Inuvik-Tuktoyaktuk Road Granular Material Estimate

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INTRODUCTION

Transportation infrastructure supporting NWT's small communities is generally scarce, and road construction proposes a number of challenges for the region. In particular, roadway construction requires large quantities of granular materials from a region with limited granular resources. Because of these limited resources, estimating the region's demand for granular resources resulting from transportation projects is important.

Figure 1 shows a map of a proposed road from Inuvik to Tuktoyaktuk. The road has been planned for many years and represents a significant share of the forecasted demand of granular resources in the region.

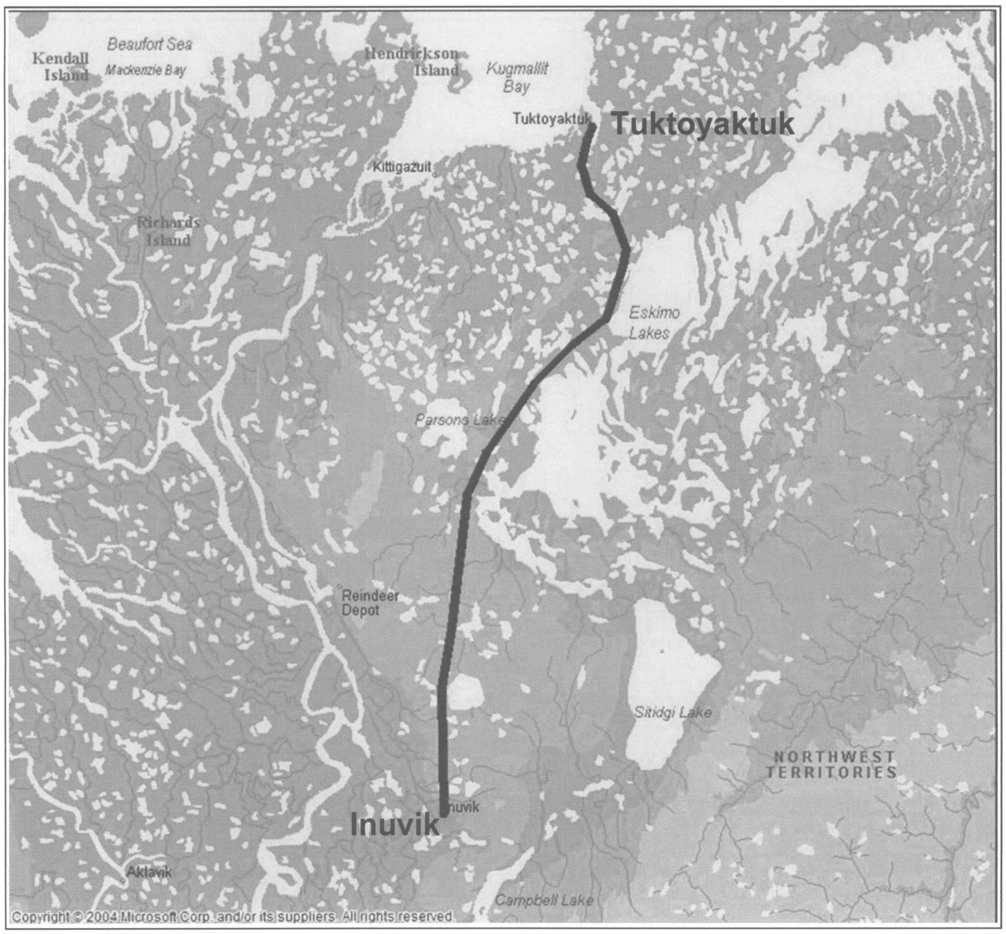

Figure 1 - Map

Estimating the granular resources required for this project is the subject of this report.

Estimate Methodology

The first step to estimate the granular resource volumes required for the roadway is to design the roadway itself. A detailed design was not available and was not in the scope of this study, so a general design was assumed to provide a preliminary basis for estimating purposes.

Estimating the granular material volumes then becomes a simple calculation of volumes based on the roadway design.

General Roadway Design

The basic design for a 10 meter wide road is shown in the following figure.

An average minimum embankment thickness of granular material of 5 feet (1.524 meters) was assumed so as to generally maintain the permafrost with the embankment. A side-slope of 3:1 was assumed to allow drifting snow to blow over the road surface.

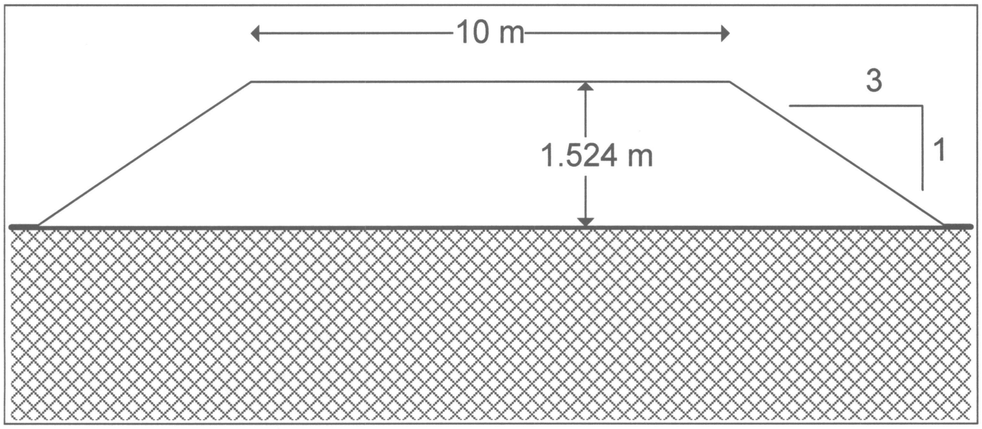

Figure 2 - Roadway Design

The above design differs from the design in a report prepared by the Department of Transportation[1]. In that report the minimum embankment thickness was assumed to be 1.2 meters, and the road width was assumed to be between 9.0 meters and 9.6 meters. These differences could result in a reduction in granular materials up to approximately 30%. However, the report did state that the embankment thickness would vary as high as 1.5 meters to 1.8 meters. The above design represents a conservative estimate for granular materials. Determining a design optimized to reduce granular materials is beyond the scope of this study.

