Granular Resource Requirements for Proposed Mackenzie Valley Pipelines:

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SECTION 4.

TECHNICAL PANEL "B"

REGIONAL BORROW DEPOSITS INVENTORIES

THE FEASIBILITY OF DEVELOPING GRANULAR RESOURCES FROM THE BED OF THE MACKENZIE RIVER

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ABSTRACT

Prior to 1987, much work had been done to identify and assess prospects for granular resource supply along the Mackenzie Valley. This work indicated that supplies of good quality material were locally deficient and in places access would be difficult because of sensitive northern terrain to be crossed. An alternative source area which was largely unexplored until then was the Mackenzie river bed. Esso Resources had shown that granular sediments could be developed from the river bed when constructing production islands at Norman Wells in the mid-1980s.

EBA in association with GVM and ESL undertook a study of the Mackenzie river bed for DIAND in 1986-87. The study considered several aspects of the feasibility of developing river bed borrow resources. Mackenzie river bed potential was assessed by examining hydrological and geological data for 19 river sections. Economic data was compiled to demonstrate the feasibility of river bed dredging and in particular the practicability of long haul distances by barge. The impact of dredging on fish populations and their migration was also reviewed. Eleven river reaches were identified with a significant potential for supplying granular materials where there are shortages of terrestrial deposits within 15 km of the river. It must be recognized, however, that there is little direct data from the river bed to identify specific source areas or dredging sites.

Introduction

This presentation discusses a study that was conducted in late 1986 and early 1987 by EBA Engineering Consultants Ltd. (EBA) on contract to Indian and Northern Affairs Canada (INAC). Previously, numerous programs had been conducted to identify and evaluate potential sources of granular materials along the Mackenzie Valley. Over 1,300 prospects along the valley have been identified. Unfortunately, the distribution and quality of these deposits are somewhat irregular. Clearly, some areas are deficient in good quality granular resources. Furthermore, access to some deposits can only be achieved by crossing environmentally or thermally sensitive terrain.

EBA's assignment was to evaluate the potential for useable granular resources in the Mackenzie River bed and to assess the feasibility of producing these resources. The concept of river bed borrow production had been previously demonstrated by Esso Resources Canada Ltd. (Esso) on the Norman Wells Oilfield Expansion Project. About 1.8 million cubic metres of river bed sand and gravel were dredged by Esso's contractors to construct six production islands in the river. This success suggested that granular resources deficiencies elsewhere along the river might be reduced by local dredging of river bed sediments.

EBA's project team for this work included Gretchen Minning of GVM Geological Consultants Ltd. (GVM), ESL Environmental Sciences Ltd. (ESL) and Hydrocon Engineering (Continental) Ltd. (Hydrocon). EBA's work focused on the potential supply and demand, and economic issues related to river bed dredging. GVM addressed the geologic regime of the valley with respect to the potential for granular materials to be in the river. Hydrocon put together data pertaining to the hydrologic characteristics of the river. This was used to indicate where preferentially-sorted sediments might be found and where fine-grained overburden sediments might be insignificant. ESL's part in the project was to consider the impact of dredging on river water quality and fish in the river.

EBA's report includes a review of data from Esso's dredging at Norman Wells that is not discussed herein. Similarly, the report provides much more information

than the present summary about fish population studies and related environmental issues which were addressed by ESL.

Study Methodology

Some specific tasks addressed by the study team included the following:

- Assessment of the potential for the river bed to contain useable deposits of sand and gravel.
- Assessment of local alternatives to river bed granular resource production (i.e., conventional valley deposits).
- Assessment of the economics of dredging and barge haul versus conventional pit and trucking operations.
- Assessment of potential granular resource demands by communities, government departments and pipelines.
- Assessment of environmental damage that might result from dredging.
- Rating the feasibility of producing river bed granular sediments from individual sections of the river.

