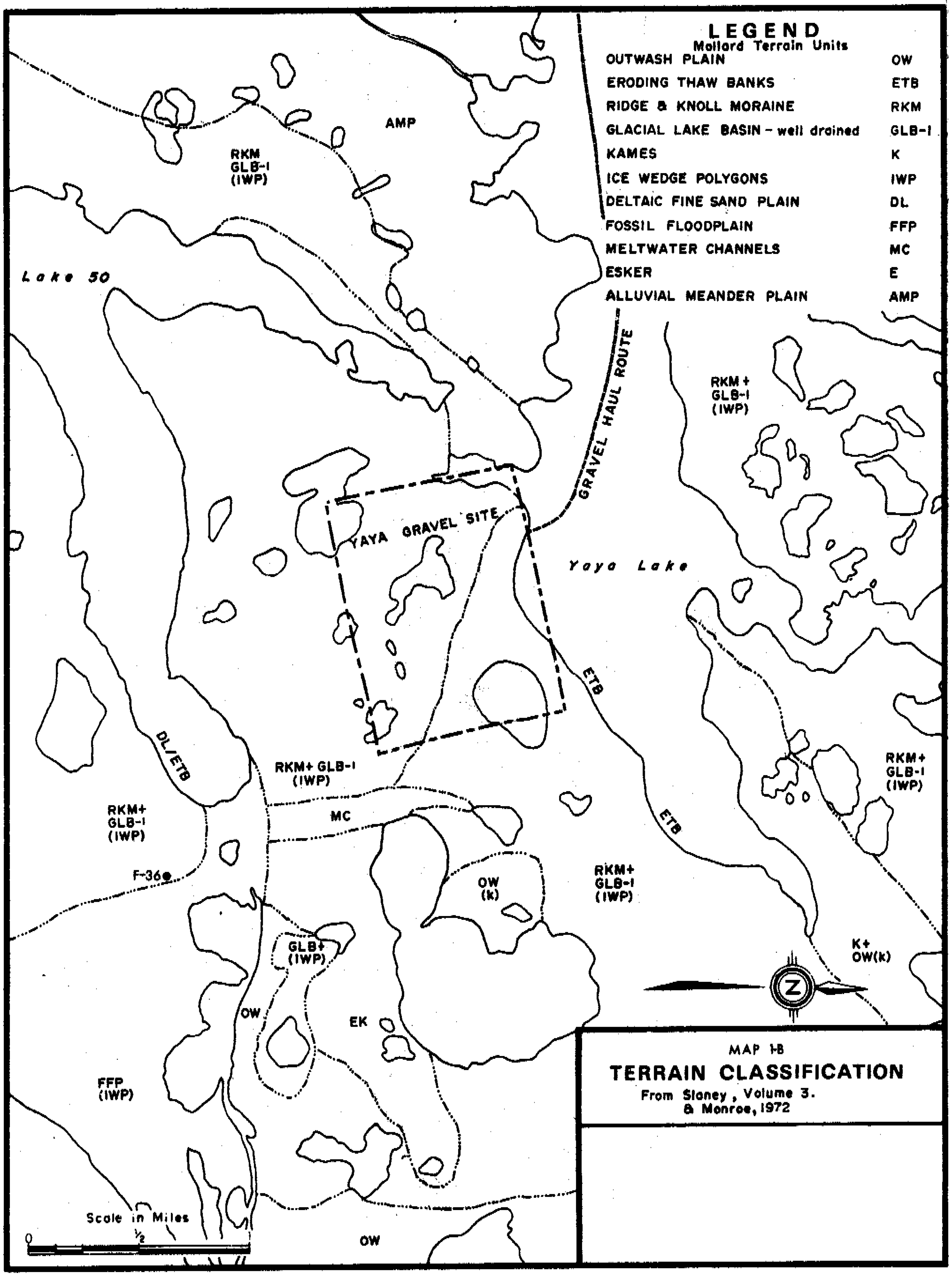
ENVIRONMENTAL MAPS



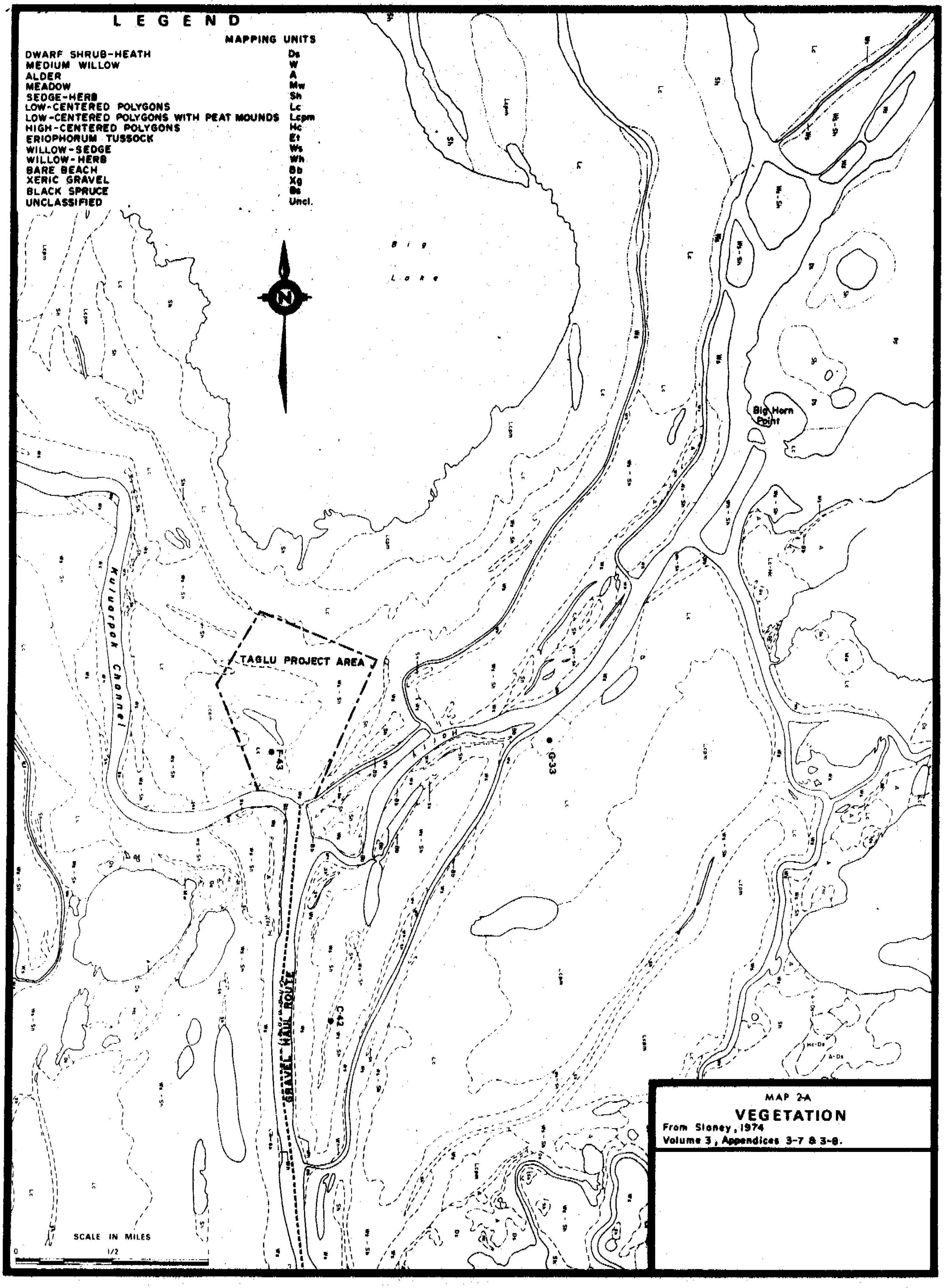
MAP 1-A

TERRAIN CLASSIFICATION

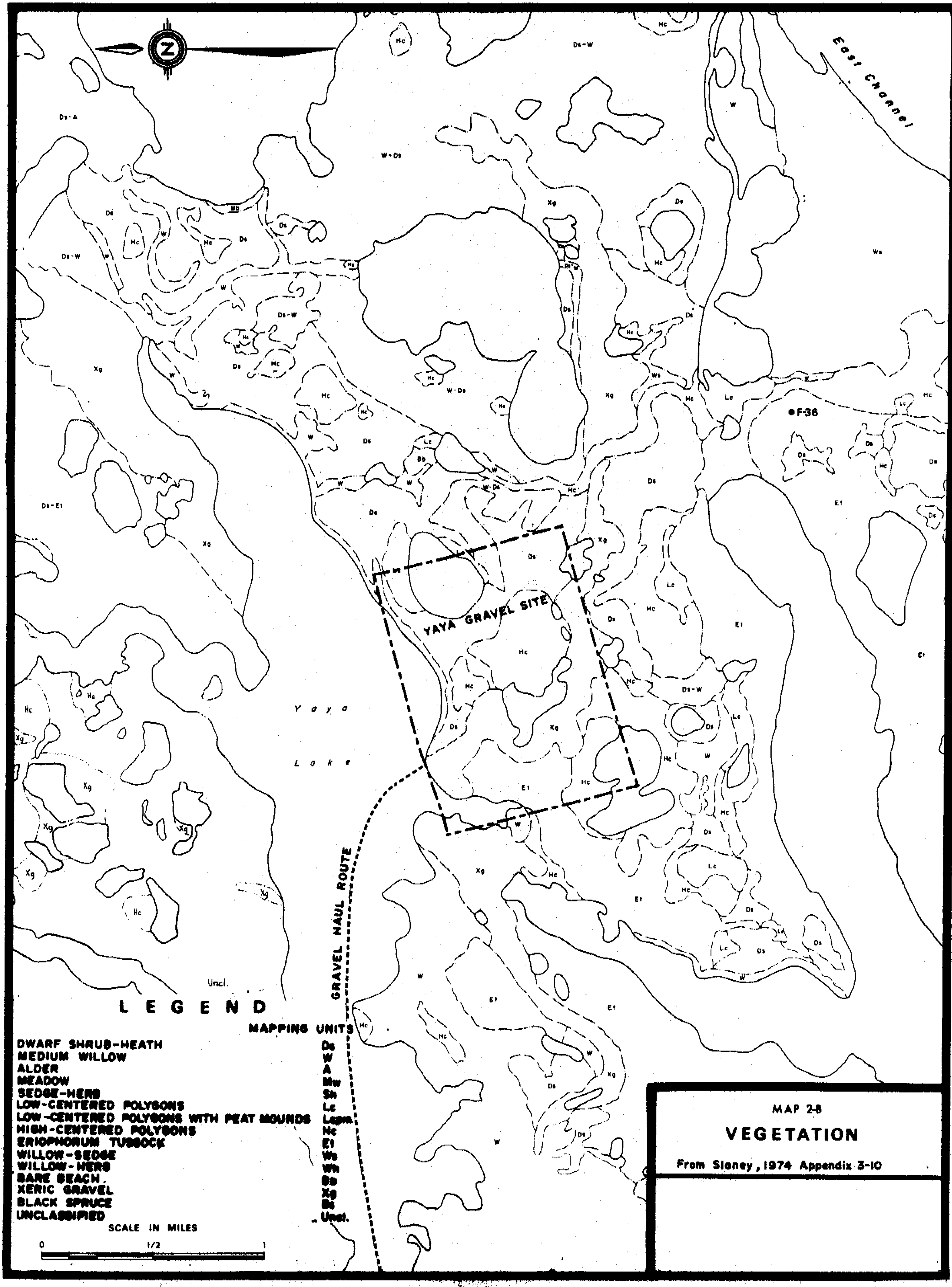
From Slaney, Volume 3 & Monroe, 1972.



MAP 1-B
TERRAIN CLASSIFICATION
From Sloney, Volume 3.
& Monroe, 1972



MAP 2-A
VEGETATION
From Slaney, 1974
Volume 3, Appendices 3-7 & 3-8.



MAP 2-8

VEGETATION

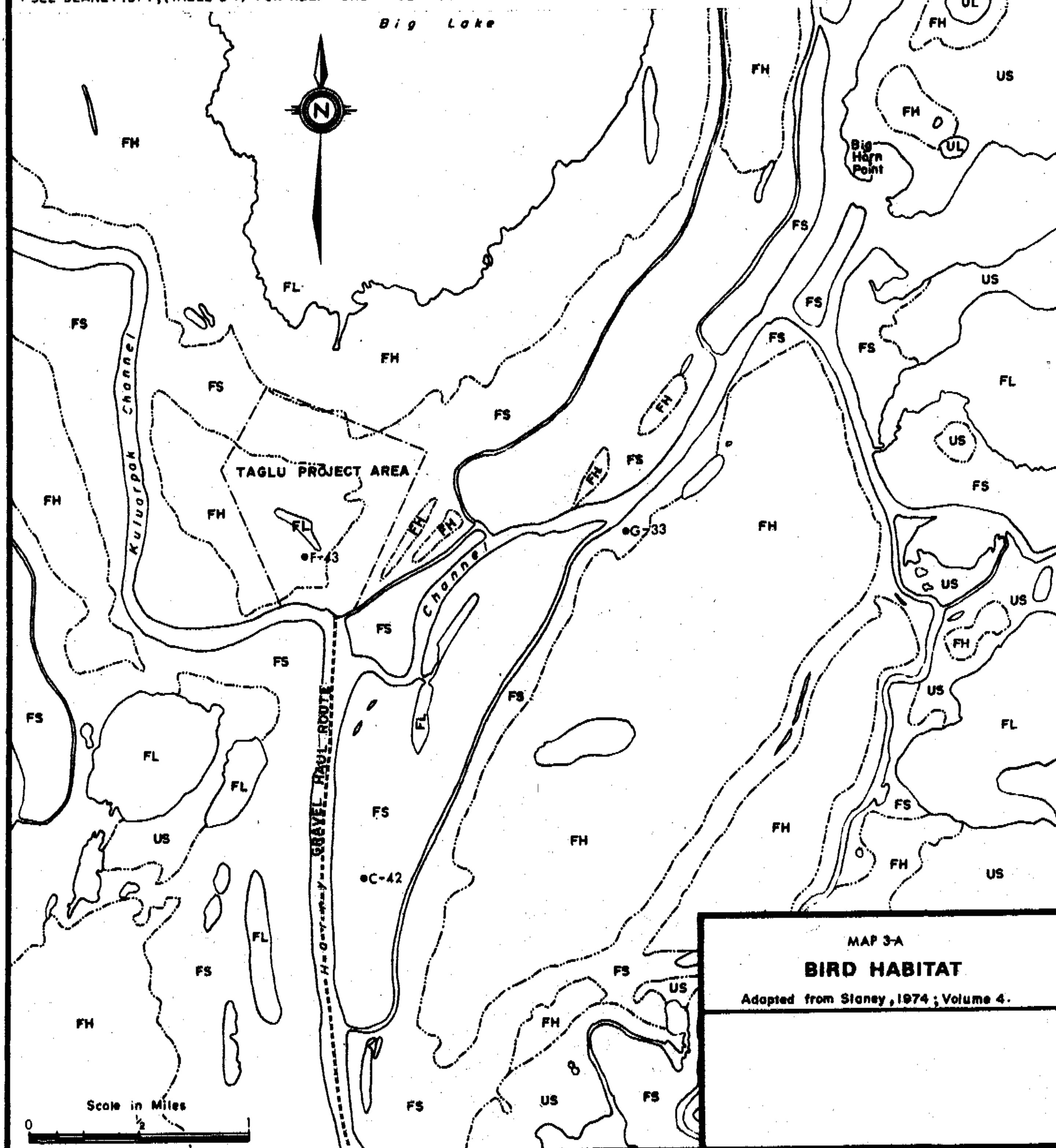
From Sloney, 1974 Appendix 3-10

RELATIVE BIRD USE OF HABITAT DURING NESTING PERIOD

	HABITAT TYPE* FLOODPLAIN HERB (FH)	SHRUB (FS)	LAKES (FL)	CHANNELS	UPLAND HERB (UH)	SHRUB (US)	LAKES (UL)
LOONS	4	4	4	1	4	4	4
SWANS	4	3	2	2	4	3	3
GEESE	3	2	3	2	4	4	3
DUCKS	4	3	4	2	4	4	4
SMALL SHOREBIRDS	3	3	2	1	3	2	2
LARGE SHOREBIRDS	3	2	2	1	2	1	1
PTARMIGAN	1	1	1	1	2	4	1
PASSERINES	2	5	1	1	2	5	1
GULLS & TERNS	4	3	3	2	4	3	3

