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MACKENZIE VALLEY PIPELINE INQUIRY

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INTRODUCTION

In order to fully appreciate the cumulative impact that development might have on the rock and granular material resources of the Mackenzie Delta area, it is necessary to understand the current and projected demand for these materials together with the quantities of suitable material that are presently known to be available. It has long been known that sources of rock and gravel are relatively scarce in the Delta and consequently a considerable amount of time and money is being spent by industry and government to improve our knowledge of the location, quantity, quality and availability of construction materials. Undoubtedly my estimates may not be the most current but they should form a basis from which one can forecast nature of potential impacts and also, indicate the sort of planning decisions which will have to be made to ensure that priority uses are established and satisfied.

Demand

First, I would like to sketch in the demand as I understand it. The present and potential users can be grouped according to major programs. In each of these programs I am assuming the worst case; the maximum potential demand.

The groups are:

(i) Gas pipeline construction - trunk pipeline demands as estimated by CAGPL and Foothills.

(ii) Gas gathering system - which includes cluster pads, gas plants, staging areas, airstrips, roads, wharves etc.

(iii) Artificial island construction - which includes islands used in both exploration and production phases.

(iv) Staging areas

(v) On shore drilling pads - which includes features associated with onshore oil and gas exploration.

(vi) Road construction and maintenance - which includes present and proposed programs over the next ten years.

(vii) Townsite development -which includes the development and maintenance of town roads, waste disposal areas, airstrips, commercial and residential development etc.

(viii) Oil pipelines - including feeder lines and trunk lines.

(ix) Railroads

I think it would be worthwhile commenting on each of these in turn:

(i) Gas pipeline construction

Partial estimates of demand have been presented by CAGPL and Foothills for a trunk pipeline.

No information has been provided, however, on the quantity or quality of fill required on the pipeline right of way for backfill and for berm construction although these operations probably account for a large proportion of the total project demand. The current estimates for pipeline related facilities in the Delta area are:

(a) CAGPL

(i) Spread A - MP 00 (Richards Island) - MP 133.00 (Travaillant Lake)
- 5,724,000 cubic yards

(ii) Spread F - MP 262.00 (Shingle Point) - MP329 (Delta)
2,758,000 cubic yards

(iii) Spread B - MP329 (Delta) - MP372 (Tununuk)
2,450,000 cubic yards.

Total = 10,932,000 cubic yards.

(b) Foothills

Taglu - Travaillant Lake - 3,135,000 cubic yards of general fill; 88,000 cubic yards for concrete aggregate.

(ii) Gas gathering systems

Some details of the proposed gas gathering systems at Taglu, Niglintagak and Parsons Lake have been provided in the respective applications for land tenure agreements. In Volume 3 of the Mackenzie Delta Gas Gathering System submission, (1974) the proponents

estimate their requirements as follows:

	Cubic Yards
Niglintgak	350,000
Taglu	950,000
Parsons (3 clusters)	2,025,000

However in Taglu Gas Development submission of September 1975, it is stated that:

> "preliminary conceptual designs require an estimated 1.5 million cubic yards". i.e. a 50% increase on the earlier estimate.

Similarly, at Niglintgak 800,000 cu. yds. is the present requirement with an additional 500,000 cu.yds. required for maintenance over the lifetime of the project. At Parsons Lake, the project has been expanded to include up to six clusters with an estimated demand of 3 million cu.yds. If a jet airstrip is included in the final design then 500,000 cu.yds. or more would be required in addition to this quantity.

(iii) Artificial islands

The first artificial island, referred to as Immerk B-48 was constructed in 1972-73 from material dredged from the sea floor. Since that time 19 islands have been constructed, are presently under construction or have been proposed. The total volume of material used in the construction of these islands has not been

accurately estimated to my knowledge, but at least 1,000,000 cubic yards have been derived from onshore sources, particularly Ya-Ya lake esker - kame complex. Other material has been derived from the cannibalization of abandoned islands and from dredging.