[1]Inuvik to Tuktoyaktuk Road (Pre-Engineering Update), Highways and Engineering Division Department of Transportation, March 1999.

Estimate Calculations

North of 60 Engineering has developed an estimating tool for DIAND that can be used to determine simple granular estimates for roadways of this type. The tool is located on the internet at the URL http://www.grancalc.ca.

The estimating tool requires the following design parameters:

- Roadway Width
- Roadway Length
- Embankment Thickness
- Side-Slope
- Terrain Type
- Bulking and Shrinkage Factors

Roadway width, roadway length, embankment thickness and the side-slope parameters were taken from the general design of the roadway. A bulking factor of 1.33 was assumed as an allowance, and no shrinkage factor was used. Specific analysis of the source material would be necessary to determine actual bulking and shrinkage factor values.

For the terrain parameter, the roadway was split into 23 sections that coincide with notes describing the conditions of the roadway alignment provided by DIAND (See Appendix A and Appendix B). Separate estimates for each of these sections were created using the estimating tool. A qualitative estimate of the terrain was determined for each of these sections using the descriptions given in the notes. Table 1 summarizes the terrain types used for each section. Additional notes describing the determination of terrain types are provided in Appendix A.

Section	Milepost Start	Milepost End	Length (miles)	Terrain
Section 01	971.5	973.5	2.0	Gently Rolling
Section 02	973.5	976.0	2.5	Rolling
Section 03	976.0	977.2	1.2	Flat
Section 04	977.2	980.0	2.8	Gently Rolling
Section 05	980.0	981.0	1.0	Gently Rolling
Section 06	981.0	985.0	4.0	Gently Rolling
Section 07	985.0	990.0	5.0	Gently Rolling
Section 08	990.0	995.0	5.0	Flat
Section 09	995.0	999.0	4.0	Flat
Section 10	999.0	1000.0	1.0	Gently Rolling
Section 11	1000.0	1002.0	2.0	Rolling
Section 12	1002.0	1006.0	4.0	Rolling
Section 13	1006.0	1008.0	2.0	Flat
Section 14	1008.0	1009.5	1.5	Hilly
Section 15	1009.5	1012.5	3.0	Gently Rolling
Section 16	1012.5	1014.0	1.5	Gently Rolling
Section 17	1014.0	1018.0	4.0	Gently Rolling
Section 18	1018.0	1019.5	1.5	Gently Rolling
Section 19	1019.5	1025.0	5.5	Gently Rolling
Section 20	1025.0	1034.5	9.5	Rolling
Section 21	1034.5	1042.0	7.5	Flat
Section 22	1042.0	1055.0	13.0	Rough
Section 23	1055.0	1059.0	4.0	Flat

Table 1 - Section Terrain Types

These terrain types are used by the tool to determine factors that allow for various terrain conditions that increase the required material volumes.

RESULTS

Granular material requirements were calculated to be 3.7 million cubic meters. Approximately 4.9 million cubic meters of material (bulk) would need to be hauled from local burrow locations along the alignment or from other sources.

The calculations from the estimating tool are summarized in Table 2 below.

Section	Milepost Start	Milepost End	Length (miles)	In-Place Volume (m^3)	Bulk Volume (m^3)
Section 01	971.5	973.5	2.0	81,316	108,151
Section 02	973.5	976.0	2.5	106,134	141,158
Section 03	976.0	977.2	1.2	46,524	61,877
Section 04	977.2	980.0	2.8	113,893	151,478
Section 05	980.0	981.0	1.0	40,658	54,075
Section 06	981.0	985.0	4.0	162,633	216,301
Section 07	985.0	990.0	5.0	203,291	270,377
Section 08	990.0	995.0	5.0	167,019	222,135
Section 09	995.0	999.0	4.0	155,240	206,469
Section 10	999.0	1000.0	1.0	40,658	54,075
Section 11	1000.0	1002.0	2.0	85,012	113,067
Section 12	1002.0	1006.0	4.0	170,025	226,133
Section 13	1006.0	1008.0	2.0	77,620	103,235
Section 14	1008.0	1009.5	1.5	69,160	91,983
Section 15	1009.5	1012.5	3.0	121,974	162,226
Section 16	1012.5	1014.0	1.5	60,861	80,945
Section 17	1014.0	1018.0	4.0	162,633	216,301
Section 18	1018.0	1019.5	1.5	60,861	80,945
Section 19	1019.5	1025.0	5.5	223,493	297,246
Section 20	1025.0	1034.5	9.5	403,677	536,891
Section 21	1034.5	1042.0	7.5	290,955	386,970
Section 22	1042.0	1055.0	13.0	720,414	958,150
Section 23	1055.0	1059.0	4.0	155,240	206,469
TOTAL			**87.5**	**3,719,291**	**4,946,657**

Table 2 - Roadway Volumes

CONCLUSIONS

A scoping class estimate of the granular volumes required for the Inuvik – Tuktoyaktuk road is 3.8 million cubic meters in place or roughly 5 million meters of bulk material from the source. Because of the preliminary nature of the design and lack of detailed alignment and topography for the route, the estimate should be considered as scoping class with an accuracy of ± 30%.

APPENDIX A – SEGMENT NOTES

The following notes are taken directly from the Public Works maps provided by DIAND. References in this text are to sections in another report that is not provided here. Text appearing in *italics* describes the determination from the notes of terrain types used for each roadway section.