BIRD USE: 5, INTENSE; 4, HIGH; 3, MODERATE; 2, LOW; 1, NIL.

* SEE SLANEY 1974, (TABLE 3-1) FOR RELATIONSHIP BETWEEN VEGETATION MAPPING AND HABITAT TYPES.



MAP 3-A

BIRD HABITAT

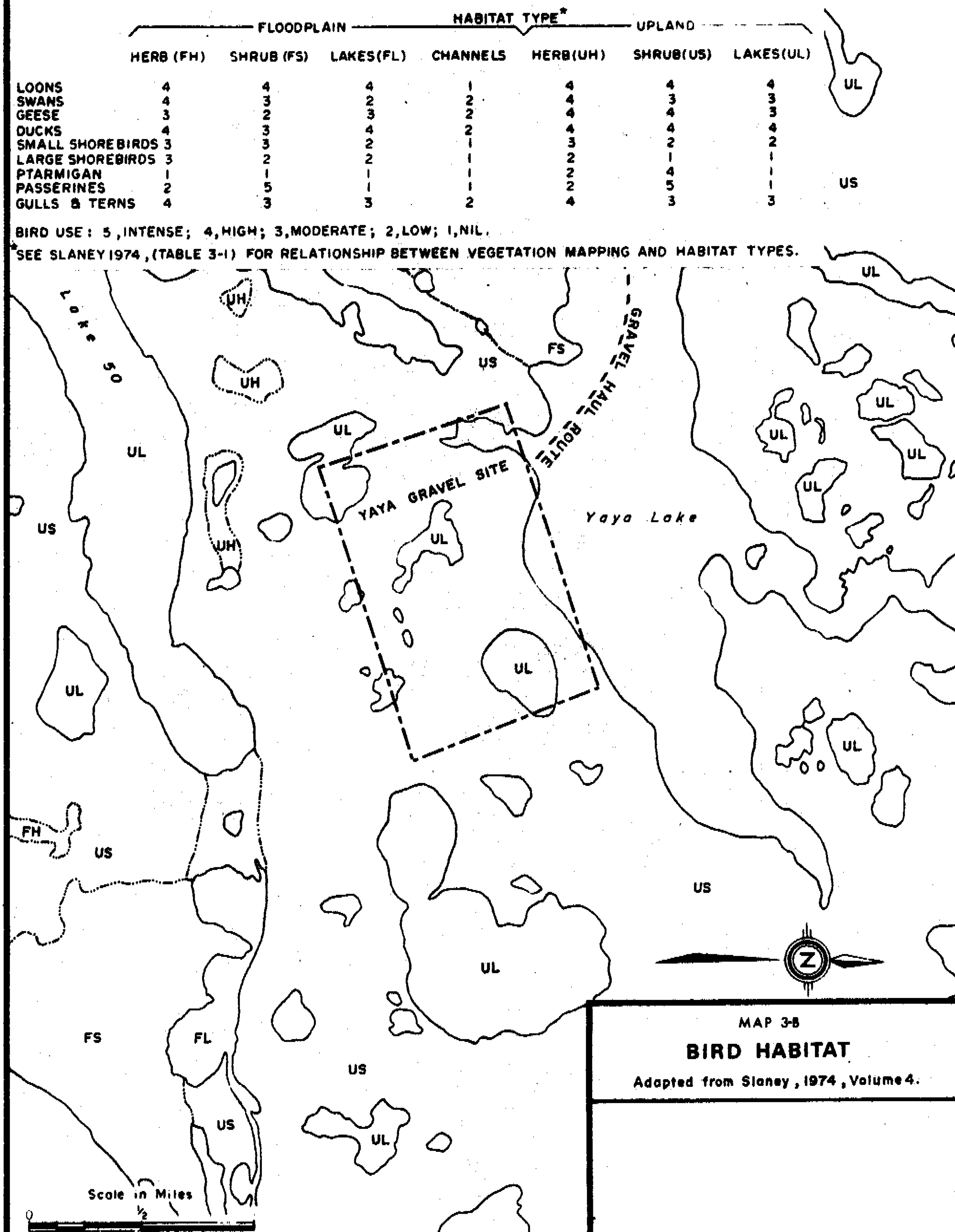
Adapted from Slaney, 1974; Volume 4.

RELATIVE BIRD USE OF HABITAT DURING NESTING PERIOD

	HABITAT TYPE* FLOODPLAIN				UPLAND		
	HERB (FH)	SHRUB (FS)	LAKES (FL)	CHANNELS	HERB (UH)	SHRUB (US)	LAKES (UL)
LOONS	4	4	4	1	4	4	4
SWANS	4	3	2	2	4	3	3
GEESE	3	2	3	2	4	4	3
DUCKS	4	3	4	2	4	4	4
SMALL SHOREBIRDS	3	3	2	1	3	2	2
LARGE SHOREBIRDS	3	2	2	1	2	1	1
PTARMIGAN	1	1	1	1	2	4	1
PASSERINES	2	5	1	1	2	5	1
GULLS & TERNS	4	3	3	2	4	3	3

BIRD USE: 5, INTENSE; 4, HIGH; 3, MODERATE; 2, LOW; 1, NIL.