There are definite advantages to the company in constructing at least parts of the islands from land based sources. The material is inexpensive and readily accessible and can be moved by truck to offshore lcoations during the winter months. Furthermore, clean, well drained, sorted gravel can be used either as easily compacted granular fill or as fill for sandbags, thus reducing the total volumes involved. Islands constructed solely from dredged materials are more costly to build and much less economical in the quantities of material disturbed during the dredging operation. For example, in placing about 200,000 cubic yards at the site of Immerk B-48, over half a million yards were actually excavated from the sea floor. Some estimates placed this figure at up to 1 million cu. yds. A recent paper by Riley, Imperial Oil Ltd., describes the design, planning and unique construction methods employed in artificial island construction. (presented at the Seventh Annual Offshore Technology Conference, Houston, Texas May 5-8, 1975).

Where on-shore sources are used in island construction, as is typically done in winter, a working estimate of 125,000 cubic yards per island may be used in predicting future requirements. (based on estimates for Sarpik P-26). There is no estimate of the number and location of islands which might be constructed in the next five, ten or twenty years. The distribution pattern of such islands, and the possible construction methods to be employed, are also unknown at this time. Obviously this information is to a large extent dependent on field potential, economics and so on. According to the scenario described recently by Mr. Shearer, up to 100 wells may be drilled in shallow offshore areas. This would place the potential demand for gravel and sand at over 12 million cubic yards.

I have been talking of the largely unknown demand picture for those artificial islands used for exploration purposes. The development phase offshore presents a somewhat different picture and again little can be predicted since the construction mode, location and number of production islands is not known. In the Adgo field, Imperial Oil anticipates that four permanent islands may be required for development purposes and that future discoveries in water depths of over 40' may be developed on artificial islands.

These more or less permanent islands will have to be better protected than those used in the exploration phase, and at the moment it is foreseen that rip-rap weights for the Adgo development islands will range from 50-3,000 lbs. As islands are built in deeper water, blocks of quarry stone up to 2.5 tons in weight will be required, with the largest weights of up to 11.5 tons being fabricated from concrete blocks. Imperial Oil has recently applied for a permit to extract 1.5 million cubic yards of rock to satisfy initial requirements. At present there is no indication of how other near-shore operators will deal with slope protection. It is evident however, that long term demand for rock, gravel and sand will be very high.

(iv) Staging areas

Staging areas, such as those presently located at Swimming Point (Gulf), Bar C (Imperial) and Camp Farewell (Shell), may be constructed in the Delta area by these and other companies to facilitate future exploration programs offshore. For example a concrete block manufacturing plant and quarrying operation could conceivably require the construction of a harbour, stol/jet airstrip, stockpile and camp area, together with the necessary road network and service facilities. Granular material demand for such projects could conceivably involve many millions of cubic yards.

I would like to provide an example of this type of development a little later in this presentation when I discuss material supply.

It may be appropriate to note that the Federal Government also has a number of small staging areas under development. Waste metal collection sites are under construction or are proposed near Kittigazuit in the Mackenzie Delta, at Inuvik and in the Horton River area. Such developments are located on existing disturbed areas, such as old radio and DEW line sites where little additional granular material is required.

(v) Drilling pads

Drilling pads do not generally account for significant quantities of granular material with, typically, 20,000 cu. yds. being used on a drill site during summer operations.

In the long term, however, such operations can account for significant quantities. There is again some difficulty in estimating future requirements. It is a requirement under the Territorial Land Use Regulations that drilling sumps be backfilled, using excavated material, to the original ground surface level. However, where sumps are dug in ice rich terrain, there may not be sufficient material to fill them. Thermokarst activity in ice rich materials may also create the need for additional fill. As a consequence, quantities of gravel in excess of 20,000 yards have been used to restore

a sump, and so satisfy the intent of the Regulations. Extrapolating from the demands of previous drilling operations, it is evident that a considerable quantity of fill will be required in the next ten or twenty years for drilling pads.