Mile 971.5 to Mile 973.5

The proposed route departs the Inuvik Bypass (Marine Access Road) at mile 971.5 and to mile 972 crosses the *gently sloping valley floor* on ice-rich slopewash sediments, at mile 972, it enters into a relatively narrow tributary valley and follows this valley to approximately mile 973 where it emerges on the adjacent uplands. Within the valley, the route is on a cross-slope on ice rich, silty clay slopewash material. Surficial deposits on the upland are glacial till which contain low to moderate subsoil ice but with random massive ice inclusions. There is no opportunity within this section for cut and it is recommended the embankment 'roll over' the terrain including the high ground from sta 95 to sta 105. This area has been burned over relatively recently (approx. 1970), hence organic cover is thinner and thermal erosion is occurring on exposed areas. There is a major source of bedrock borrow on the upland adjacent to the route – See Appendix D – Area 2.

Terrain Assumed: Gently Rolling – The terrain involves valley slopes.

Mile 973.5 to Mile 976.0

Through this section, the route crosses very irregular hummocky terrain composed of clay till, with variable ice content. Because of the irregular terrain, 'rolling' the grade line will result in high fills and it would be advantageous here to cut some of the ridges. Boreholes reveal the till in some ridges is at moisture contents on thawing below the liquid limit. This type of material could be used at the base of fills, and after draining and drying, would provide good embankment material. It is also believed that cut backslopes would 'heal' without extensive slumping at moisture contents less than the liquid limit. However, it must be emphasized here that a single 'good' test hole in a cut section does not mean the entire cut will be similar material and in fact, experience has shown the opposite to be true. If cut sections are to be considered, it is recommended at least three test holes be drilled every 50' of cut to confirm the subsoil to 5' below the ditch line before final design. Secondly, it is recommended cuts be avoided where the route is on a severe side slope and the upper backslope will, as a result, be extensive.

Areas that could be considered for cuts on the basis of drilling to date are:

Sta 125 to Sta 133	Hole #973-C-6
Sta 206 to Sta 210	Hole #975-C-1

and possibly scratch cuts at

Sta 217 to Sta 220	Hole #975-C-2
Ste 225 to Ste 228	Hole #975-C-3

A cut should be avoided in the area of Sta 237 as the upper 8-9' is ice rich organic material.

Terrain Assumed: Rolling – Specific terrain and slopes are described.

Mile 976.0 to Mile 977.2

The highway descends a gradual slope to a major creek crossing at Sta 279, then ascends a similar gentle slope to once again enter an area of hummocky terrain. There is no need or opportunity for cuts through this portion and minimum design fill heights should be maintained.

Terrain Assumed: Flat – A single gentle slope is described with no cutting.

Mile 977.2 to Mile 980

This terrain is irregular and hummocky with numerous small lakes. Again, cut sections would be most beneficial, however, only one hole (979-C-1) at Sta 412 is indicative of suitable material and a cut only at Ste 412+00 would probably not be justified.

A major topographic feature (Area 6) within approximately 3,000' of the R.O.W. at mile 978.5 was test drilled as a borrow source. There is dry borrow material here, however, the extreme variability of both the overburden and the material itself negates against this area as a viable borrow source (See Appendix D), unless stage construction and the use of poor quality material is considered.

Terrain Assumed: Gently Rolling – Irregular terrain is described.

Mile 980 to Mile 981

The route descends to a creek crossing then rises to the hummocky uplands west of Noell Lake. There are no opportunities for cuts, and embankments should be not less than the design minimum.

Terrain Assumed: Gently Rolling – No cuts, but hummocky areas are described.

Mile 981 to Mile 985

Through this section, the route follows a height of land along the west side of Noell Lake. The topography is hummocky glacial till that contains significantly more massive ice than preceeding sections. There are no opportunities for cuts here, however, should consideration be given to utilization of frozen glacial till as a borrow source, one area for investigation would be near Hole 984-4 (Sta 716+50) where till at moisture contents midway between the liquid and plastic limits was encountered.

There are two areas of granular crevasse fillings adjacent to route on the west between mile 983 and 985 (Areas 10 and 11). Unfortunately, deposits are small and contain massive ice (See Appendix D). These areas would, however, provide a ready source of granular material for culvert backfill.

Terrain Assumed: Gently Rolling – No cuts, but hummocky areas are described.

Mile 985 to Mile 990

There is a significant drop in elevation through this section as the route descends from the height of land near Noell Lake to the vicinity of Jimmy Lake. Topography and subsoil are unchanged. Cuts would be most advantageous near Mile 986 and could possibly be considered from Sta 763 to Sta 777 (no massive ice in boreholes) however, extensive additional drilling would be required as moisture contents are near the liquid limit. The remainder of this section offers more gently rolling terrain and there is no opportunity for further cuts. The frequent occurance of massive ice in the random boreholes suggests a high probability of encountering massive ice in any cut section, and a low probability of locating a usable source of low moisture (ice) content till borrow.

Terrain Assumed: Gently Rolling – Gently rolling terrain is specifically described.

Mile 990 to Mile 995

The route descends to lowlands adjacent to Jimmy Lake and for five miles crosses an area of subdued relief dissected by numerous drainage channels. Subsoil is largely glacial till with some overlying slopewash. Boreholes through this area indicate less massive ice, but soil moisture contents are not appreciably better. Hole 994-3 indicates the possibilty of locating low moisture (ice) content till.

There are no opportunities for cut sections here and embankment heights should be the design minimum.

Terrain Assumed: Flat – No cuts and subdued relief are described.