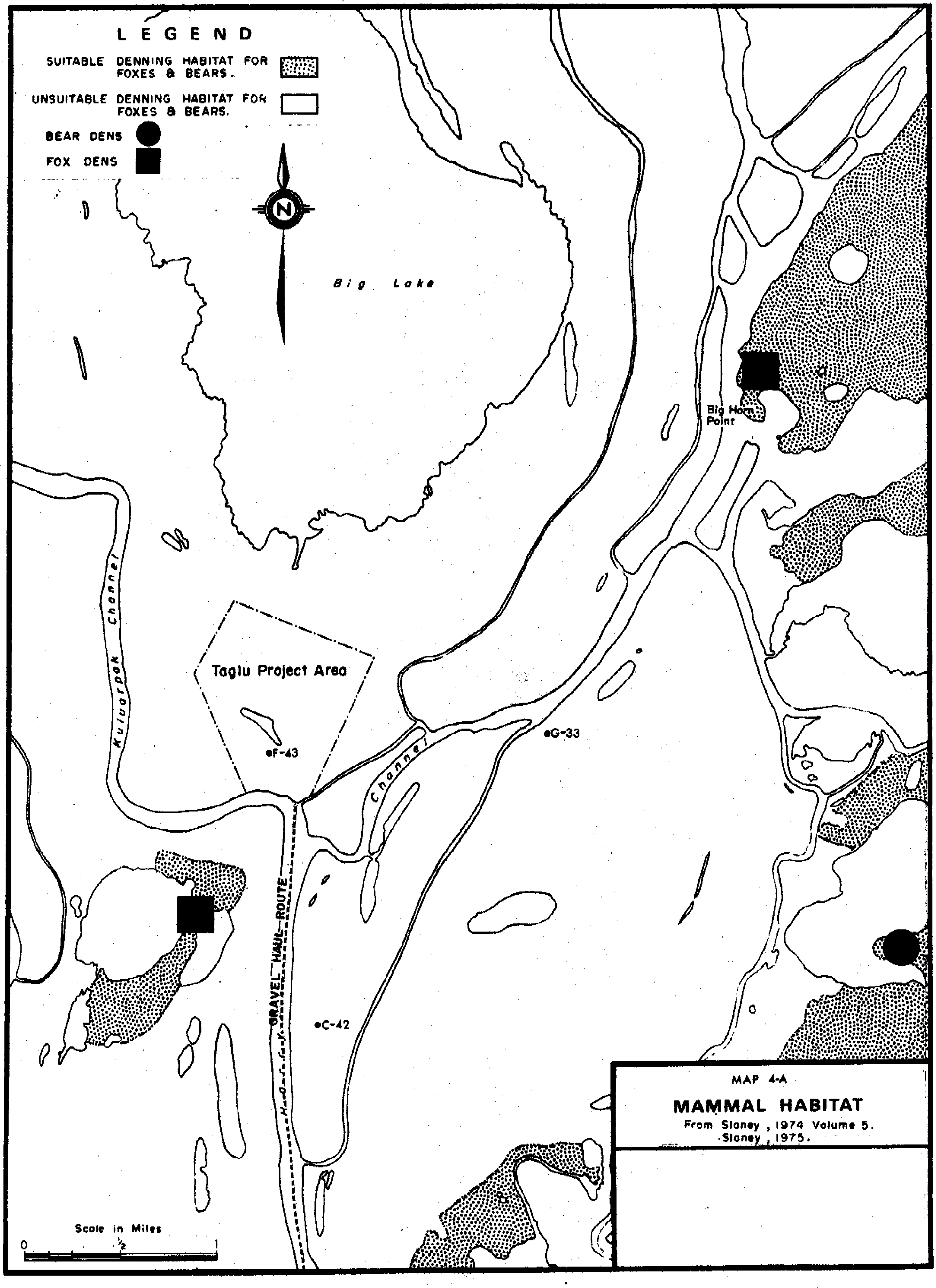
*SEE SLANEY 1974, (TABLE 3-1) FOR RELATIONSHIP BETWEEN VEGETATION MAPPING AND HABITAT TYPES.



MAP 3-8

BIRD HABITAT

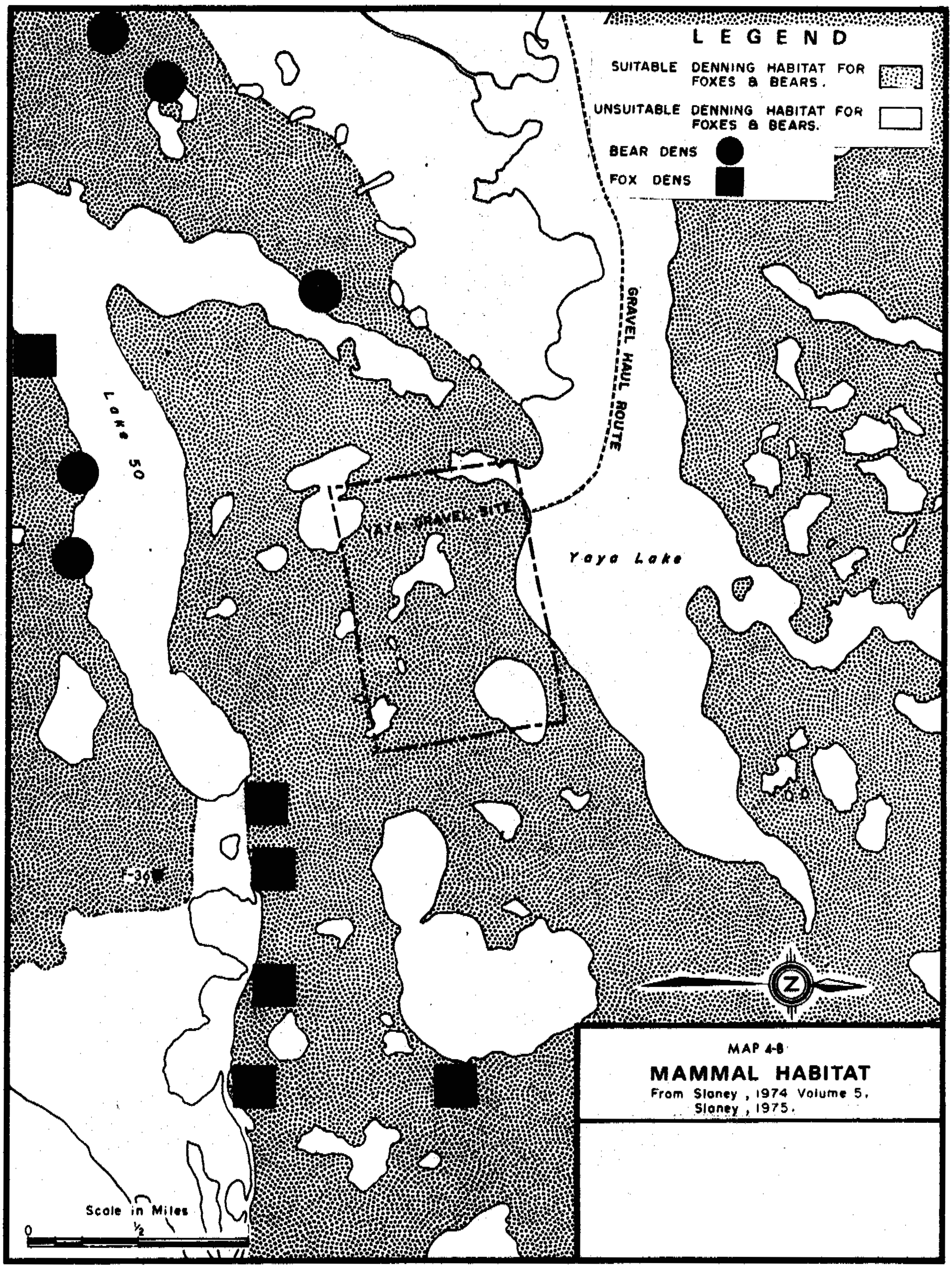
Adapted from Slaney, 1974, Volume 4.

