Appendix 20

•Excerpts from Final Report on an Airphoto and Map Study of Lupin to Ulu Alternative Haul Route Locations Examined with Terrain Mapping, J.D. Mollard and Associates Ltd., September 30, 1996.

Figure 9 shows biologist/author George Calef's barren-land caribou migrating routes, the northernmost route of which is questioned (see later).

Figure 9A shows barrenground caribou herd habitats and calving grounds, also taken from George Calef's book.

4.0 REGIONAL TERRAIN CONDITIONS AND WINTER ROUTE CONTROLS

4.1 The Rationale

Approximately 1:60,000 scale stereoscopic airphotos were ordered covering a large area in order to make certain that all potential haul routes would be sought out, examined and evaluated to the extent possible from engineering, geological, economic, environmental, and Inuit land parcel standpoints. Our initial study area was widened to include haul route corridors shown on a map forwarded by Barry Lowe, Land Use Administrator, Lupin Mine Operations (**Block mosaics 1 and 2, Sheets 1 and 2**).

Our airphoto study involved 3-D analysis and interpretation of terrain features at a scale of 1:60,000. This examination was required to discover narrow corridors containing routes that possess gentle enough and smooth enough right-of-ways (ROWs) so that granular pad thicknesses and pad quantities -- required to develop a smooth riding surface without damage to the tundra landscape -- are not excessive. Moreover, a route located on or close to granular deposits is highly desirable to reduce padding costs.

It was apparent from the outset that a high proportion of the bedrock terrain is rough with steep slopes around plateau areas, that the cost of ROW bedrock blasting and rock removal would be prohibitive, and that the volume and cost of gravel padding on routes with irregular bedrock surfaces, locally up to several metres, would be excessive. The volume of granular padding is lessened by a route that has few abrupt slope changes. In this respect, the pad volume is expected to be less on smooth till (T) than over frost-shattered rock (felsenmeer) or over wet marshy ground.

4.2 Geologic, Engineering, Economic, and Environmental Controls

After examining airphotos showing the terrain in a broad swath between Lupin and Ulu, we listed a number of controls to guide narrow corridor and ROW selection.

- Avoid bedrock terrain because of difficult larger-scale relief scarplike features, and choppy and jagged smaller relief features on frost-shattered bedrock. Such relief affects vertical grades, horizontal alignment, route length, volume of gravel padding, and cost. Preferably, follow soliflucted (i.e., permafrost induced) smoothly undulating and smoothly rolling till, smooth glacial-lake sediments, and level and gently sloping granular deposits. Uniformly and more gently sloping surfaces tend to occur along narrow corridors between exposed bedrock, bedrock-controlled relief, and locally steeper till slopes (see Block Mosaic 3, Sheets 1 and 2, and Strip Mosaics 1 to 8).

- Avoid bumpy, kettled eskers and uneven bedrock topography because both involve tight curves, steep slopes, steep sidehill, and rapid slope gradient changes along the route alignment. Avoid costly cuts and fills. In the case of large bumpy eskers, one can often shift the route onto the lower flanks to obtain better topography. However, the sidehill slope requires visual assessment.

- Fewer curves and straighter horizontal alignment provide a route that is easier to follow during bad weather, as during times of heavy snow drifting and blizzards (**Block Mosaic 2, Sheets 1 and 2**). Gentle (vs steep) grades speed the rate of ore haul travel, and the haul trip turnaround time.

- Note and evaluate the significance of large icings (also referred to as aufeis and "glaciers"). Note and avoid actively collapsing terrain with large gaping cracks created by ongoing meltout of buried ice masses. These tend to occur on some steep south-facing esker slopes and on high terraces eroded into outwash-deltas and underlying fine-grained (silty) lacustrine deposits along the south side of the Hood river valley east of the proposed crossing (**Block Mosaic 3, Sheets 1 and 2**).

- Granular material for padding is likely to contain less permafrost and ground ice where eskers cross water bodies, along river and lake shores, and on steeper and higher sun-facing slopes where the active layer is thicker.

- Directness (short overall length) is also important. In general, haul problems tend to increase with length increase, other things being equal. Thus the more direct and shorter the land route section the better.

- Follow smooth terrain. Smoothness significantly affects the travel rate in km/hr, and the number of travel hours en route. It also significantly affects the amount of granular padding required in order to smooth out uneven travel surfaces, based on assumed padding thicknesses for the Izok mine site to Arctic Ocean haul route (**Appendix A**). For estimating one may assume 10,000 m^3 of granular padding per kilometre will be required on land segments. One may want to lay a thinner pad thickness in places, assess its performance after a winter's travel, and increase the thickness in those locations where the thickness is inadequate. Pad volume and pad material haul distance are major cost items in route construction, maintenance and operation -- thus in route selection. One must consider the occurrence of angular frost-shattered rock, tussocks, turf hummocks and thufur (mostly less than 1 m in relief) along glacial meltwater channels. Where these channels have large, angular frost-cracked rock they will require a thicker gravel capping to provide a smooth travel surface. In these locations the route might be shifted laterally a short distance where the microrelief amplitude is less.

- Vertical grades. Grades affect travel speed, travel time, and therefore cost. Try to keep grades below 5 percent, except for crossing the Hood River valley and the area north of Reno Lake.

- Avoid sidehill locations because of the potential for ore-load tilting and tipping. However, a gentle cross-slope is tolerable.