Mile 995 to Mile 999

The route enters into an area of high ground that is an eastern extension of the Caribou Hills. Bedrock is relatively shallow with a thin till overlay. Glacial meltwater has cut large spillways that dissect the uplands to reveal soft, poorly indurated sandstone or 'compaction' shales in the steep-sided valley walls. As the terrain is relatively flat, there is little opportunity for cut, although consideration could be given to cuts near Sta 1410 and near 1423. Massive ground ice through this section was not encountered with frequency and subsoil moisture (ice) contents are relatively low (see holes 995-1, 995-3, 996-2, 997-1, 997-2 and 997-3) as the holes extend into material that is probably weathered bedrock. A 'roadside' borrow pit could possibly be developed through this section if a design decision was made to utilize material wet of optimum, and drying and stabilization following thaw. A close drilling pattern would be required to fully assess a potential borrow area.

Terrain Assumed: Flat – Terrain is specifically described as being relatively flat.

Mile 999 to Mile 1000

This is the crossing of an old meltwater channel that is now occupied by a major creek. Bedrock is exposed downstream of the highway and is a strategic source of borrow material (See Area 18, Appendix E). A major cut could be considered from Sta 1580 to 1586 - Hole 999-1 indicates clay till at moisture contents less than the liquid limit. Additional drilling is recommended to evaluate the risk of cut.

Terrain Assumed: Gently Rolling – A major creek and a major cut will require more materials.

Mile 1000 to Mile 1002

To mile 1002 the route crosses a rolling till plain. Subsoil is clay till with frequent massive ice. Frost polygons are common in drainage channels or topographic lows. Cut sections are not recommended here and embankment heights should be the design minimum.

Terrain Assumed: Rolling – Terrain is described as rolling.

Mile 1002 to Mile 1006

Beginning near Mile 1002, the route enters into an area of thermokarst topography characterized by hummocks, deep pot-hole lakes and very abrupt elevation changes. From mile 1004 to 1006, features are kame-like, composed in part of granular deposits. Massive ice is abundant and variable throughout. It is impossible to 'roll' the gradeline through this section on the present alignment, and a location review here is recommended. Drifting snow will be a problem through this area due to the irregular terrain. It is not expected that a revised location will be able to eliminate all cuts. Holes 1104-1 to 1004-4 all reveal relatively low moisture content material at depth, and holes 1005-3 to 1005-5 reveal sandy gravel at depth, indicating that cuts may not be entirely unrealistic here. However, extensive drilling will be required following a location review. There is a gravel deposit near mile 1006 that may, despite variable overburden and massive ice, be a viable borrow source (see Area 19A - Appendix D).

Terrain Assumed: Rolling – Hummocks, pot-holes and abrupt elevation changes are described.

Mile 1006 to Mile 1008

At mile 1006 the route leaves the hummocky terrain and for two miles crosses an area of little relief to the Hans Creek Valley. There are no opportunities for cuts and the minimum design embankment is recommended over the ice rich subsoil.

Terrain Assumed: Flat – Area is described as having little relief.

Mile 1008 to Mile 1009.5

This is the crossing of the Hans Creek Valley - a major stream on the route and containing extensive deposits of outwash sands and gravels. This material source has been investigated and documented by others (See "Granular Materials Inventory - Parsons Lake, N.W.T.", October 1974, by Klohn Leonoff Consultants Limited). A volume of sandy gravel in the order of two million cubic yards is estimated here, much of it immediately adjacent to the highway. Gulf Canada may have reserves on much of this gravel, thereby limiting the quantity available for highway construction.

Major cuts will be required on either side of the valley. On the south, holes 1008-1 and 1008-1A reveal some sandy gravel, however, a cut will require sub-cutting and backslope protection in part. On the north, boreholes indicate a cut will be primarily in gravel and sub-cut or backslope protection should not be necessary. A single test hole at the proposed crossing of Hans Creek encountered dense granular deposits which will provide a good base for a multiplate culvert.

Widening of the approach cut on the north to gain granular embankment material is recommended here.

Terrain Assumed: Hilly – Major stream crossing, possible cuts and slopes will require additional materials.

Mile 1009.5 to Mile 1012.5

Within this section the route crosses a series of low till ridges near Eskimo Lakes with extensive areas of frost polygons in the intervening depressions. There are no opportunities for cuts as moisture (ice) contents in the till are near the liquid limit. Minimum design fill heights are recommended.

Terrain Assumed: Gently Rolling – Low till ridges describe some rolling terrain.

Mile 1012.5 to Mile 1014.0

Near mile 1012.5 the route climbs onto a high ridge with a north-south orientation and to mile 1014 follows the top of this ridge. Subsoil is clay till with occasional granular pockets, small granular ridges, and erratic and extensive massive ice. Several features were test drilled here for borrows, however, no suitable material was discovered in quantity. No cuts should be considered in this portion. Minor quantities of culvert gravel can be obtained from small gravel ridges, although massive ice will be a problem.

Terrain Assumed: Gently Rolling – Terrain could be flat to rolling, so gently rolling is assumed.

Mile 1014.0 to Mile 1018.0

Beginning near mile 1014, the highway descends to a flat expanse that is abandoned lake bed of nearby Eskimo Lakes. From mile 1014.2 to approximately 1014.8 is an area of high-centre frost polygons that is exceptionally rough. It is expected that differential thaw settlements will be severe and a minimum fill height of five feet is recommended across this area. Beyond mile 1014.8, the subsoil is silty clay lake sediments with vary high ice contents in the upper 6-8'. Minimum design embankment height may be used here as less differential settlement is expected.

At mile 1015.8 is the crossing of Parsons Creek, one of the major streams between Inuvik and Tuk. The creek channel is narrow (250-300') and relatively deep (30-35'). Test borings in both banks reveal high ice contents in the upper 6-8' and cuts should be avoided if possible - alternately, backslope and sub-cut thaw protection will be required. Test drilling in the stream bed was not possible due to extensive snow drifting in the channel.

Terrain Assumed: Gently Rolling – Terrain is described as flat, except for one small section. The stream crossing may require additional granular materials.