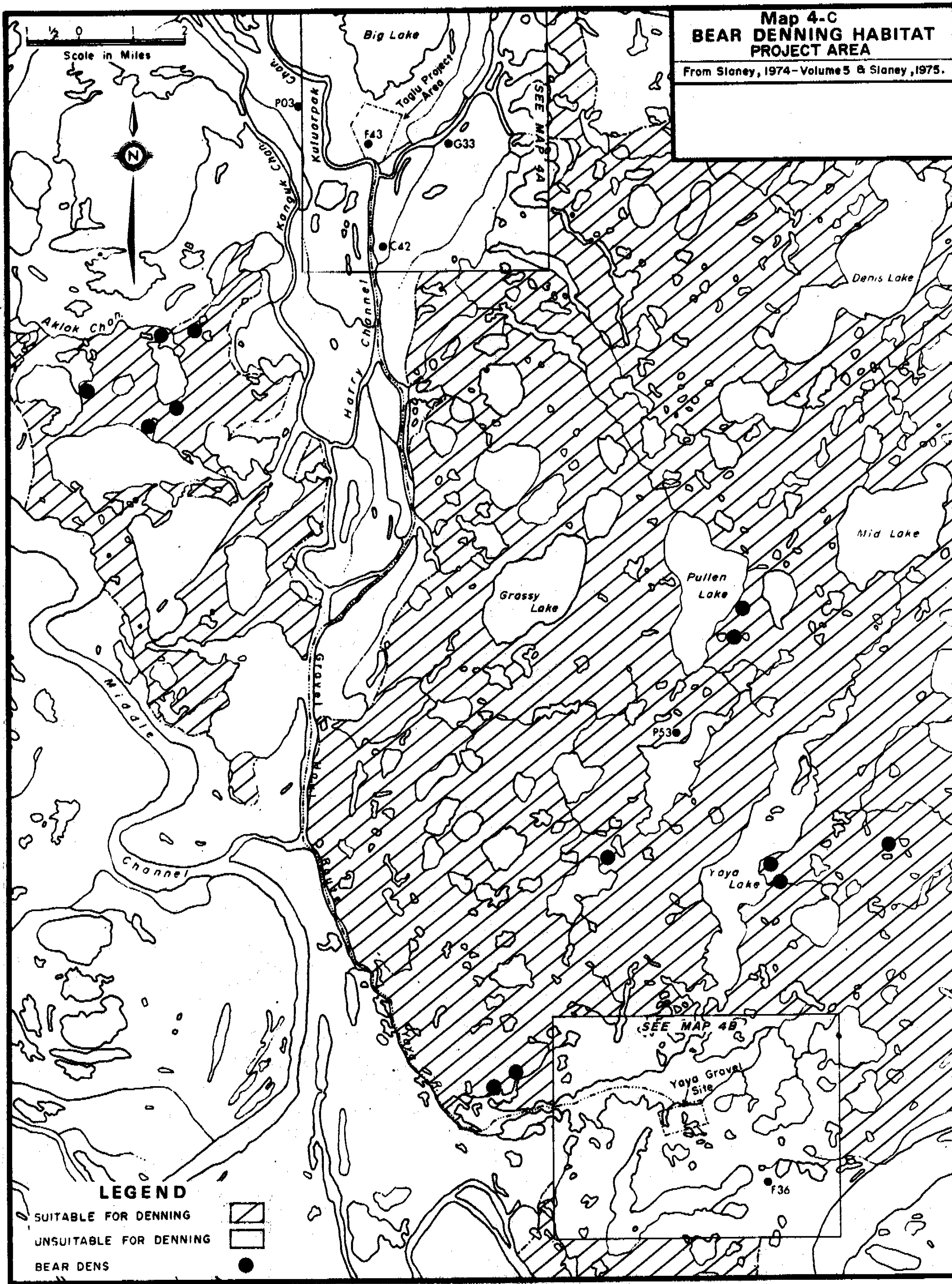


MAP 4-A

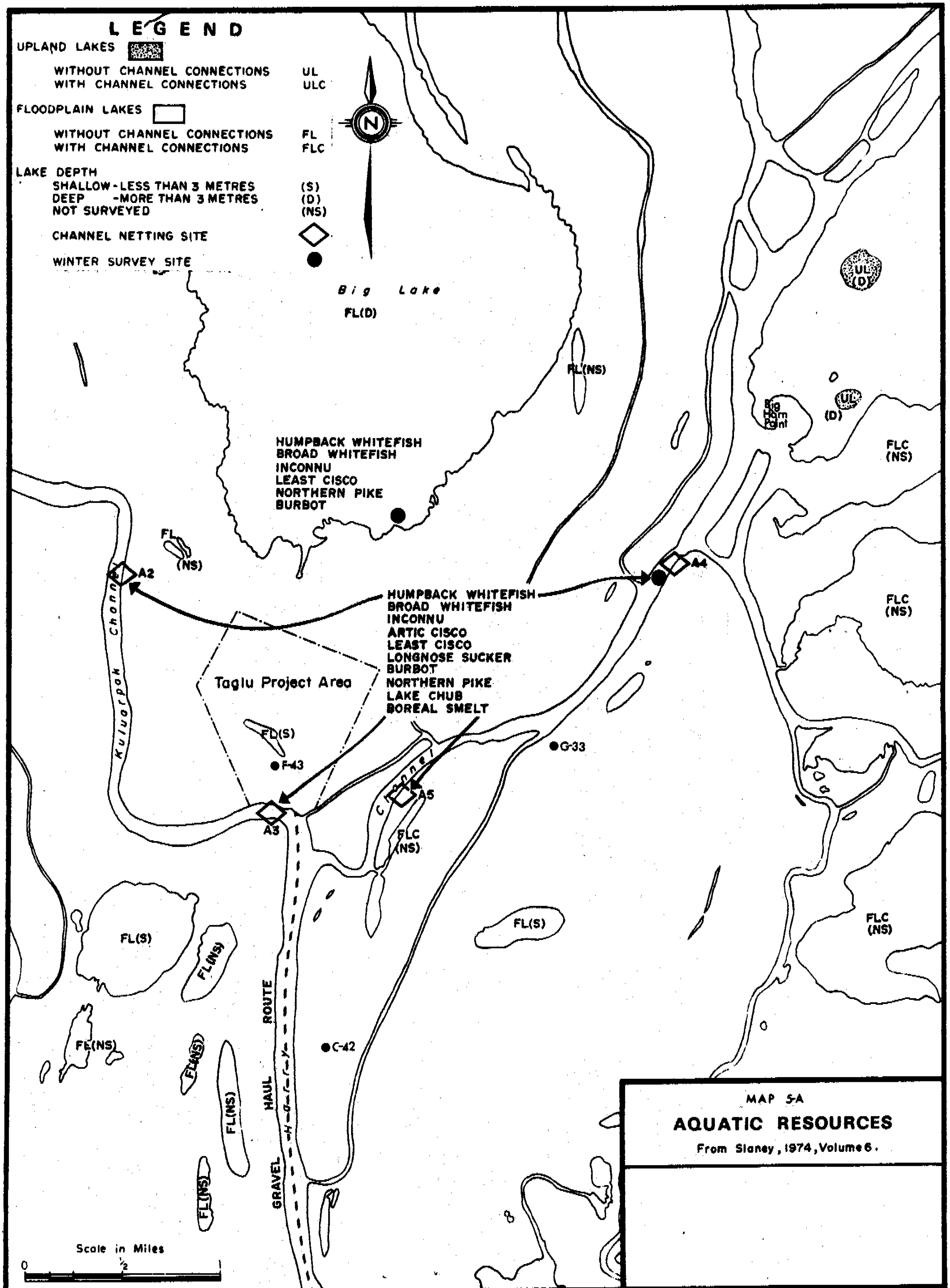
MAMMAL HABITAT

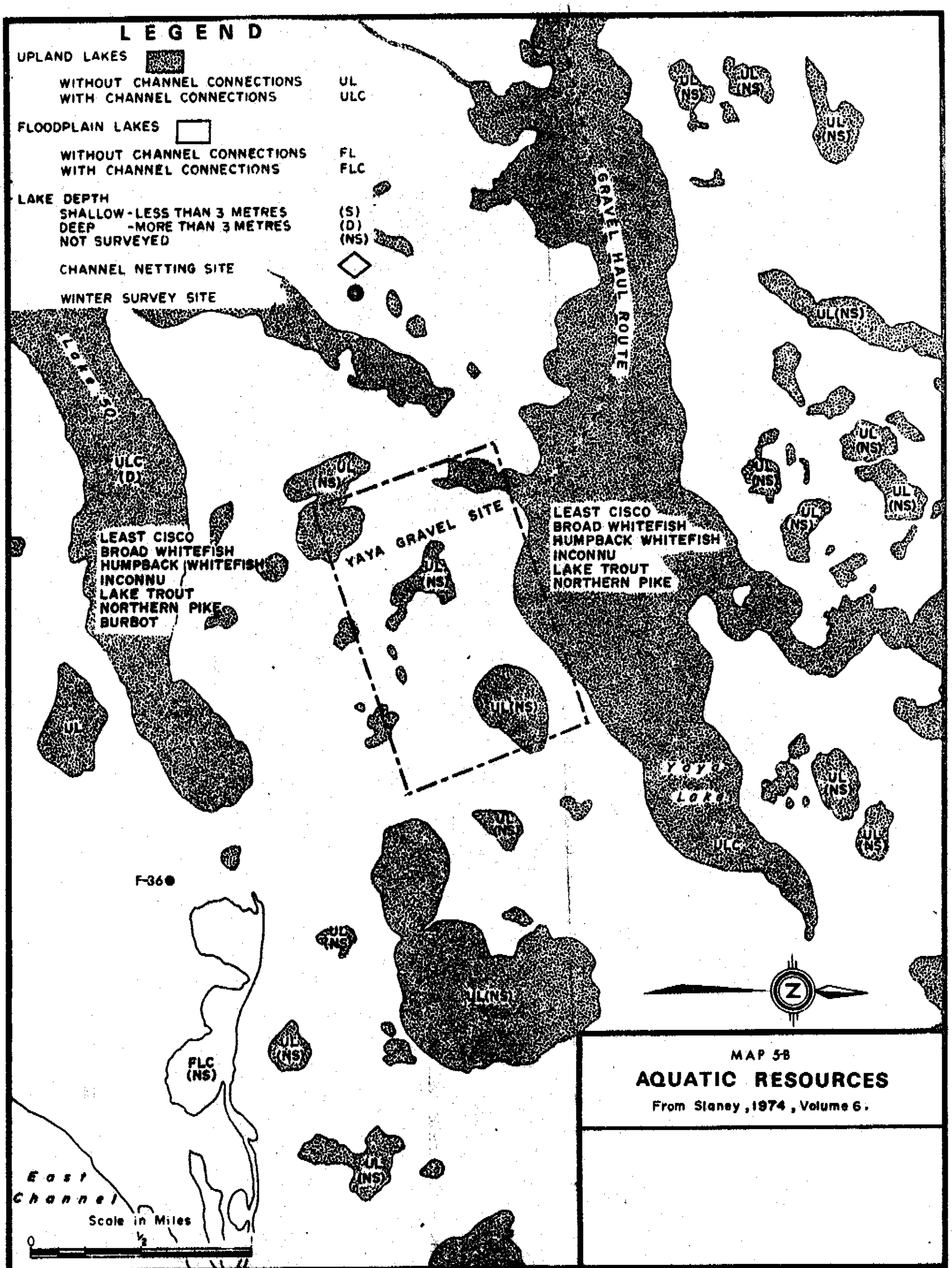
From Slaney, 1974 Volume 5.
Slaney, 1975.


LEGEND
SUITABLE DENNING HABITAT FOR FOXES & BEARS.
UNSUITABLE DENNING HABITAT FOR FOXES & BEARS.
BEAR DENS
FOX DENS
GRAVEL HAUL ROUTE
YAYA GRAVEL SITE
Yaya Lake
Lake 50
Scale in Miles
0
½
MAP 4-8
MAMMAL HABITAT
From Sloney, 1974 Volume 5,
Sloney, 1975.