- Where options exist, favor gentler (flatter) grades in a southerly direction because ore loads are moving this way. Assume lighter loads going north to Ulu.

- Crossings of lakes, rivers and creeks require special field checking and winter evaluation to assess identified pressure ridge concerns, ice waves, ice cracks, thin ice patches, etc. Areas to avoid are swift-water sections above and below rapids. Most of these appear on 1:50,000 NTS maps and on the 1:60,000 airphotos. Field observations at these locations are necessary.

- Proximity to granular deposits. Several different origins and types of sand and gravel landforms occur in the 6800 km^2 study area. We have lumped them into two main groups: E, eskers (both large and small), and all other granular deposits, including kame hills, outwash plains, outwash-deltas, and short segments of beach (former lake shoreline) deposits (O).

From an environmental as well as a routing standpoint, avoid crossing the Burnside River owing to expressed concerns. Stay 1 km from the Burnside River.

Part of the Bathurst caribou herd migrates across the route alignments en route to calving grounds in May going northeast and again upon return in July. There might be some movement of caribou across the area at other times of year. I talked with Stephen Mathews and Ann Gunn in Yellowknife and John Niski in Kuglutuk to determine their knowledge of caribou migration routes. I also talked with Barry Lowe and environmental consultant Ben Hubert, Yellowknife. The migration routes appearing on Figures 8 and 9 are tentative according to Ms. Gunn. I also question George Calef's east-west caribou migration route north of Ulu because of the extremely rugged bedrock terrain along this corridor (**see Figure 9 and also the false color satellite imagery, enclosed**).

- Locate a route that does not involve unnecessary disturbances to the tundra and underlying soil. (In the 1970s I observed deep thaw ruts in the tundra on the North Slope of Alaska, south of Prudhoe Bay, and again on Sabine Peninsula on northern Melville Island in the high Arctic Islands.)

- We show all routings, including a preferred alternative (**Block Mosaic 3 and Strip Mosaics 1 to 8**). We also show short route segments along the preferred alternative, where options exist for site-specific viewing and field assessment (see strip mosaics along the preferred route via 458 Lake. Route options are desirable because land use administrators and environmentalists like to weigh and evaluate them during governmental and Inuit environmental and socioeconomic route assessment processes.

5.0 LEGEND FOR TERRAIN UNITS ON BLOCK AND STRIP MOSAICS

The generalized terrain map (**Block Mosaic 1, Sheets 1 and 2**) shows rather large areas and groupings of complexly intermingled terrain units in the study area (6800 km^2). In many locations the intermingling of till and bedrock areas is highly complex. This is indicated and shown along terrain-typed narrow route corridors (**Block Mosaic 3 and Strip Mosaics 1 to 8**). The explanatory terrain legend also describes haul route trafficability in general terms. The legend used for mapping terrain throughout the whole mosaic area (**Block Mosaic 1**) is also used for terrain conditions along our preferred route corridors and ROWs (**Block Mosaic 3 and Strip Mosaics 1 to 8**).

Letter Symbol	Landforms and Surface Materials
A	**Alluvial floodplains.** Braided gravel-bed channels and associated floodplain. Floodplains slope gently down-river. Only those floodplains wide enough to be mappable at 1:60,000 scale are shown (at and below the icing on a tributary to the Hood River and along a channel leading into 458 Lake west of a large esker). Poor haul route terrain.
E	**Esker systems.** Esker, esker-kame, and flat-topped esker-delta complexes. Typically the large kettled ridges, associated mounds and flat-topped mesalike forms consist of a core of stratified sand and/or gravel -- in places with variable silt or boulder content. The larger esker systems (E) commonly contain

Letter Symbol	Landforms and Surface Materials
	massive ice bodies, possibly up to 50%, and are frequently associated with knobs and mesas composed of sand, gravel and boulders with variable silt content, called kames and esker-deltas. In some locations, narrow corridors of bare bedrock adjoin esker systems. These associated bare rock areas result from meltwater erosion and removal of drift along the bottom of esker tunnels and in esker trenches that eventually became open to the sky. The higher parts of this terrain unit are too bumpy and kettled for a haul route. Moreover, long esker systems often run in the wrong direction to serve winter haul route objectives. However, it may be possible to locate a route along the lower flank of an esker that is oriented in a favorable direction. Here padding requirements are minimized and granular haul to adjacent till sections of routing is shortened. Poor trafficability along higher sections of large esker and fair along the base of large eskers. Small eskers are shown by close spaced Vs on their side on Strip Mosaics 1 to 8.
C	**Channel beds.** These are the beds of abandoned glacial meltwater channels that were eroded through the cover of glacial deposits into bedrock, leaving dense glacial boulders and exposed rock surfaces that are extensively frost-shattered and angular. Where these channels were partially filled with outwash sand and gravel and later eroded by meltwater, one can expect discontinuous granular terrace remnants of the former outwash fill. A good example can be seen a few kilometres north of 501 Lake, extending to the large outwash-delta south of the Hood River. Good haul route on level gravel terrace sections and poor to fair on jagged frost-shattered rock, depending on pad-depth requirements.
F	**Fine-grained (silty to clayey) thick glacial-lake deposits.** These deposits are located between the Reno esker and a large icing to the east, and are locally gullied.