On-Land Alternatives

It was assumed by the study team that wherever good granular resources could be obtained within 15 km of the river, it was unlikely that river bed deposits would be developed. Therefore, the location of all known deposits on either side of the river and within 15 km of it was plotted. Most of the data upon which this was based comes from two original studies; one by Hardy & Associates in 1986 for the Lower (Northern) Mackenzie Valley and the other by Pemcan in 1972 for the Upper (Southern) Mackenzie Valley.

The older Pemcan report was somewhat incomplete, but it gave a reasonable overview of on-land prospects. A year after the river bed study, EBA with GVM prepared a more complete inventory of the Upper Mackenzie Valley for INAC. Unfortunately, the assessment of river bed granular resource production has never been re-examined in light of the updated inventory.

To evaluate where deficiencies in on-land borrow prospects existed, the deposits within 15 km of the river were tabulated on a kilometre-post basis. The Canadian Hydrographic Service navigation charts for the river were used to identify kilometre-age. These tables were set up for individual zones of the river, 19 of which were defined on the basis of river morphology. Table 1 shows typical information for Zone XI, which extends for 57 km south of Wrigley.

Subsequently, the volume of available coarse granular within 15 km of the river was plotted for each 25 km section of the river. Large deposits of fine-grained sand were excluded from the summary because they are only marginally useful. Based on 59 sections of 25 km each (1,475 km total between Great Slave Lake and Point Separation at the south end of the Mackenzie Delta), there is a potential demand for river bed borrow, if it exists, in four long sections including:

- Kilometre 0 to 500 - Great Slave Lake to McGern Island.
- Kilometre 750 to 875 - Near the Great Bear River.
- Kilometre 1,000 to 1,100 - Sans Sault Rapids to Fort Good Hope.
- Kilometre 1,325 to 1,475 - Thunder River to Point Separation.

This may or may not be a conservative assessment of where shortage occurs. On one hand, large deposits may exist just beyond the 15 km river setback limit that was arbitrarily selected. On the other, deposits on both sides of the river were considered together; whereas, one side may be completely deficient in on-land prospects. Furthermore, the large fine-sand deposits, which were excluded from the summary, may have some potential such as pipe bedding (if unfrozen) or road embankment core, but they couldn't be used for road surfacing or in erosion sensitive areas.

Potential Demand

A brief summary of potential demand was conducted to determine if there were any major granular resource shortages affecting Mackenzie Valley residents or government consumers. Contacts were made with representatives of:

Table 1. **Mackenzie Valley Upland[1] Granular Resources and Granular Channel Deposits (River Zone XI – km 520 to km 577)**

Kilometre Posting (km)	Deposit Number	Reserves of Known Granular Materials[2]					River Bed Data	
		Bank						
		Right (R)	Left (L)	Material	Distance From River (km)	Estimated[3] Volume (m^3)	Boreholes[4]/ Hydrographic Observations	Material
532	P142	R		Sand & Gravel	5	3,000,000		
536	P143	R		Sandy Gravel	7	1,000,000		
537	P144	R		Sand & Gravel	3	N/D		
540	P146	R		Sand & Gravel	4	600,000		
540	P148	R		Sand & Gravel	7	N/D		
542	P147	R		Sand & Gravel	1	N/D		
547	P151	R		Sand & Gravel	3.5	1,500,000		
549	P150	R		Sand & Gravel	6	N/D		
550	P152	R		Sand	1.5	N/D		
551							Left Bank	Sand & Gravel
553	P153	R		Gravel	4	3,000,000		
554.3	P154	R		Sand & Gravel	0.5	10,000,000		
556	P155		L	Sand & Gravel	0.5	N/D		
556	P156	R		Silty Sand & Gravel	4	N/D		
560	P157	R		Silty Sand & Gravel	8	N/D		
560-565							Left Bank-Isle	Sand & Gravel
562.5	P158	R		Silty Sand & Gravel	7	N/D		
564	W1	R		Sandy Gravel	0	5,000,000		
565.5	W20		L	Gravel	0.5	200,000		
566	W3	R		Silty Gravel	1.5	1,000,000		
567.5	W11	R		Sandy Gravel	0	150,000		
569	W2	R		Sandy Gravel	0.5	40,000,000		
571-582							Left Bank-Wrigley R. Intersection	Gravel
573	W5	R		Sandy Gravel	0.5	10,000,000		
574								
575	W6	R		Sandy Gravel	0.5	1,000,000		
576	W10	R		Sandy Gravel	2	300,000		
577	W7	R		Sand & Gravel	4.5	250,000		

1) Upland deposits greater than 15 km from the river have not been considered.
2) Pemcan 1972.
3) N/D - Quantity not determined.
4) Public Works Canada, 1976.