Mile 1018 to Mile 1019.5

At mile 1018, the abandoned lake-bed narrows, forcing the route onto higher abandoned beach ridges and benches. Deposits here are till-like in composition and, while some holes reveal relatively low moisture content material (i.e. #1018-1, 1018-4 & 1019-1), the remaining holes encountered some massive ice which is expected to be the norm in this area. No cuts are recommended here as the terrain is not especially rough. Some granular material was encountered adjacent to mile 1019, however, the deposits are very erratic and will provide little more than granular material for culverts.

Terrain Assumed: Gently Rolling – Beach ridges and benches are described, but the terrain is not rough.

Mile 1019.5 to Mile 1025

Throughout this section, the route continues across abandoned lake bed of the Eskimo Lakes varying between two distinct strand-line elevations. Subsoil for the most part is silty-clay with extensive ice in the upper 6-10’. Between mile 123 and 123.8 the route is on a significant cross-slope near the edge of the abandoned lake-bed, and from mile 123.4 to 123.8 is forced onto the adjacent upland where clay till was encountered. Consideration could be given to cuts in the till material, however, additional drilling will be required to confirm the suitability of the till (see hole 1023-2 and 1023-3). Mile 123-124 will present construction problems because of the proximity to the high ground and cross-slope and a location review is suggested here - possibly a shift to the east toward Eskimo Lakes would be beneficial to avoid this problem area, or alternately a more direct approach to the high ground to avoid the side-slope. There is a kame field 2-3 miles west of mile 1025, however, the combination of distance plus erratic ice-rich deposits make this area unsuitable as a borrow source (See Appendix D - Areas 23 to 23D).

Terrain Assumed: Gently Rolling – Lake bed is probably flat, but elevation changes and cross-slopes are specifically described.

Mile 1025 to Mile 1034.5

Near mile 1025, the route enters into an area of complex, dead-ice topography and the location alternates between abandoned lake-bed and till ridges. Kames or kame-like deposits are frequent although few contain granular deposits in significant quantity. There are numerous lakes and occasional pingoes. The till ridges often present marked elevation changes and cuts would be beneficial in most instances, although cuts can be considered in only a few areas (see holes 1026-3, 1028-1 1028-2, 1030-1, 1033-2, 1033-3, 1034-1 and 1034-2). It would seem imperative that cuts be made at some locations (i.e. mile 1034.1) and backslope and sub-cut protection will be required in most cases. On low ground, high ice contents are the norm in the surficial silty clay subsoil. Polygonal ground is common and a minimum fill height of five feet is recommended across these areas.

There are kame fields west of mile 1030 to 1032, however, again the erratic nature of the deposits and the haul distances make these areas generally unsuitable as borrow sources. There are several small kames within ½ mile of the alignment near mile 1029.5, which contain in the order of 150 to 200,000 yd^3 with little stripping. Development of these areas in winter without haul roads would appear feasible (See Appendix D - Areas 24 & 24A).

Terrain Assumed: Rolling –Terrain features are described that could require additional granular materials.

Mile 1034.5 to Mile 1042

To mile 1042, the route crosses a flat expanse that is abandoned lake bed of the adjacent Eskimo Lakes. Relief is virtually non-existent with the exception of occasional low, dead-ice deposits, usually ice rich materials with a granular cap. There are two sources of granular borrow within this section - at mile 1034 is a major kame complex (See Appendix D - Area 25) and at mile 1041 a below grade, gravel-sand deposit (See Appendix D - Areas 27 & 27A).

The subsoil is generally ice rich in the upper 6-10' with the exception of some low ridges which will provide small amounts of sandy, gravelly borrow (eg. hole #1037-1). The clay tills at depth in this area contain the lowest moisture (ice) content of any encountered along the route and although granular borrow is available, the possibility of using till borrow exists (See holes #1037-1, 1038-2, 1038-3, 1039-2, 1040-1 and 1040-2). There are few opportunities for cuts - at mile 1041.9 a cut in a low ridge would significantly reduce embankment requirements and should extend below an ice layer from 3-7' – sub-cut and backslope protection will be required.

Terrain Assumed: Flat – A flat expanse and virtually non-existent relief is described.

Mile 1042 to Mile 1055

At mile 1042, the route climbs from the abandoned lake-bed of Eskimo Lakes Onto thermokarst topography that is the most difficult terrain on the entire route. The landscape is marked by deep pot-hole lakes and depressions, abrupt elevation changes and extensive polygonal ground. The till subsoil generally contains extensive and erratic massive ice. There are granular kames, crevasse fillings, and similar features, however, few contain suitable material in quantity that are devoid of massive ice blocks or layers. Although an occasional test hole on centerline did encounter relatively low moisture (ice) content till, the possibility of cut sections without sub-cut and backslope protection are considered remote. North of approximately km 1050, the relief becomes more subdued, however, there is no apparent decrease in the subsoil ice on massive ice. Embankment quantities through this section will be high due to the rough terrain. There is one source of granular borrow near mile 1044 where 250,000 $cu.yd^3$ are estimated which is insufficient for this section: other small features do exist, however, quantities are unproven and ice blocks make extraction difficult (See holes 1043-5 to 1043-9).

Construction here will be costly unless 'poor' quality material is used for a pad with granular capping.

Terrain Assumed: Rough – Most difficult terrain and thermokarst topography are described.

Mile 1055 to Mile 1059 (Tuktoyaktuk)

There has been no drilling carried out on this section. The terrain is relatively flat and there are no borrow sources. Subsoil here tends to be silty-sandy in composition and subsoil ice is relatively high. Again, construction will be very expensive unless local materials are utilized for the lower portion of the embankment and only capping material imported long distances.

Dredge material from the ocean bottom has apparently been used by others (Dome Petroleum) for road construction at Tuktoyaktuk and may be an alternate to long hauls from land-based borrow sources.