Letter Symbol	Landforms and Surface Materials
G	**Granular deposits, undifferentiated.** (On Block Mosaic 3 only.) G deposits on Sheet 1 are numbered **G26 to G61.** G deposits on Sheet 2 (the north sheet are not numbered). G includes eskers, kames, outwash plains, outwash-deltas, short raised beach deposits with no distinction as to deposit origin.
K	**Kames.** Isolated mounds of ice-contact sand and gravel. Most kames occur along large esker-kame complexes (<u>see</u> above).
M	**Mingled (or, better, intermingled)** rough bedrock and till terrains. Areas of lower relief yet bumpy and jagged bedrock intermingled for the most part with generally thin and discontinuous (<u>i.e.</u> patchy) till deposits. Higher relief in many of the dominantly till areas is bedrock-controlled. In addition, locally **M** includes narrow strips of frost-shattered angular rock. Routing is confined to narrow corridors that avoid rough bedrock and steep till slopes. Poor to good, depending on the bedrock relief and its distribution in the **M** complex.
O	**Outwash-deltas (on Block Mosaic 1 and Strip Mosaics 1 to 8).** Outwash deltas, plains, and terrace remnants. Most were deposited into a temporary glacial lake. Occurs mainly along and well back from the Burnside and Hood river valleys. Dominantly flat-topped sand and/or gravel deposits that in places have been eroded and channelled by glacial meltwater and later by postglacial stream erosion. In places flat surfaces have been pitted (kettled) from the meltout of massive buried ice bodies. Where ground collapse is still ongoing, the area is marked **"col,"** which stands for **"collapse."** Although it is expected that unit **O** is composed dominantly of sand and gravel, silt and boulders can be expected in a few locations. In fact, thick silty and clayey silt lacustrine deposits underlie sand and gravel at the Hood River valley crossing. These deposits are frozen away from the shore of rivers and lakes, where warm summer water thaws the perma-

Letter Symbol	Landforms and Surface Materials
	frost. This unit represents good to excellent trafficability across the essentially level sections. Note, however, that steps and benches occur along the margins of channelled upland surfaces and undercut stream banks. Small outwash-deltas (mounds) and short raised glacial-lake beach deposits deposits are all marked "O" north and south of Bunside River and Kathawachaga Lake chain. Large outwash-delta deposits (with areas that are level, kettled, and channelled) occur north of 501 Lake, and on the bench south of the Hood River in the area south of the gorge.
R	**Rock terrains.** Generally rough high to moderate relief bedrock terrains, frequently cut by deep trenches along eroded linear joint, fault, and eroded dyke zones. This terrain unit includes extensive areas of bare rock with variable concentrations of frost-shattered surface rock and glacial boulders. Winter haul route options through most of this terrain unit are essentially non-existent because of jagged rock surface, rocky slopes, bedrock trenches, low scarps and high cliffs. Intersecting bedrock trenches -- some only partly filled with till and frost-shattered boulders and bedrock -- commonly strike in unfavorable directions for winter haul routes. Trafficability is extremely difficult to impassable on higher relief bedrock surfaces and is fair on short sections of relatively smooth frost-shattered rock.
T	**Till moraines.** Mostly undulating and rolling till deposits composed dominantly of a nonsorted nonstratified mixture of particle sizes, consisting of approximately 5% clay and 15 to 20% silt, with the remainder consisting of sand, gravel, cobbles, and boulders. In hummocky moraine areas this landform consists of soliflucted till (smooth relief because of little run-in and longtime runoff and sheet erosion on frozen ground). Fine-grained glacial lake deposits veneer patches of till below elevation 520 m straddling the Burnside river and elevation 450 m or higher straddling the Hood River. This unit also includes narrow boulder-strewn surfaces where boulders have been washed out of the till by glacial meltwater and postglacial running water and then shattered by frost action. Good trafficability with a relatively uniform thickness of granular pad material.

Letter Symbol	Landforms and Surface Materials
W	**Wetland terrains.** Mostly seasonally wet smooth slopes and depressions where surface runoff and slow ground-water migration occurs in the active layer. The surface is expected to consist of tussocks and peat where water collects. Because of the small scale of contact airphotos used in regional terrain mapping, the **W unit is not used in Block Mosaic 1.** However, the **W unit is used in Block Mosaic 3 and on strip mosaics,** which show detailed terrain conditions along route corridors and ROWs.

Complex Terrain Units Used in Regional Terrain Mapping

M+R, R+M, T+R, R+T, etc. These landscapes consist of two complexly intermingled terrain units described above. They are grouped together for purposes of mapping terrain over the 6800 km^2 study area. The first unit is typically dominant (assume two-thirds of the outlined area), whereas the second unit is subordinate (assume one-third of the outlined area).

Other Symbols

<<<< Narrow, mostly discontinuous esker ridges south of 501 Lake to Contwoyto Lake.

col Collapse of ground surface from ongoing if slow and intermittent meltout of massive ice in stratified glaciofluvial and underlying finer-grained glacio-lacustrine sediments.

I Icing areas (aufeis, "glaciers").

6.0 INFORMATION ON ENVIRONMENTAL CONSIDERATIONS

Environmental and Inuit considerations are important and require assessment by persons with local knowledge and experience. The information summarized here is available in the public domain, and is sketchy in terms of detail.

Environmental and social factors continue to play an important role in route and site selection in Canada's subarctic and arctic regions. These considerations became increasingly important as terrain evaluation studies progressed on northern route selection and terrain evaluation studies during the TransAlaska, Mackenzie Valley, and Arctic Island pipeline investigations. These studies began in the late 1960s and continued to the early 1980s, and after that along the pipeline route from Norman Wells, NWT, to Zama, Alberta.