- Indian and Northern Affairs Canada community resource management officers.
- Government of the Northwest Territories granular resource managers.
- Public Works Canada for highway demands.
- Transport Canada for airports.

From the information provided, it appeared that projected demands (to 1991) could be satisfied with available resources for all areas except the community of Arctic Red River.

The potential demand for pipeline users of granular resources was also considered. Contacts were made with Interprovincial Pipe Line (IPL), who had built a northern oil pipeline, with Gulf Canada Resources who had just completed a paper pipeline study of a 508 to 610 mm oil line, and information previously prepared by Canadian Arctic Gas Pipeline Ltd. (CAGPL) and summarized for Polar Gas was used. Quantity estimates were found to vary from 1,350 to 7,500 m^3/km. This information was not directly tied into the river bed borrow study, however, because there was not enough detail to link pipeline demand to sections of the pipeline that were likely to be within 15 km of the river.

Cost of Development

It was necessary to demonstrate that dredging of river bed granular materials could be done at a reasonable cost. To define "reasonable", development costs for conventional (on-land) pits were considered. Several different contractors, government departments and planners were contacted to establish an estimate of pit costs. Unit prices in the order of those shown on Table 2 were developed.

For a 15 km haul distance, the cost of granular materials on site is about $25 to $31 in the southern Mackenzie Valley and about $35 to $39 in the northern Mackenzie Valley.

The cost for developing river bed granular deposits similarly contains many variables. The size and type of equipment is related to the desired output. Big dredges can produce 8,000 to 10,000 m^3/day or more. To compare with conventional on-land operations, the study also considered a dredge producing at 1,400 m^3/day. That is the focus of the following discussion.

The equipment required for dredging includes the following:

- Barge loading dredge.
- Haul barges or floating pipeline.
- Tug support to move barges and reposition dredge.
- Loaders on the dock to empty barges and load trucks.
- Trucks to move the borrow inland.

It was not easy to directly compare on-land versus dredging borrow operations because they are so different. Table 3 gives some unit rates for comparison to Table 2, and Figure 1 graphically shows the comparison. For a long haul of 35 km, the dredge and barge method can be up to 40% cheaper.

Environmental Considerations

As indicated previously, ESL provided more information on the potential environmental impact of dredging in the Mackenzie River. Some of the items considered by ESL included:

- Hydrologic regime.
- Suspended sediment concentrations (natural and after dredging).
- River morphology (width, depth, shape).
- Dredging impacts such as:
  - Increased suspension load.
  - Downstream sedimentation.
  - Changes to channel morphology.
  - Water quality with respect to heavy metals and absorbed hydrocarbons.
  - Fish population.
  - Fish spawning and migration areas.
  - Direct interference of migrating fish.
  - Damage to spawning areas.

ESL concluded that the large dilution factor offered by the high year-round flow in the Mackenzie would likely reduce the impacts of dredging to short term, minimal levels and, in many cases, to negligible

Table 2. Cost for Conventional Borrow Development

Item	Unit Cost ($/m³)		For 15 km Haul ($/m³)		Average for 35 km Haul
	Southern Valley	Northern Valley	Southern Valley	Northern Valley	
A. Pit Development and Reclamation	$ 1.00	$ 1.00	$ 1.00	$ 1.00	$ 1.00
B. Excavation	$ 4.00	$ 4.50	$ 4.00	$ 4.50	$ 4.25
C. Access & Heritage (per kilometre)	$ 1.70	$ 2.20	$ 25.50	$ 33.00	$ 68.25
		Total	$ 30.50	$ 38.50	$ 73.50