(vi) Road construction and maintenance

At present, road construction and maintenance is confined to the Dempster Highway and to roads in and around Inuvik. The major remaining work on the Mackenzie/Dempster Highway consists of gravelling the surface. Approximately 120,000 cubic yards of crushed rock or gravel will be required for the Inuvik - Arctic Red River section, and 140,000 cubic yards from Arctic Red River to the Yukon Border.

A high priority has been accorded to the Inuvik - Tuktoyaktuk highway and construction could get underway within the next five years. Estimates of material requirements vary widely with from 4 to 10 million cubic yards of fill being suggested. A figure of 5 million cu. yds. seems realistic. The quality of material that might be used varies widely, from broken shale to till, and from sand to gravel, according to the supply. Shale is being used for construction of the Dempster Highway west of Fort Macpherson and up to 69,000 cu.yds. per mile are being used. Maintenance requirements on northern highways will vary according to the quality of the original fill materials (texture, moisture,content etc).but may be

estimated at 10% per year - that is, that the road is effectively reconstructed every ten years.

(vii) Townsite development

Community requirements for granular materials have increased dramatically in recent years and, among the Delta communities, Inuvik and Tuktoyaktuk are outstanding in this respect.

According to the Government of the Northwest Territories, Inuvik will require approximately 3,000,000 cu.yds. The report prepared by Makale, Holloway and Associates for the Government of the N.W.T. indicates that industrial development may require as much as three or four million cubic yards, for a total estimated demand of 7 million cubic yards. Requirements are for shale and/or crushed rock.

Similarly, in Tuktoyaktuk, townsite demands, developed in 1975 for the period 1976-1982, are estimated at 460,000 cu.yds. However, recent Government of the N.W.T. figures indicate that 1 million cu. yds. may be required and that when industrial development is taken into account, this figure could reach 3 million cubic yards.

The Aklavik Development Plan indicates that about 35,000 cu. yds., will be required for road up-grading over the next seven years and that at least 70,000 cu. yds. will be required for further townsite expansion.

Up to date figures were not obtained for Fort Macpherson and Arctic Red River but estimates of 600,000 and 220,000 cubic yards respectively were cited in the Mackenzie Valley Granular Material Inventory.

(viii) Oil pipeline

I have no estimates of material demand for an oil pipeline in the Delta area, although some figures are given in the Mackenzie Valley Granular Material Survey based on information received from Mackenzie Valley Pipeline Research Ltd., in 1972.

(ix) Railroad

While a railroad is not under active consideration for the Mackenzie Valley and Delta area, the enormous quantities of fill, subballast and ballast should be kept in mind in assessing the impact of future developments on the supply of construction material in the Mackenzie Delta. A double track system would require from 500 to 575 million cubic yards of fill and ballast. In the Delta area, considerable quantities of rock would be required to meet ballast specifications.

It is clear from this brief review that our understanding of the present and potential demand for rock and gravel in the Delta area is far from complete and, in terms of major development projects, it will only improve as final design information becomes available from industry.

c) To designate and reserve certain granular material sources for public purposes. These reserved deposits will be used for community development purposes, and for roads, airstrips and other public facilities.

d) The development of policy regulations and administrative structure to conserve and control the utilization of granular resources.

The inventory was carried out by three consultants, each investigating a major part of the area. Of particular importance here is the work carried out by Ripley, Klohn and Leonoff who covered the Tuktoyaktuk Peninsula, Richards Island, and the Mackenzie Delta south to Fort Macpherson and Arctic Red River. The area to the west of the Delta and the Yukon Coastal Plain was not included in the inventory. Four reports were devoted to descriptions of potential sources of material in the immediate vicinity of Tuktoyaktuk, Arctic Red River, Fort Macpherson and Inuvik while a further four reports detailed sources in the remainder of the contract area.