Environmental considerations were kept in mind during the present office airphoto study. They include 1) archeology (e.g., teepee rings), whose effects in the landscape are not identifiable at an airphoto scale of 1:60,000, but are expected to be found at rapids, rocky gorges, and along the crests of flat-topped esker-deltas; 2) fish habitat constraints, which necessitate avoiding the removal of gravel from riverbeds that alter spawning grounds or cause silt to enter river water; 3) published caribou migration routes and calving grounds (**Figures 8, 9, and 9A**); 4) falcon nests along steep rocky cliffs and possibly the crests of high eskers; 5) denning sites of small rodents and larger mammals in thawed sections of small eskers.

Information we have on caribou migration routes to and from calving grounds in published documents is considered tentative. I purchased a copy of Calef's book on Caribou and the Barren-lands (1984) shortly after it was published. Calef's book contains a small-scale map showing what at the time he believed to be five general routings of Bathurst caribou herd migration to calving grounds located east of Bathurst Inlet (**Figure 9**). Three routes are shown to cross Contwoyto Lake, and nearly at right angles. One of the five trails is shown to cross close to Lupin Mine. Another crosses Contwoyto Lake in vicinity of an island where Canadian Pacific Airlines had a weather station I visited in the mid-1970s. A fourth route is shown north of the Burnside River, and one that would be logical for caribou migration because of generally smoother terrain, better walking conditions, less energy required, and more uniform and generally thinner snow depth to paw for food.

The winter satellite image negative I purchased for the NTS mapsheet 76L area has extensive cloud cover over the area between a point west of Ulu and lakes along upper Tree River on the north and Contwoyto Lake on the south. However, I can see a small area south and east of Ulu to 501 Lake in the winter space image. From previous terrain mapping and space pictures (see July 8, 1973, summer false-color satellite image, and 35-mm slide of another false color satellite image acquired on July 15, 1975, both attached), I expect terrain conditions between the Coppermine River and Bathurst Inlet in the region north of the Hood River would be difficult for a traditional caribou migration route. One would think that caribou in the gathering ground that Calef shows to the west along the Coppermine (where I have made a number of airphoto and field studies) would join the Bluenose herd and migrate north instead of east through the Ulu area (Figure 9). John Niski seems to agree with that contention. Ms. Ann Gunn also says she considers Calef's traditional caribou migration routes to be tentative.

A calving ground mentioned by John Niski lies between the confluence of the Burnside and Mara rivers and the bend in the Hood River directly north of that confluence (Figure 9).

While there may be something that we could do from airphotos on identifying traditional Caribou migration routes, the chances of success are not good. If one were to try this, one should list all caribou migration physical controls one is aware of, match these with the best available knowledge on existing routes, then evaluate what if anything appears from remote sensing of 1:60,000 aerial photographs (or other larger scale airphotos, if flown over known calving grounds) and false color satellite imagery acquired in summer and winter. Environmental consultant Ben Hubert, Yellowknife, may be able to extract useful information on caribou habitat from the summer satellite images that reveal essentially bare rock (greyish on the print and purplish blue on the 35-mm slide) and richer tundra vegetation in areas of fine-grained lacustrine deposits (scarlet red on the 35-mm slide), and sparser tundra in areas of dominantly soliflucted till and granular deposits (orange and reddish orange on the print and 35-mm slide).

7.0 DISCUSSION OF WINTER HAUL ROUTE ALTERNATIVES FROM PRE-FIELD OFFICE STUDY OF AIRPHOTOS AND MAPS (BLOCK MOSAICS 1 and 3)

Roughly 6800 km^2 of arctic terrain between Lupin and Ulu was examined in contact stereoscopic airphotos, airphoto mosaics, satellite images, and topographic maps. This was done to identify relatively smooth terrain corridors, and to outline large granular deposits. Total length of route (land plus ice) was considered significant; so direct routes between Contwoyto Lake and Ulu were preferred.

We identified what we believed at the time to be the best corridors from geological, engineering, economic, and travel safety standpoints (**Block Mosaic 3, Sheets 1 and 2**). These corridors were reviewed with Lupin Mine personnel, environmental consultant Ben Hubert, and haul road contractor John Zigarlik owing to the importance of knowledgeable environmental and construction logistical inputs to final route selection. This review of alternative routings was held at Lupin Mine September 11 to 13, 1996, with the following individuals in attendance: Rodney Cooper, Technical Services Superintendent, Lupin Mine; Barry Lowe, Land Use Administration, Lupin Mine; Phil Flaumitsch, ore haul route location and road planning advisor, Lupin Mine; Adam Hamel, winter haul road construction, Lupin Mine; John Zigarlik, Nuna Logistics, northern contractor; Ben Hubert, environmental consultant, Yellowknife. I also met Ian Berzins, acting manager at Lupin Mine. These meetings and a helicopter reconnaissance flight over routes preferred from our round-table discussion were helpful in orienting follow-up airphoto terrain studies.

An east and a west preferred route located from office airphoto interpretation and terrain evaluation were downgraded because of proximity of the route to the Burnside River, environmental constraints (fish, wildlife), and because of long granular material haul distances to the southern end of the routes. Crossing of the Hood River valley location was considered important, and we quickly agreed on that crossing location (**Block Mosaic 3, Sheet 2**).