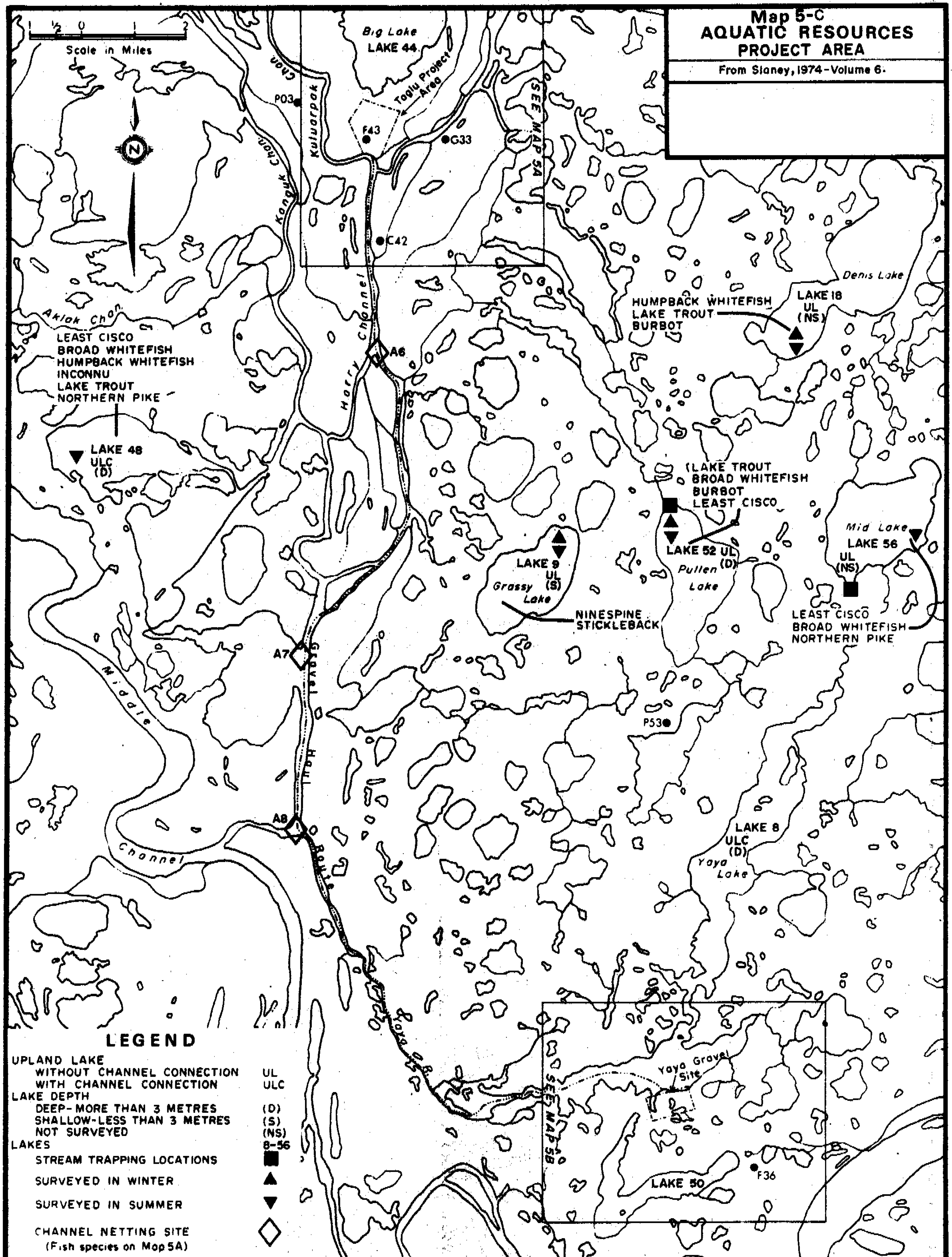


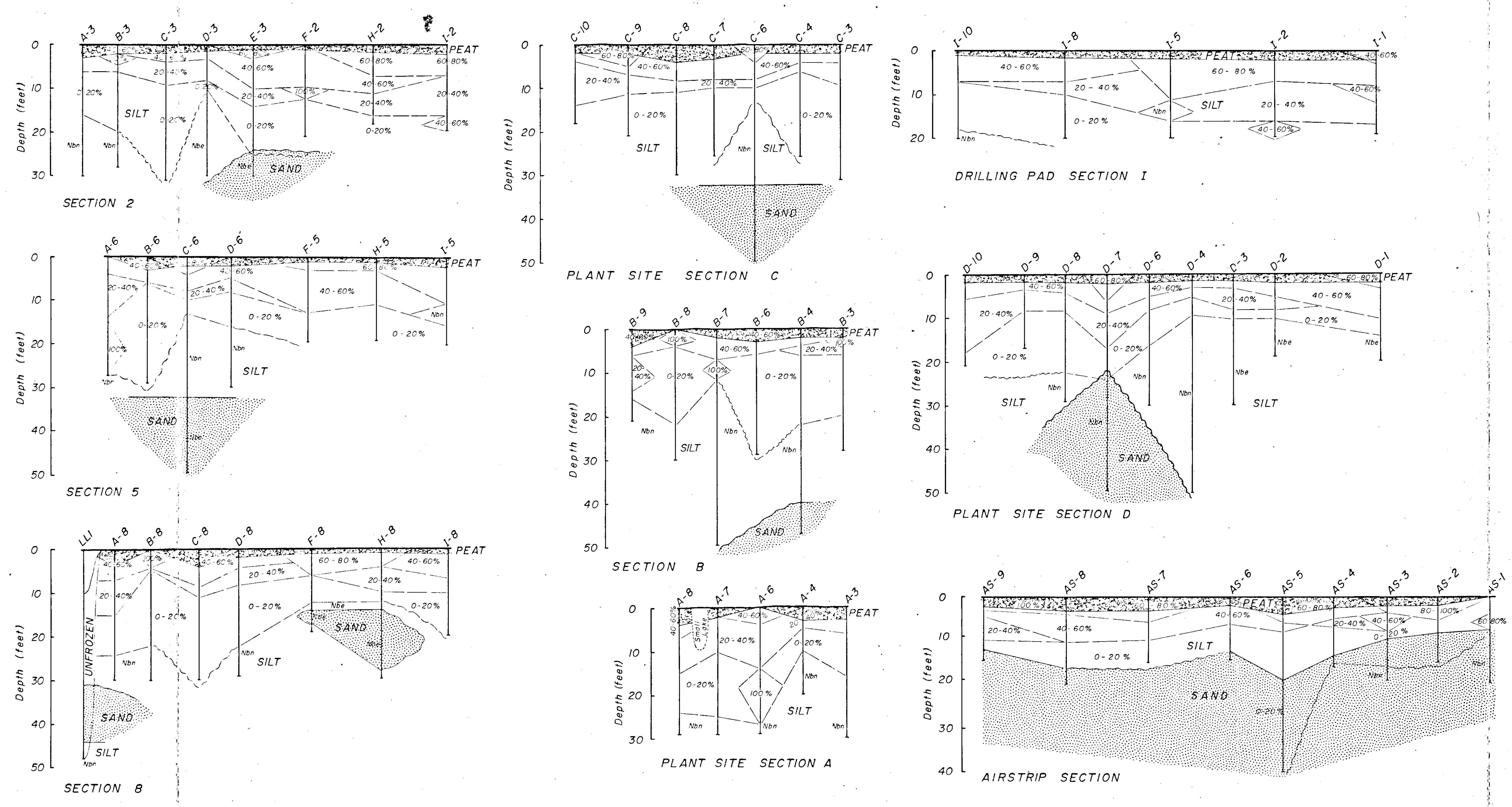
Map 4-C
BEAR DENNING HABITAT
PROJECT AREA
From Slaney, 1974-Volume 5 & Slaney, 1975.
Scale in Miles
Big Lake
Taglu Project Area
Kuluarpak Chan.
Kanguk Chan.
(SEE MAP 4A)
P03
F43
G33
C42
Aklok Chan.
Harry Channel
Denis Lake
Mid Lake
Pullen Lake
Grassy Lake
Middle Channel
P53
Yaya Lake
SEE MAP 4B
Yaya Gravel Site
F36
LEGEND
SUITABLE FOR DENNING
UNSUITABLE FOR DENNING
BEAR DENS

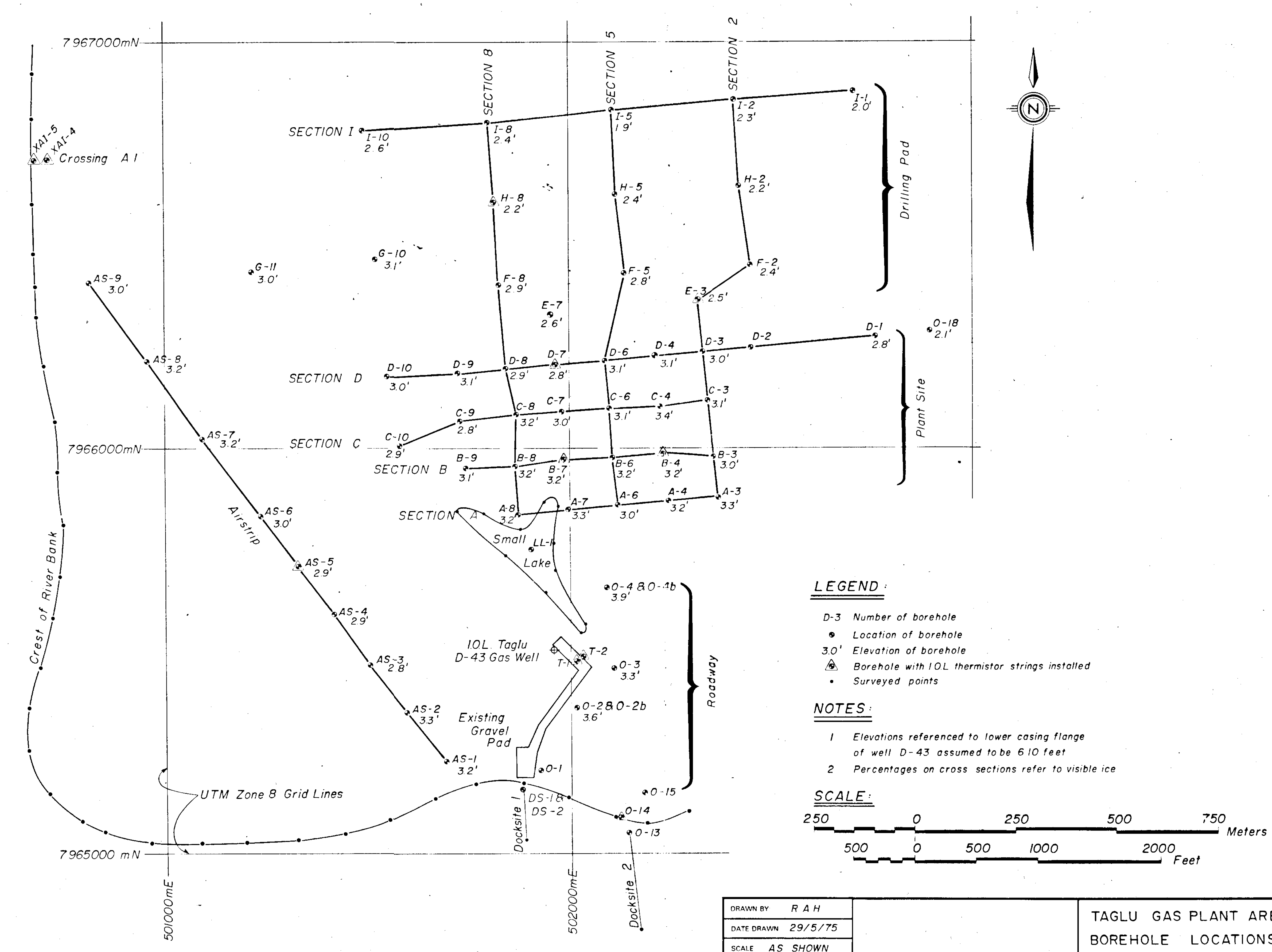

LEGEND
UPLAND LAKES
WITHOUT CHANNEL CONNECTIONS UL
WITH CHANNEL CONNECTIONS ULC
FLOODPLAIN LAKES
WITHOUT CHANNEL CONNECTIONS FL
WITH CHANNEL CONNECTIONS FLC
LAKE DEPTH
SHALLOW - LESS THAN 3 METRES (S)
DEEP - MORE THAN 3 METRES (D)
NOT SURVEYED (NS)
CHANNEL NETTING SITE
WINTER SURVEY SITE
N
Big Lake
FL(D)
HUMPBACK WHITEFISH
BROAD WHITEFISH
INCONNU
LEAST CISCO
NORTHERN PIKE
BURBOT
FL(NS)
UL (D)
Big Horn Point
UL (D)
FLC (NS)
FL (NS)
A2
A4
HUMPBACK WHITEFISH
BROAD WHITEFISH
INCONNU
ARTIC CISCO
LEAST CISCO
LONGNOSE SUCKER
BURBOT
NORTHERN PIKE
LAKE CHUB
BOREAL SMELT
FLC (NS)
Kuluarpak Channel
Taglu Project Area
FL(S)
F-43
G-33
Channel
A5
A3
FLC (NS)
FL(S)
FL(S)
FL(NS)
FLC (NS)
FL(NS)
FL(NS)
FL(NS)
FL(NS)
C-42
GRAVEL HAUL ROUTE
Scale in Miles
0 1/2 1
MAP 5-A
AQUATIC RESOURCES
From Slaney, 1974, Volume 6.