Terrain Assumed: Flat – Terrain is described as relatively flat.

APPENDIX B – SEGMENT MAPS

The following maps are taken from the Public Works maps provided by DIAND.

North of 60 Engineering Ltd.
1400, 800 5th Ave S.W.
Calgary, Alberta, T2P 3N6
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REVISIONS			
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FILENAME: SECTION 1 (REV0).VSD	DATE: 2004-05-25	PAGE: 1 OF 1

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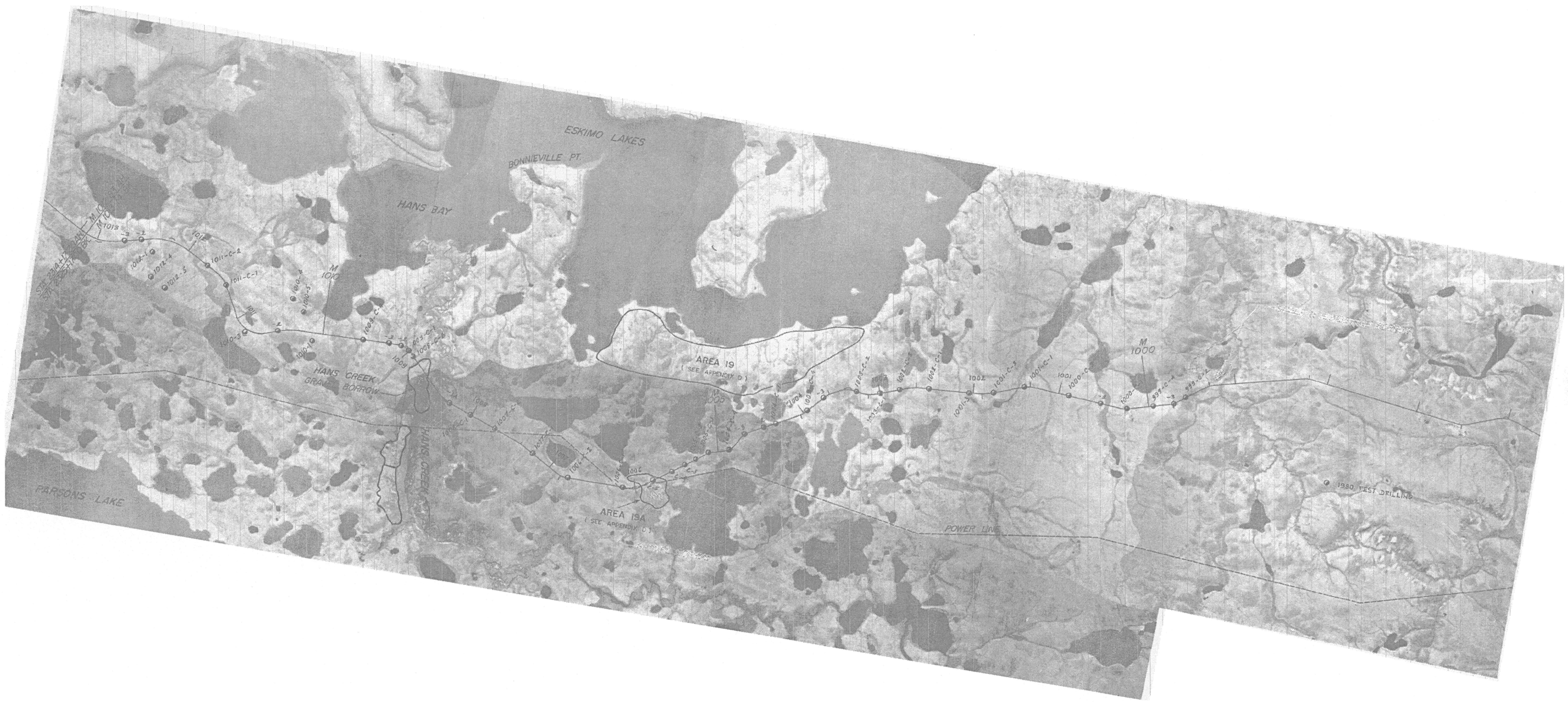

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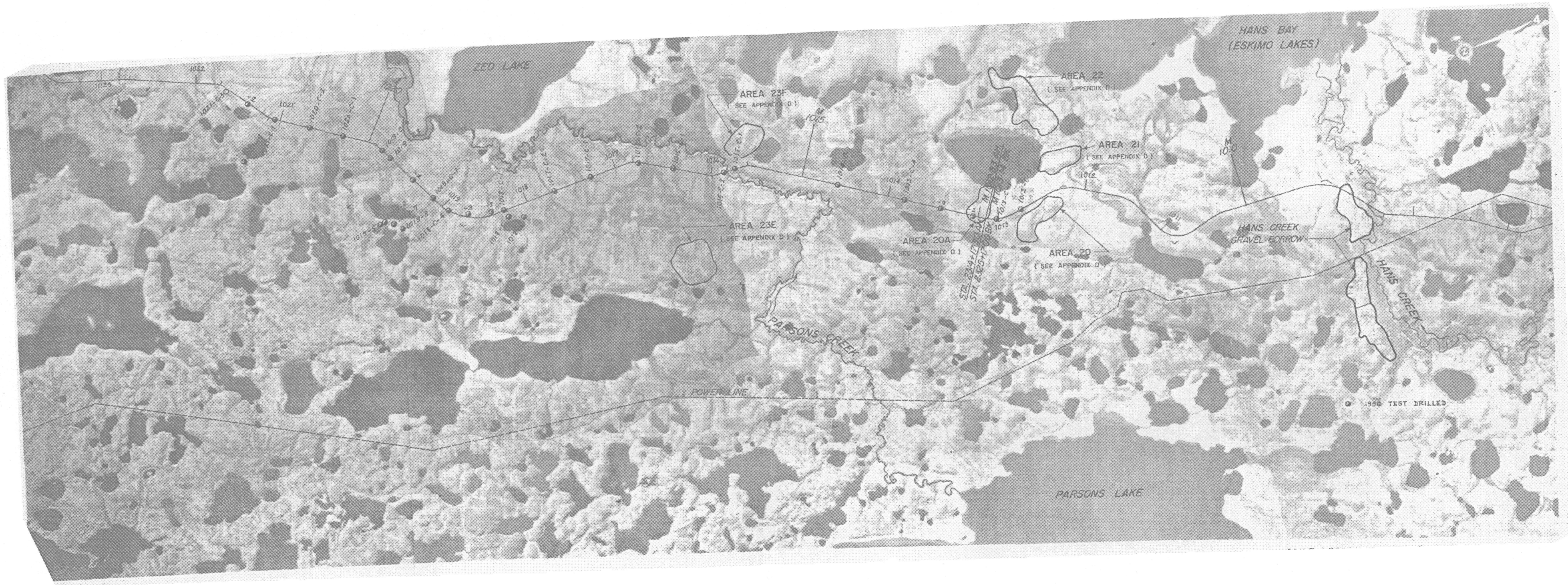