Several critical locations were identified from our pre-field office airphoto and map study. Several helicopter stops were identified and suggested for viewing by Lupin personnel and by consultants having ore haul and northern construction experience and environmental knowledge and information on existing environmental guidelines.

Stops listed below identify suggested sites to be viewed during helicopter aerial reconnaissance. All stop sites were marked on Block Mosaic 3, Sheets 1 and 2, for possible checking prior to my visit to Lupin Mine and aerial reconnaissance of the routes flown with Phil Flaumitsch and helicopter pilot John Buckland. Note that Stops 1 through 20 are located along the preferred east alternative route.

Stop 1 Smooth exit from Contwoyto Lake onto land.

Stop 2 Check approximate narrow roughly 100-m-wide benches between the toe of rocky slopes and the top of nearby river bank. Terrain along route looks good.

Stop 3 Large granular deposit. Probably a non-frozen coarse (gravelly) outwash deposit. If granular borrow is required here, removal of gravel could create a fish concern in the Burnside River. Note: Consider removal of gravel in winter at locations away from the river. Gravel occurs above the river on the west side of the Burnside.

Stop 4 Route requires careful field location to avoid exposed bedrock and steeply sloping till over bedrock **(R)**. Much **R** terrain is impassable for vehicular travel.

Stop 5 Will winter flows into Kathawachaga Lake influence the ice thickness at the crossing here? One should shift the route location downstream, far enough to avoid the inflow effects of river water and ice thickness.

Stop 6 Note the smooth soliflucted till slopes. **G** stands for two small granular deposits. **S** refers to solifluction terraces a metre or so high (very slow downslope creep).

Stop 7 This is a tight location (see length of STOP segment) in order to keep the route on smooth terrain and avoid bedrock (i.e. outlined **R** off ROW).

Stop 8 Similar to Stop 7. Mostly tight location from Km post 30 to Km post 40. Keep route on smooth terrain to avoid bumpy bedrock **(R)**.

Stop 9 Glacial-lake strandlines. The old shorelines indicate that a glacial lake, located mostly to the south of this STOP, covered the area below elevation roughly 470 to 480 m. Till here could have a thin and discontinuous cover of lacustrine silt and clay.

Stop 10 Tiny esker ridge and small (bare/whitish) granular deposits.

Stop 11 Tight location for a smooth route between rough rocky terrain.

Stop 12 Wet marshy area. Suspect tussocks and/or boulders.

Stop 13 Fairly tight alignment location to avoid small rock outcrops surrounded by sloping till.

Stop 14 Tight alignment. Follow ice on small lakes. Rough rock surrounds lake shores. Thicker gravel padding required on short segments.

Stop 15 The route here follows smooth gravel bars and small elongate and round lakes separated by rapids. Route location looks good if ice, where crossed, is thick enough. Nearly all of the generally lower-lying area from here to the Hood River consists of level granular deposits with localized kettled and collapsed **(col)** surfaces. Surficial sand and/or gravel here may overlie thick silty glaciolacustrine deposits. Collapse areas **(col)** are caused by meltout of massive ice. Note degraded ice-wedge polygons, and small isolated bedrock "islands." Geologically this section consists of a large channelled outwash-delta that was built into a glacial lake occupying the Hood River valley at several elevation levels -- from about 450 m or so down to around elevation 400 m.

Stop 16 Note the two large white-surfaced icing **(aufeis)** areas, appearing in mid-July airphotos. The ice had still not melted by July in 1957. Note that the icing covers significant portions of a gravelly alluvial floodplain that has many small channels surrounding gravelly to cobbly braid bars. Two large icings are marked Stop 16. Question: Is it feasible to cross this wide floodplain area in the winter?

Stop 17 In this general area the windswept bare slope at Stop 17 has the gentlest gradient from the upland down to the level of Hood Lake. However, the route follows a fairly narrow neck, varying in width from about 150 to 300 metres. Consequently, a route here will likely require flagging (signing) for vehicular travel during bad weather. The outwash-delta deposit probably consists largely of sand with lesser contents of gravel and silt, and with massive buried ice bodies. I expect that a coarser surficial layer may overlie finer (silty) lacustrine sediments that are susceptible to runoff erosion.

Stop 18 The section immediately north of the Hood is a steep "climb-out" northward through a couple of relatively narrow alternative passes to Reno Lake. We examined several routings across the Hood River valley -- each routing avoiding the gorge area for archaeological and steep grade reasons.

Stop 19 Assume that one can make a cut through the esker ridge in winter, and use the granular material for route padding south to the Hood River (less fill quantities required) and to Ulu (large granular padding quantities required).

Stop 20 The route section from Reno Lake to Ulu is steep and mostly bare rough bedrock with shallow rocky depressions requiring substantial gravel padding. I suspect the terrain north of the Hood River to Ulu is too jagged and rugged for efficient migration of caribou. Much better terrain conditions occur north of Contwoyto Lake (**Mosaics 1 and 3**).

Note that Stop 21 is located on a preferred west alternative route.