MAP 5-B
AQUATIC RESOURCES
From Slaney, 1974, Volume 6.


Map 5-C
AQUATIC RESOURCES
PROJECT AREA
From Slaney, 1974-Volume 6.
Scale in Miles
1/2 0 1 2
Big Lake
LAKE 44
Taglu Project Area
SEE MAP 5A
Kuluarpak Chan.
Kanguk Chan.
P03
F43
G33
C42
Harry Channel
A6
Aklak Chan.
LEAST CISCO
BROAD WHITEFISH
HUMPBACK WHITEFISH
INCONNU
LAKE TROUT
NORTHERN PIKE
LAKE 48
ULC
(D)
Denis Lake
HUMPBACK WHITEFISH
LAKE TROUT
BURBOT
LAKE 18
UL
(NS)
LAKE TROUT
BROAD WHITEFISH
BURBOT
LEAST CISCO
LAKE 52 UL (D)
Pullen Lake
LAKE 9
UL
(S)
Grassy Lake
NINESPINE STICKLEBACK
Mid Lake
LAKE 56
UL
(NS)
LEAST CISCO
BROAD WHITEFISH
NORTHERN PIKE
A7
Gravel Haul Route
Middle Channel
P53
A8
LAKE 8
ULC
(D)
Yaya Lake
Yaya
Yaya Gravel Site
SEE MAP 5B
F36
LAKE 50
LEGEND
UPLAND LAKE
WITHOUT CHANNEL CONNECTION UL
WITH CHANNEL CONNECTION ULC
LAKE DEPTH
DEEP-MORE THAN 3 METRES (D)
SHALLOW-LESS THAN 3 METRES (S)
NOT SURVEYED (NS)
LAKES 8-56
STREAM TRAPPING LOCATIONS
SURVEYED IN WINTER
SURVEYED IN SUMMER
CHANNEL NETTING SITE
(Fish species on Map 5A)



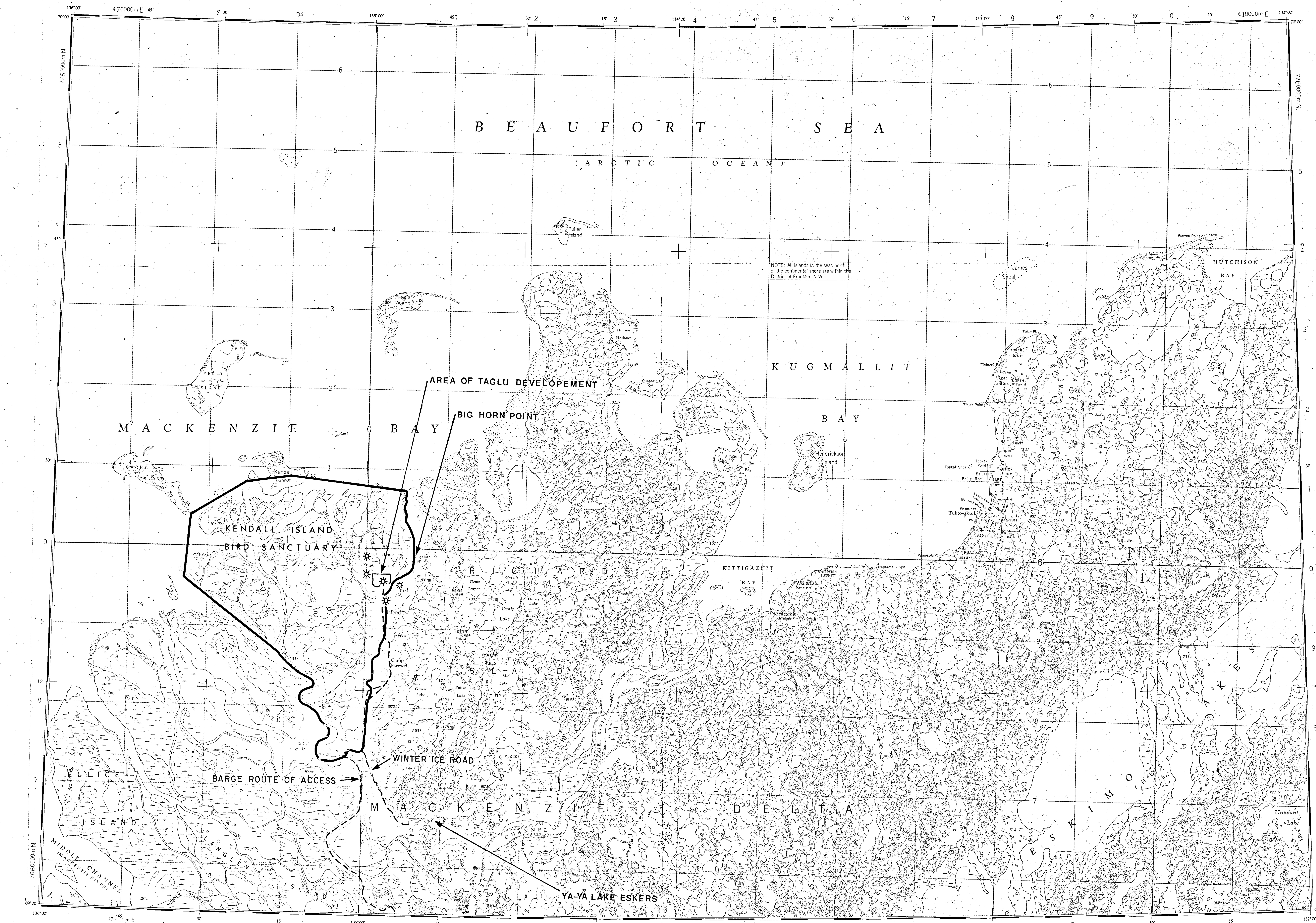


DRAWN BY	R A H
DATE DRAWN	29/5/75
SCALE	AS SHOWN
JOB No.	E-965

TAGLU GAS PLANT AREA
BOREHOLE LOCATIONS
STRATIGRAPHIC SECTIONS

FIGURE 4

BASE ONLY 107-0483-010-006



MACKENZIE DELTA

DISTRICT OF MACKENZIE

NORTHWEST TERRITORIES

Scale 1:250,000 Échelle

NO.	TITLE	NO.	DATE	REVISIONS	BY	APP'D
	REFERENCE DRAWINGS					

IMPERIAL OIL LIMITED

PRODUCTION DEPARTMENT, CALGARY, ALBERTA

BEAUFORT GAS PROJECT

MACKENZIE DELTA MAP

PROJECT LOCATION FOR LAND TENURE APPLICATION

DRAWN	CHECKED	SCALE	DRAWING NO.	REV.
DATE	APPROVED		107-0483-010-008	

TRANSLAR 300-11-73