Table 3. Cost of River Bed Dredging for Granular Resources

Item	Unit Cost[1] ($/m³)	Example 1 10 km River Haul Plus 5 km In Land Haul ($/m³)	Example 2 30 km River Haul Plus 5 km In Land Haul ($/m³)
A. Equipment Mobilization	$ 6.00	$ 6.00	$ 6.00
B. Excavation	$ 2.00	$ 2.00	$ 2.00
C. River Haul (per kilometre)	$ 0.75	$ 7.50	$ 22.50
D. Over Land Haul (per kilometre)	$ 1.70	$ 8.50	$ 8.50
E. Dock Site Rehandling and Stockpiling	$ 3.50	$ 3.50	$ 3.50
Total		$ 27.50	$ 42.50

[1] For 1,400 m³/day operation.

Figure 1. **The Relative Cost of Conventional and Riverbed Borrow Production**

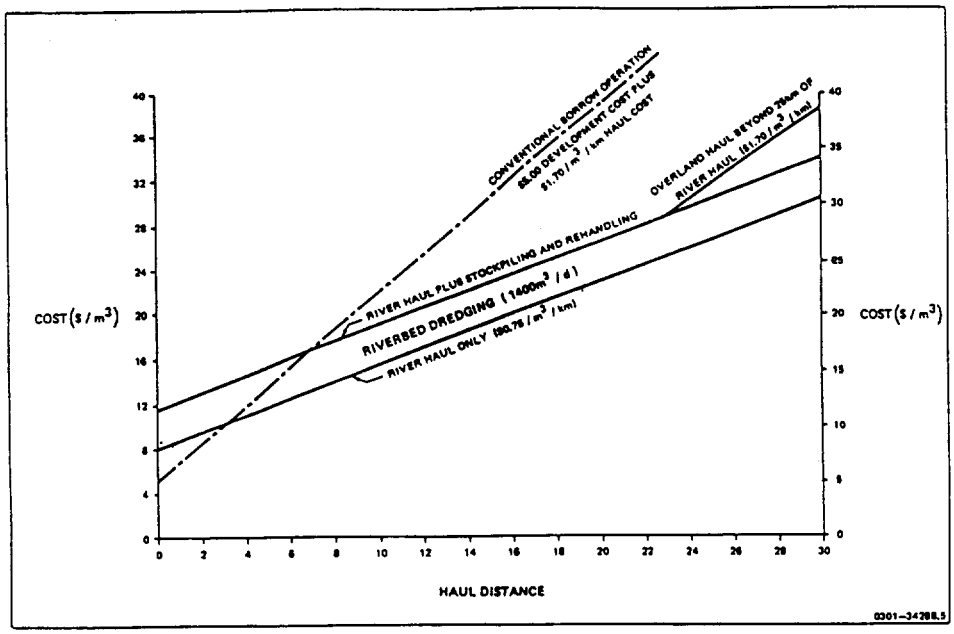
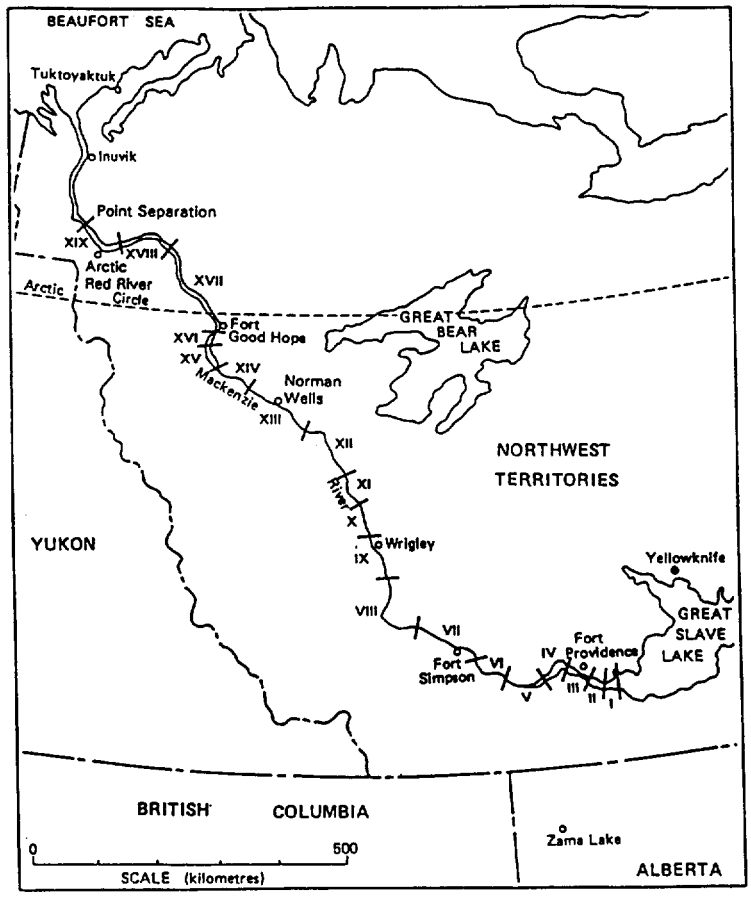