Stop 21 This long section consists of generally good alignment: fairly low gradient, smooth and direct. The grades are good if one keeps to the best route available. However, to follow the

> best route in the field will require careful field location of the route indicated. In many places, lateral shift in route of less than 100 m can move the route from good going to difficult going. Assuming the indicated route can be transferred from the strip mosaic to the field, I believe it should be possible to avoid almost entirely: 1) the several rapids and swift-flowing reaches; 2) sharp kame knobs composed of silt, sand, gravel, boulders; 3) steep slopes and rapid slope changes; 4) sidehill locations; 5) deep snow drifts downwind of scarps. A short distance away from this tributary valley to the larger Hood River valley the terrain becomes excessively rough and rocky and is virtually impassible.

Route lengths, terrain data, and federal and Inuit land lengths were tallied by segment (**Table 1**) and summarized (**Table 2**) for reference and for comparison of alternative haul routings. Five routings have been color-coded: orange, green, red, blue, pink. The orange (east) and green (west) routes are preferred.

From discussions held at Lupin Mine it was agreed that environmental constraints and lack of large granular deposits on the southern section of the preferred routes downgraded them. It was decided further that the easterly route corridor identified on a map sent to our office by Barry Lowe was preferable -- even though it is considerably longer in total than routes identified from our pre-field office airphoto and map study. Reasons for favoring the easternmost route are given in the following section.

8.0 DISCUSSION OF WINTER HAUL ROUTES BASED ON AIRPHOTO AND MAP ANALYSIS OF TERRAIN GUIDED BY ENVIRONMENTAL AND CONSTRUCTION LOGISTICS CONSIDERATIONS AT LUPIN IN SEPTEMBER 1996

Our pre-field recommendations of preferred east and west haul route alternatives were based on the overly optimistic assumption of hauling 2000 74-tonne ore loads each winter for 10 winters. Total haul length, travel speed, haul cost, and pad volume were primary considerations as well as use of a large coarse gravel deposit adjoining the Burnside River north of Contwoyto Lake. However, our pre-field preferred routes had yet to be evaluated against available information on fish, falcon nests and wildlife (mammal) habitat as well as the logistics of summer vs winter construction, the location of staging and camp sites, summer vs winter airstrip sites, and the haul distances to large granular material sources for padding.

Because ore reserves at Ulu are still in the proving-up stage, it was suggested that a figure of 40-tonne loads and 6750 trips a winter (135 days and 50 trips per day) was more realistic at this time. As a result emphasis was given to the longer route via 458 Lake. However, a significant proportion of it crosses over winter ice, resulting in a relatively short land length. Large and more frequent granular deposits are also located close to the proposed east ROW (see Strip Mosaics 1 to 8). Moreover, one-kilometre separation is said to be required between the ore haul route and the Burnside River. The east route is said to cross less sensitive wildlife habitat for small mammals, which occupy narrow esker deposits on routes located south of the latitude of about 501 Lake. These requirements favor an easterly route that extends from Contwoyto Lake to Kathawachaga Lake, then north to 458 Lake, west to a point north of 501 Lake, thence to the Hood River and north to Ulu (see Strip Mosaics 1 to 8).

The east route via 458 Lake is favored. It has better pad material availability and lesser mammal constraints than a shorter more or less north-south route alternative that joins the east route just north of 501 Lake.

The section of a central route alternative north of Kathawachaga Lake can be accessed from that lake and from an alternative route via the Jericho Project (Strip Mosaics 1, 2, 3, 6). A single ROW is shown for both the central and Jericho alternatives. However, both alternatives have scanty granular borrow nearby for padding as well as wildlife environmental constraints.

Short competing within-corridor segments are shown on the east route west of 458 Lake. Because these competing segments are much the same length and avoid difficult adjoining terrain, the choice of which one to follow is left to the discretion of those responsible for environmental and logistical inputs. If time and weather permit, these short alternatives might be walked out on the ground.

Terrain conditions that influenced detailed location of the short competing segments are outlined on Strip Mosaic 7. Distance to archeological, falcon, and granular borrow sites, and widths of short marshy (W) and short creeklet crossings are local environmental and logistical decisions. They can be aided by office 3-D study of strip mosaics that show route alignments without the clutter of terrain on them, and with reference to 2-D terrain information outlined on the same strip mosaics for guidance. The more critical sites to check from walking over the ground are circled on the strip mosaics.

Care should be taken in locating the camp site and airstrip north of 501 Lake because extensive flat areas consist of deep coarse gravel on the east and till and a thin veneer of stream-reworked gravel over till on the southwest.

To simplify comparison of post-field selected routes from a terrain standpoint, a key map (**Figure 11**) and accompanying tables (**Tables 3 and 4**) have been prepared. In the absence of field decisions at a very few locations, I prefer the orange route on Strip Mosaics 2, 3, 4, 5, 7 and 8 (**see also Table 4**).

9.0 HOOD RIVER TO ULU ROUTINGS

This section of the route alignment is perhaps the most difficult from construction and operation standpoints and thus warrants consideration for a number of reasons:

- There appears to be one "best" route up the north side of the Hood River valley based on detailed examination of the terrain extending several kilometres upstream and several kilometres downstream from the proposed preferred crossing site.

- There is a relatively small yet strategically located granular prospect at the top of the slope on the north valley side. It should be visited to assess it as a local granular pad source (**Strip Mosaic 8**).

- The route between the top of valley wall and Reno Lake follows a narrow bedrock valley with a discontinuous cover of thin drift (till, lacustrine sediment, slopewash colluvium, peat) on lower valley sideslopes and on the valley bottom.

- A small area on Reno Lake is said to have thin (or no?) ice in winter. At least it is a concern to be checked.