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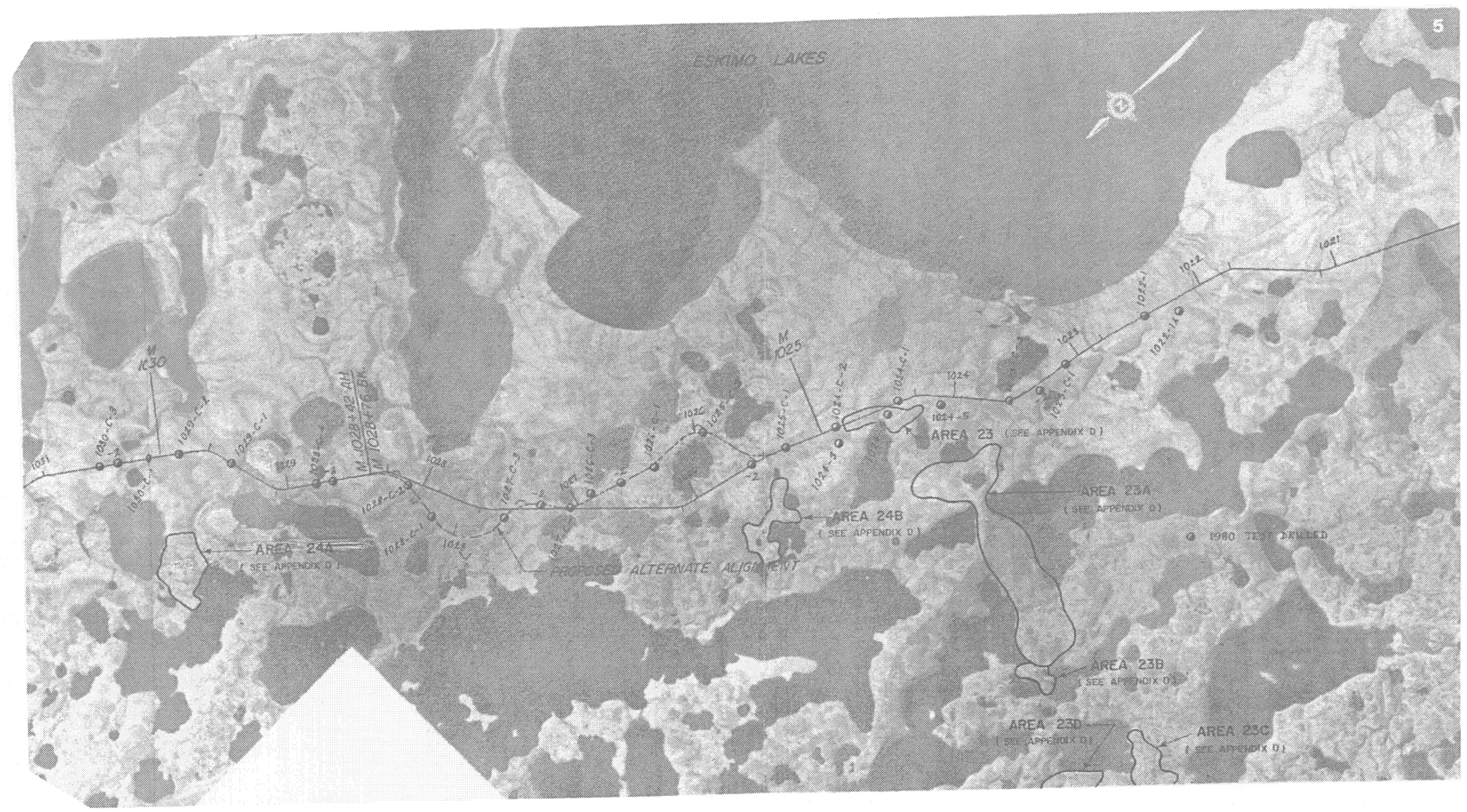