Figure 2. **Mackenzie Riverbed Granular Resource Study Zones**



levels. They cautioned, however, that site specific concerns related to fish migration and spawning would have to be considered. In some cases, negative impacts would occur if inappropriate time windows for dredging were used.

Dredging Feasibility

It was shown that dredging was economically feasible in some practical cases. It was shown that environmental impacts of dredging are manageable, if not negligible. It was shown, at Norman Wells, that suitable reserves exist in at least one area of the river. It was also shown that some sections of the valley along the river do not have locally available, conventional granular resource prospects. What remained to be shown was that granular sediments exist where they might be a feasible alternative to conventional sources. Unfortunately, there is very little to almost no direct data pertaining to the river bed strata for most of the Mackenzie River.

To assess the potential for finding granular resources, the following steps were undertaken:

- The river was subdivided into 19 zones of 26 km to 176 km each, based on reaches of similar channel morphology.
- Hydrologic data was compiled including flood frequency, ratio of peak to low flow rates and suspended sediment loads.
- River bed borehole information (270 borehole logs) were obtained from Public Works Canada.
- Geologic background data including bedrock (source rock potential) and surficial geology (granular sediment potential) was compiled for each zone.
- Each zone was evaluated for its potential to contain deposits of granular sediments based on characteristics such as hydrologic gradient and tributary channel bed sediments.

Figure 2 shows the 19 zones and Table 4 provides a brief description of each. Table 5 illustrates typical data considered for River Zone VII (4.2) which is located in the Fort Simpson area.

A rating system was developed to assess the relative characteristics of each section of the channel. Table 6 shows the characteristics considered to be most important and how they were rated. The potential demand in each section, primarily related to conventional (on-land) reserves and ESL's environmental considerations were also factored into the rating. Table 7 shows the overall potential rating for each of the 19 zones. Subsequently, this was refined by focusing on local variations (25 km sections) in on-land resources versus the potential of the river to supply granular deposits. Table 8 shows the areas where it was concluded that river bed borrow development has the highest potential.

Conclusions

The study team concluded that producing granular resources from the Mackenzie River bed was technically feasible, that it was economically feasible in some areas and that there is a moderate to high potential for some river reaches to have bed deposits which would be suitable for engineering uses. Unfortunately, the direct data to support these conclusions was weak, particular with respect to the river bed deposits. It was not possible to identify specific source areas or potential dredge sites to substantiate these conclusions. Additional geological and fisheries related data is needed, before such reserves of granular material can be considered developable.