It is important to bear in mind that the inventory was of a general nature and that the information on the quality and quantity of materials presented in the reports is based on very limited field reconnaissance, hand dug test pits and limited drilling.

A total of 132 potential sources of bedrock and granular material were identified by the consultants of which 33 were rejected for geotechnical or environmental reasons. These related to such factors as high ground ice content or conflicts with proposed IBP sites and Migratory Bird Sanctuaries.

I would like to discuss the supply available to each community first.

Fort Macpherson - Arctic Red River - both communities are served by good material supplies with an additional 2.5 million cubic yards available from a newly developed pit near Frog Creek on the Dempster Highway. (Source 650). While the deposit is being used as a source of gravel for the Highway, it is being managed by DIAND to ensure a continuing supply to these two communities.

Aklavik - Granular material for Aklavik is currently obtained from the Willow River, about 10 miles from the settlement. Some material has also been obtained from the Caribou Hills. While the potential supply at Willow River (over 500,000 cu. yds.) will satisfy long terms demands of the community, the supply available to any major industrial development in the area from this source will be limited.

While these three communities enjoy a reasonably accessible supply of good quality gravel, Inuvik and Tuktoyaktuk face serious shortages of suitable rock and gravel in meeting long term demand.

Inuvik

There are virtually no remaining sources of sand or gravel in the vicinity of Inuvik. There are however a number of rock quarries in operation, the principal ones being the Department of Transport pit at the airport and two pits used during highway construction. Other locations have been identified where shale and dolomite can be obtained by pit development.

If the three readily accessible sources of bedrock listed by the consultant (I-402, I-403, I-404) were to be fully exploited, approximately 8,600,000 cu. yds. of fill and aggregate would be available, an amount which does not greatly exceed the projected demands of the community alone.

These three sites, together with two recently proposed by D.P.W. (Mackenzie Highway- Campbell Lake) and Imperial Oil (Gull Creek - Rocky Hills), are located on the periphery of the proposed Dolomite Lake - Campbell Lake Ecological Site and Campbell Lake Hills National Wildlife Area. Both of these proposals have the Mackenzie Highway and East Channel of the Mackenzie River as two of the major site boundaries.

According to the proposal by the Canadian Wildlife Service to establish the Campbell Lake Hills as a National Wildlife Area, the quarry sites proposed by the D.P.W., Imperial Oil and the consultants pose a threat to the survival of a population of rare and endangered peregrine falcons, as well as to the existence of rare plant assemblages and the natural beauty of the area.

Quarry operations involve such intrinsically noisy activities as blasting, crushing, screening, stockpiling and hauling of rock and gravel. They may also be very dusty operations. The case for excluding quarrying operations from the area is put succinctly in the following quote, taken from a section of the Canadian Wildlife Service proposal dealing with the effects of human impact:

> "Quarrying and recreational activities have already resulted in territory and nest abandonment by one pair of peregrine falcons, reduced the esthetics of the area, and almost obliterated a rare plant assemblage. Litter buildup and tree destruction are becoming widespread. Campfires and inadequate screening on wood-burning stoves pose the additional threat of forest fire. Proposed quarrying activities and developments which would increase accessibility threaten further disruptions of the falcon population and rare plant assemblages. The esthetics of the

area, known historic and possible prehistoric archaeological sites, and important staging areas for migrating whistling swans are also in jeopardy. Unless measures are taken to control or redirect the type, location, and chronology of future use, any increase in accessibility will probably result in irreparable damage to an area unique in North America for its faunal and floristic elements."