- The Reno esker is said to be the only one in the study area that Inuit people have indicated to be a concern. Deep cuts through a low narrow section of the esker where it crosses the lake is therefore said not to be an option.

- From airphoto examination and a helicopter circle around the east end of Reno Lake, it would seem that groundwater (rather than overflow water) is leaking from the lake.

- For some unknown reason there is no north-south discharge through the esker since there is a 4-m difference in lake level elevation (±419 m elevation on the south lake and ±415 m on the north lake). Is this caused by a frozen core, or by an impermeable soil barrier within the esker?

- I have located several haul route options between Ulu and the Reno esker. All would appear to have somewhat better gradients than the present as-built road alignment. A low contour interval map, prepared photogrammetrically, would assist if there ever were a need in future to construct a haul road having lower grades. There is no vegetation (essentially bare rock), and the two level lake surfaces of Reno Lake can be used for stereomodel leveling. Although the routes I have indicated seem preferable to the one that has been constructed, there may well be other factors that influenced the present location: proximity to an airstrip close to Ulu, restrictions on use of the level western part (esker-delta/outwash) of the Reno esker system as an airstrip, and possibly other factors.

- What appears like a small but strategically located granular deposit just south of the Ulu adit should be visited and assessed. We did not do this during our helicopter reconnaissance. However, it is shown on a strip mosaic of the Ulu area.

10.0 GRANULAR BORROW SOURCES FOR PADDING

All granular material prospects along or near competing route corridors have been identified and mapped. Only the larger granular deposits were outlined in our interim (draft) report (G1 to 25), submitted prior to a visit to Lupin Mine. For this final report all granular deposits -- large, medium and small -- have been identified and outlined.

Note that esker (E) and outwash deposits (O) are shown in some locations on Block Mosaic 1, and granular deposits undifferentiated as to origin and landform (E and/or O) are shown as G on Block Mosaic 3. Granular deposits on individual strip mosaics are shown as E and O. Small arrows (the standard esker symbol) show eskers that are too narrow to outline properly at the airphoto scale 1:60,000.

Large esker and outwash deposits in the study area contain so much granular material it is not necessary to estimate the recoverable volume in them. We did begin estimating the quantities of granular material in small deposits but decided this is better undertaken by the granular-pad construction contractor, after he has selected those deposit locations he wants to use. One can estimate the surface area of a prospect from the 1:60,000 airphotos, in square metres, then estimate the recoverable depth from ground examination. At a scale of 1:60,000, 1 inch = 1500 metres. Thus 1/20 of an inch on an engineer's scale is about 75 m, the approximate width of several of the smaller eskers, gravelly outwash-delta mounds, and short beach ridges.

Eskers can be notoriously variable, varying from salt-sized sand (even silt) to cobbles and boulders. A first assessment of granular material gradation can be made by landing on an esker in a helicopter and digging through the active layer. In places a thin coarse surface layer overlies sand. From my visit to Lupin I learned that several persons closely associated with the Lupin and Ulu projects have wide experience in developing esker deposits as a road-building construction material. Granular deposits that are ultimately used will depend on contractor logistics, haul distance, and padding length and volume variations, e.g., over wet ground and frost-shattered rock.

11.0 SUMMARY AND CONCLUSIONS

- Some 6800 km^2 of terrain between Lupin and Ulu has been examined in 3-D (stereoscopic) airphotos, airphoto mosaics, false-color summer satellite imagery, B&W winter satellie imagery, and two scales of topographic maps (1:50,000 and 1:250,000). Airphoto mosaics, satellite images and maps have been used to select and examine narrow corridors and ROW alignments within them.

- Initially, an east and a west preferred route were selected from airphotos based on directness, total land and water/ice length, terrain smoothness and grades. Alternative route corridors identified by others were sent to this office. They were also examined and were terrain typed in somewhat less detail, largely because they were considerably longer routes.

- It was decided that an interim (draft) report along with accompanying terrain-mapped mosaics with route ROWs be delivered to Rod Cooper, Technical Services Superintendent, Lupin Mine, then followed by a site visit to discuss environmental, land use, and logistical issues that bear importantly on route selection. Initial discussions at Lupin Mine were followed by helicopter reconnaissance of favored route corridors. Following the field visit and route selection decisions based on inputs by several persons with local experience, alternative competing routes were chosen, and one was identified as preferred (the east "orange" corridor shown on the strip mosaics).

- The decision as to which ROW should be constructed within the east corridor -- where, also, short alternative segments are indicated -- is left to others more familiar with local environmental, logistical, land-use administration, and construction, maintenance and operating costs as well as proven ore reserves at Ulu. I can support from a terrain standpoint any of the ROWs indicated on the eight strip mosaics. All alternative routes have been viewed and evaluated.

- All routes on the block mosaics and on strip mosaics have kilometre posts identified for reference purposes and discussion.
- Detailed terrain unit outlines are shown in corridors on all strip mosaics. These outlines show the distribution of terrain units. Descriptions of their characteristics are given in a terrain legend.

Recommended favorable terrain units to follow in routing.

- Relatively level granular deposits in the outwash unit (O).
- Smooth, dry, gentle slopes in the till unit (T).
- The lower, smoother and gentler flanks of large eskers (E).