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SUBJECT: Inuvik-Tuk Road, Map 5 of 7		
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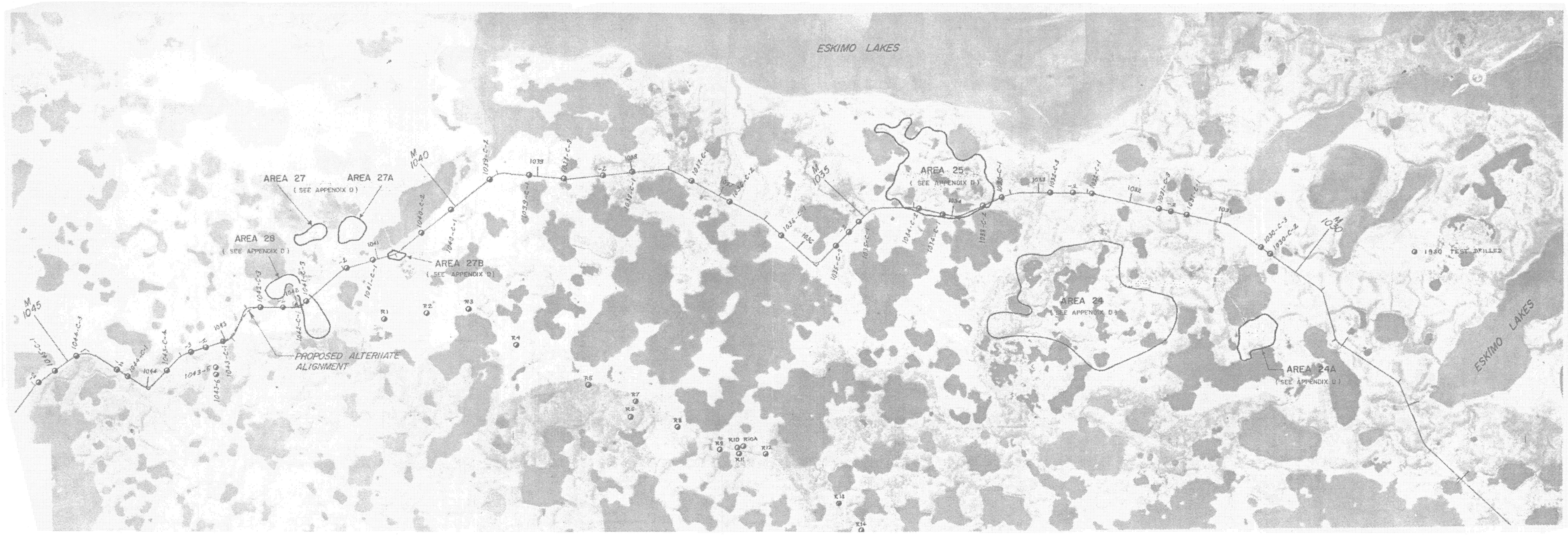
FILENAME: SECTION 5 (REV0).VSD	DATE: 2004-05-25	PAGE: 1 OF 1



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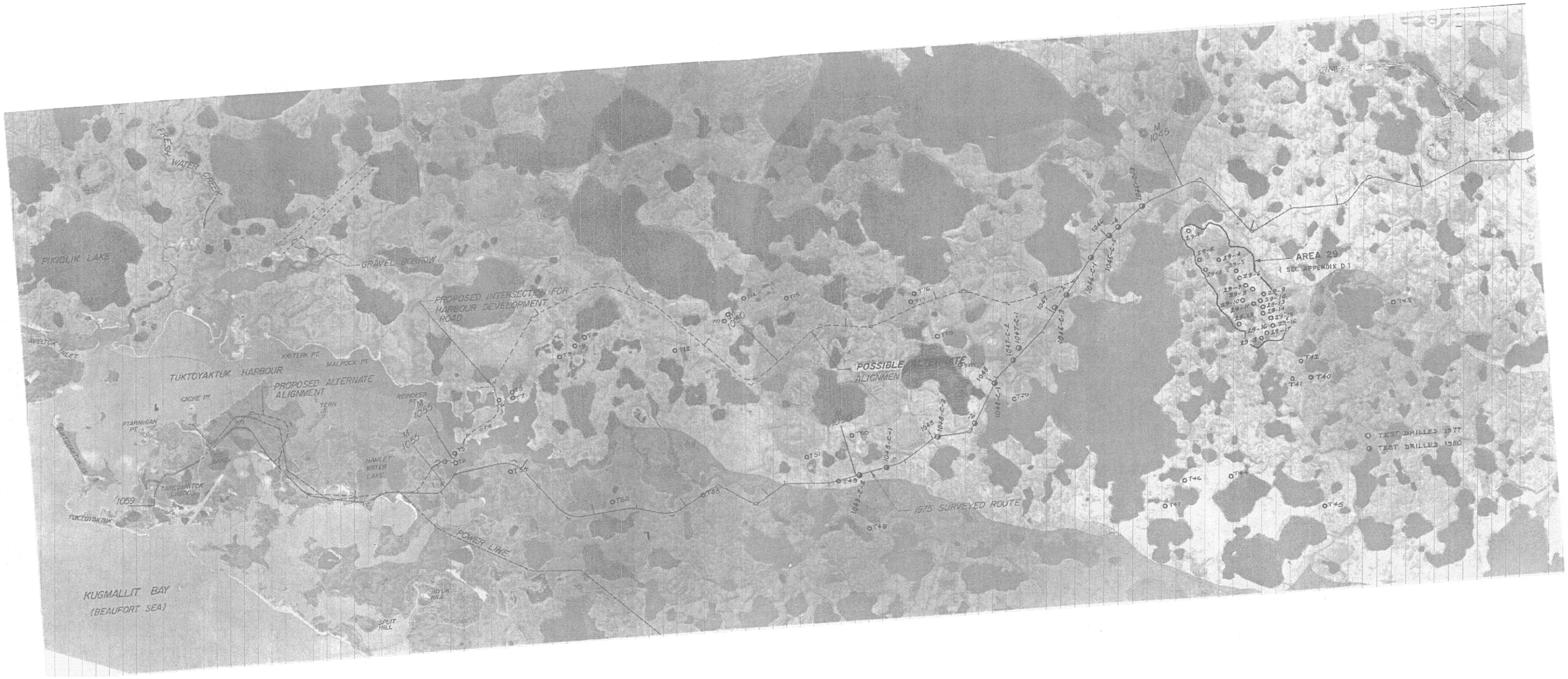

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