Much can be done to mitigate the impact of quarrying operations on the falcons by restricting most of the work to the winter months. However, this may impose severe restrictions on material supply to critically timed construction programs, and inevitably some summer operations such as barge loading or truck hauling would be carried out if these quarries were to be fully developed. Further, the Canadian Wildlife Service consider in their proposal that:

"Accidental spills of toxic chemicals used in quarrying supportive activities and shockwaves from blasting could potentially result in injury to several aquatic and semi-aquatic species. Inasmuch as predatory raptors will tend to select live prey species exhibiting abnormal behavioral patterns (see literature review in Mueller 1974), the effects of delayed-lethal and nonlethal poisoning of prey species could be transmitted to peregrine falcons. Even if blasting activities are confined to winter operations, ground shockwaves and air concussion may cause loose overhanging rock to collapse on a few eyries (some of which appear to be traditionally used)."

At the present time I understand that an interdepartmental Working Group on Proposed IBP Ecological Sites is currently considering the proposal for the establishment of the Dolomite Lake - Campbell Lake Ecological Reserve and that no quarrying permits will be issued (including those applied for by Imperial Oil and DPW) until the Minister has reached a decision on the status and future management of the area.

However, assuming that quarrying will not be permitted near or within the presently proposed boundaries of the Reserve, then the demand for fill and aggregate could be met by one or more of the following measures:

1) by locating and developing sources of competent bedrock in other areas

2) by locating and developing pits in areas where shale or sandstone occurs close to the surface

3) by trucking and barging unconsolidated material from other parts of the Delta.

With respect to the first option, a number of companies are actively searching for alternate sources of bedrock in the Delta area. Such surveys would be an essential part of the pre-engineering work required for railroad construction and other developments where specific standards of sub-ballast and ballast material must be met.

The second option is one which has been actively followed in road construction on the Dempster/Mackenzie Highway, on the Inuvik by-pass road and which has been proposed for the southern half of the Inuvik-Tuktoyaktuk Highway.

It is an option followed where extremely large quantities of general fill are required at the minimum of expense. Some of Inuvik's requirements have been met by use of shale but there are certain major problems associated with this type of pit development:

(i) In lowlying areas a considerable volume of saturated organic material must be stripped from the pit area and piled.

(ii) Frequently, up to 25 feet of overburden must be removed. In the Delta area, this overburden consists of ice rich silty-clay soils which commonly contain massive ground ice. For example geotechnical data from a pit recently used on the Dempster Highway, indicated that sixteen feet of overburden was composed of 8 feet of ground ice overlying 8 feet of ice rich silty clay. The prenence of extensive ground ice masses and supersaturated silty clays on the walls of a pit can be hazardous. There is a potential for serious slumping, with accompanying mudflows. Successive retrogressive flow slides may also occur. The ice rich overburden must be stockpiled near the pit

while quarrying is in progress. These piles are inherently unstable and slumping is common as thawing progresses in the summer months. Mudflows from such waste piles can enter streams and waterbodies and spread into undisturbed terrain. These problems can be reduced by adopting low profile waste piles, although much greater areas are then required. Restoration and revegetation of these pits is often very difficult and costly. Few plants establish readily on mounds of rather sterile, arid soil.

In low lying areas overland drainage patterns are often disturbed, resulting in the creation of large shallow ponds which may be impossible to drain and restore. Surrounding vegetational patterns are altered. Because tree growth is limited in much of the region, these pits are difficult to screen from roads, and the results are aesthetically unpleasing.

These are some of the realities of this type of operation and numerous examples can be seen around Inuvik and along the highway.

Conflicts with fish and wildlife have been identified and any development would also have to take into full account the possible impact on coastal erosional and depositional processes.

Of the remaining four sources, one is a small gravel island which is in current use (T-106) while the others are esker, kame and outwash deposits located up to 17 miles southeast of the community to which access is difficult. Gravel could possibly be obtained from actively eroding offshore islands, such as Garry Island, or from the sea bottom. A consequence of road construction between Inuvik and Tuktoyaktuk is that distant, high quality, sources of material will be brought within reach. Conversely, the construction of the highway may itself exhaust many of these supplies.

I have briefly outlined some of the factors which must be taken into account in meeting community demand for sand and gravel. I would like, now, to outline material supply in other parts of the Delta.