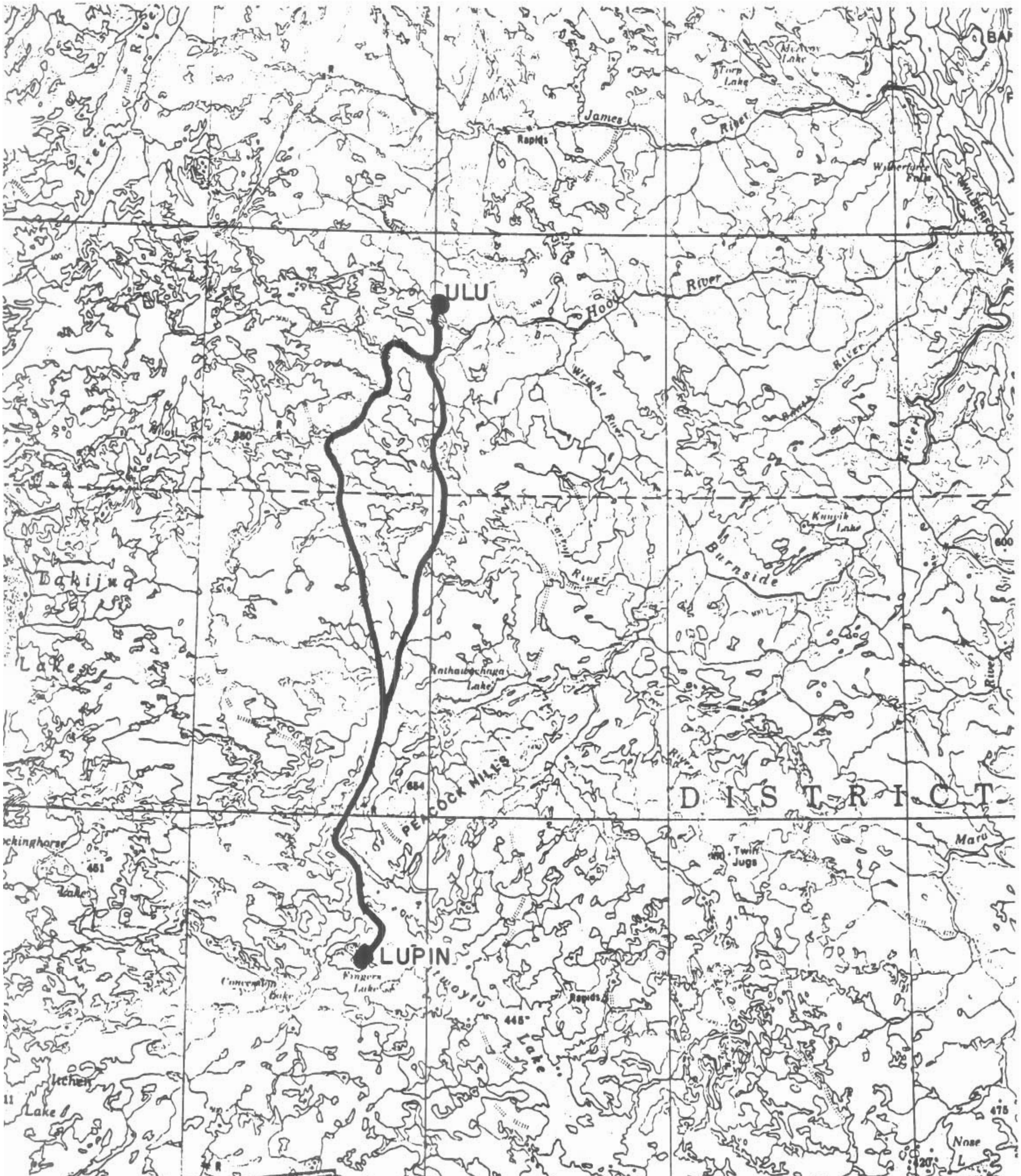
Unfavorable terrain units that in general should be avoided in routing.

- Bedrock (R) unless it has low relief and a relatively smooth surface, and can be crossed without ascending or descending steep rocky slopes.
- Alluvium (A) because of periodic flooding and local icing constraints.
- Glacial meltwater channels (C) or parts of them that consist of frost-cracked glacial boulders and frost-shattered bedrock.
- The upper parts of highly kettled esker-kame complexes (E), especially where the relief is high, steep, and choppy.
- Recently and possibly actively collapsing (col) slopes that have large open cracks, as locally along steep-sided large eskers and high steep slopes along the margins of large outwash-delta deposits.

- o Wetlands (W). These include shallow (active layer) slope seepage that can be dammed by permafrost aggrading into a pad, and wet level and depressional marshy tracts. I expect that in places a peaty surface layer is underlain by fine-grained (dominantly silty) glacial-lake sediments -- for example, west of the large esker south of 458 Lake.
- o I Icings (large snow and ice patches).
- o A few locations have been circled and flagged for closer examination on the ground. They appear on terrain-typed strip mosaics 1 to 8.

The above lists of desirable and undesirable terrains are intended to guide route selection. They can be used in route evaluation along with information on the distribution of granular deposits of varying volume as well as environmental, archeological, and land-use administration concerns or constraints.

Based on the present haul route selection and terrain mapping study -- and with the knowledge of others made available to us to this time -- I believe we have selected the best narrow route corridor, and have also located the better-looking ROW alignments within that corridor.



(from Maps Canada, Ottawa)

RIVER SYSTEMS IN THE LUPIN - ULU REGION

0 50 100km

J. D. Mollard and Associates Limited

FIGURE 1

September, 1996