As I mentioned in the discussion of demand, there exists a very large demand for bedrock as a source of fill and aggregate, but particularly for massive rip-rap for use in slope protection on offshore development islands. I have already mentioned the Campbell Lake site, which is preferred by Imperial Oil. The only other source of bedrock of the

required quantity and quality so far identified is located at Mount Sedgewick, in the British Mountains. This site was first identified by D.P.W. in the course of a survey for possible harbour sites. (Herschel Island - feasibility of a marine terminal. D.P.W. Canada). To develop this site a road, harbour, staging area and airfield complex would be required in what is known to be an environmentally sensitive area. The proposal put forward by Imperial Oil as an alternative to exploiting the Campbell Hills site, also involves a concrete block manufacturing plant.

This proposal, which I understand is not under active consideration by Imperial Oil at this time, poses some very major environmental problems:

(i) Rock would be quarried immediately adjacent to the channel of the Trail River with the attendant possibility of disturbance to the channel and fish resources.

(ii) The movement of an undetermined quantity of massive rock some 30 miles across the Yukon coastal plain will require the establishment of a permanent road network since much of the terrain is underlain by extensive ground ice and is thus sensitive to disturbance.

(iii) The area forms part of the range of the Porcupine caribou herd and critical calving grounds may be affected by quarrying and road construction activities. The area is also used extensively by migratory birds and other wildlife populations.

(iv) Road construction or extraction of sand and gravel from the Babbage River may result in siltation and sedimentation with a serious impact on the fish resources of the region.

(v) The dredging of a gravel bar at the harbour site may affect coastal erosion and deposition processes.

(vi) The creation of an extensive staging area and concrete block manufacturing plant would create a heavy demand for granular materials in the Yukon coastal plain area.

Now, given the assumptions that:

(a) alternative bedrock sources are not available in the Delta or on the Beaufort Sea coast and

(b) there are no workable technological alternatives to the use of artificial

islands protected with massive rock rip-rap which are acceptable to industry and government,

then the advantages and disadvantages of developing the known sources in the Campbell Hills area, as opposed to those of developing Mount Sedgewick, would have to be closely examined. It is essential therefore that these assumptions are supported or rejected on the basis of a thorough geotechnical, engineering and environmental evaluation, before a comprehensive resource management plan is formulated.

Since most of the major exploration and development activities are centered on the Richards Island and Parsons Lake areas, it follows that the heaviest demand for sand and gravel will be from nearby sources.

In the Richards Island-Caribou Hills area the consultant has evaluated a large number of potential sources, which together have been estimated to contain 80 million cubic yards of sand and gravel. However, many of the sources on Richards Island contain fine grained material in amounts of less than 500,000 cubic yards. Most of the better

material is concentrated in six deposits, three of which make up the currently exploited Ya-Ya lake source. Of the three remaining sources, only one has a significant potential, Source 222 at Swimming Point, which is estimated to contain 10 million cubic yards.

In the Caribou Hills area, adjacent to the East Channel of the Mackenzie River, the consultant has evaluated ten sources each containing over 500,000 cubic yards. Eight of these are located within the proposed Caribou Hills IBP site. If these sources are not available for development this would leave only two deposits, located near Tununuk and Lucas Point respectively for development yielding a possible 7½ million cubic yards.

Now, what I wish to demonstrate in citing these data, is that, excluding the Ya-Ya lake deposit and those deposits located within the proposed IBP Reserve, that less than an additional estimated 18 million cubic yards of sand and gravel are readily available in the Richards Island-Caribou Hills area to meet the demand for high quality construction material. In this area this includes the cross-Delta pipeline, gas gathering systems at Taglu and Niglintgak, artificial islands drilling and staging areas, and the communities.

I have specifically excluded small sources, that is those containing less than 500,000 cubic yards, from this discussion of supply since many of these sites contain quite variable material, are underlain by massive ground ice and are accessible only during the winter. While these difficulties are associated with many of the larger sites the quantity and quality of material available may well justify the impact of road construction, barge landing sites, air-strips, camps, stockpiles, processing equipment and so on - the infrastructure which goes hand in hand with such activity. Undoubtedly small deposits would be developed in response to local project demands. For example, it may be expedient to open a small quarry near a remote facility where only limited quantities of material are required.

One of the major difficulties involved in estimating supply is that little is known of the quantity and quality of material in each deposit, and whether the material can be readily extracted. To remedy this situation, industry has undertaken a considerable amount of geo-technical work in the Delta, and in particular, the Ya-Ya deposit has been thoroughly investigated.

In addition DIAND has recently concluded the geotechnical evaluation of three sources of granular material which are estimated to contain up to 36 million cubic yards. One of these sites, Source 326, one of the largest in the Delta, is located within the buffer zone of the IBP Reserve. Work on this site was carried out in consultation with IBP. I feel that if this site is eventually developed it can be done in such a way that the natural features and aesthetic appearance of the area are not affected.

The principal objective of the DIAND drilling program was to obtain detailed information on the three largest sources of material in the area. This information, supplemented with that supplied by industry, will form the basis for a management plan. In the long term, however, the total amount of material available from these sources, and the Ya-Ya esker-kame complex, will be insufficient to meet the demand. Other sources and alternative technological approaches will almost certainly have to be considered.

The situation in the Parsons Lake area is somewhat different. There the Inuvik-Tuktoyaktuk Highway and the gas pipeline are for the most

part remote from other development and their material requirements may be less rigorous than those of the more regional activities focused on the Richards Island area. There may nevertheless be conflicting demands from the gas producers, communities and highway engineers for material near Parsons Lake. The consultant has identified several large sources of granular material in the area so that, with careful management, these demands could probably be met. Before any development could take place a considerable amount of geotechnical information would need to be provided for each of the deposits, together with an environmental impact assessment. The needs of the various users would also have to be much better defined.

CURRICULUM VITAE - JULIAN T. INGLIS

Education:	B.Sc. (Zoology) Aberdeen University 1967 M.Sc. (Biology) with Distinction. Carleton University 1975
Employment History	
1967-1968	Teacher - Science Dept. Peterhead Academy, Scotland
1968	Organisation and participation as Biologist (small mammals, reptiles), Aberdeen University Expedition to N.E. Afghanistan
1968-1970	Assistant Manager and Range Biologist, Canada Reindeer Project, Canadian Wildlife Service, Inuvik, N.W.T.
1971	Range Biologist - Arctic Island range studies. Canadian Wildlife Service - contract.
1972	Range Biologist - Vegetation and landforms of winter range, Reindeer Grazing Reserve, N.W.T Canadian Wildlife Service - contract.
1973-1976	Land Management Biologist and Acting Head, Land Management Section, Water, Forests, Lands and Environment Division, DIAND, Ottawa.

Relevant Training and Experience

1. Postgraduate courses - periglacial geomorphology, soils, slope stability, pleistocene and Quaternary geology.

2. Field studies
   - vegetation and soils of the forest - tundra ecotone, Sitidgi Lake area N.W.T.
   - range studies, Queen Elizabeth Islands
   - geomorphology, soils and vegetation Ellesmere Island; Ellef Ringnes Island

3. Environmental Impact Assessment of major northern developments

4. Inspection - Liaison - Design Review on behalf of the interdepartmental Mackenzie Highway Environmental Working Group.

5. Assessment of granular material availability in relation to demand, Mackenzie Delta area; formulation of ongoing granular material inventory program.

Reports and Publications

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In Proceedings of the First International Reindeer and Caribou Symposium. Biological Papers of the University of Alaska, Special Report Number 1, September 1975. pp. 335-341

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Dept. Indian Affairs and Northern Development 90 pp. plus appendices.

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