Table 4. Identification of Mackenzie Riverbed Granular Resource Study Zones

River Zone No.	Start[1] Kilometre Post	Geographic Boundaries	NTS Map Sheets	Geographic Features
I	0	Great Slave Lake	85F	South Channel
II	26	West Side of Big Island	85F	Beaver Lake
III	60	West End of Beaver Lake	85E & F	Providence Rapids, Fort Providence (km 79)
IV	107	Horn River and Mills Lake	85E	Mills Lake
V	130	West End of Mills Lake	85E, 95H	
VI	229	Trout River	95H	Jean-Marie R. (km 270), Green Island Rapids (km 320)
VII	300	Rabbitskin River	95H & J	Liard River, Ft. Simpson (km 340)
VIII	410	East of Burnt Island	95J	Camsell Bend (km 461) McGern Island (km 492-514)
IX	520	Willowlake River	95J & O	River Between Two Mountains (km 538) Wrigley (km 574)
X	580	Wrigley River	95O & N	Ochre R. (km 605), Johnson R. (km 635)
XI	665	Blackwater River	95N, 96C	Dahadinni River (km 678)
XII	714	Redstone River	96C	Saline Is. (km 724), Keele R. (km 737) Fort Norman (km 827)
XIII	828	Great Bear River	96C, D & E	Norman Wells (km 905)
XIV	966	Patricia Island	96E, 106H	Mountain River (km 1015)
XV	1017	Sans Sault Rapids	106H & I	Dummit Island (km 1020-1026)
XVI	1087	Extrance to Ramparts	106I	Fort Good Hope (km 1101)
XVII	1098	Exit to Ramparts	106I, J & O	Ontaratue River (km 1200)
XVIII	1261	North of Little Chicago	106O & N	Thunder R. (km 1299) Travaillant R. (km 1327)
XIX	1438	Lower Ramparts	106N	Arctic Red River (km 1454)
End	1475	Point Separation		

1. Kilometre postings are interpreted from the Mackenzie River Navigational Charts prepared by the Canadian Hydrographic Service. Chart Numbers 6404 to 6426.

Table 5. **Mackenzie River Terrain and Borrow Summary (River Zone VII – km 300 to km 410)**

River Topography	River Land Forms	Upland Topography	Upland Land Forms
A) Elev: East of Rabbitskin 137 m to east of Burnt Island <120 m.	A) Straight Channel: Three minor multi-channel streches.	A) Undulating to flat plain west of river.	A) Bedrock: Shale, sandstone in low land near river.
B) Width: 1.5 - 3 km.	B) Alluvial deposits to 153 m.	B) Flat plain with dunes south of river.	B) Shale and sandstone in Ebbutt and Martin Hills.
C) Depth: 1 - 10 m usually 2 - 7.	C) Near Rabbitskin River three terrace levels representing old river.	c) 152 m represents glaciolacustrine/ till boundary north of river; 213 m on south side of river.	C) Morainal deposits above 152 m north of river; above 213 m south of river.
D) Tributary Rivers: Liard Harris Martin Trail Several Unnamed Creeks	D) Islands (all small) Green, Hanson, Martin, Ft. Simpson, five unnamed.	D) Martin Hills rise above plain to south.	D) Glaciolacustrine deposits thickest south of river.
	E) Alluvial plain and terrace deposits and sand and silt.	E) Ebbutt Hills rise above plain to north.	E) Dunes on glaciolacustrine plain.
	F) River bottom in till; boulder pavement (6 m till/bedrock).		F) Quaternary deposits 12 m thickn north of river, 12 - 20 m south of river.
	G) River banks high and steep, particularly south side.		G) Intermittent high ice content permafrost beneath organics in fine-grained deposits.
	H) Green Island Rapids.		H) *Only several upland granular deposits associated with glaciofluvial and alluvial terraces.
	I) Some boreholes show gravel near Green Island Rapids.		
	J) *Low potential for granular material in river except downstream of Green Island Rapids.		

*Comments relative to granular material sources.

Table 6. Rating System for the Granular Materials Potential of the River Zones

Rating Points	
	A. River Channel Characterisitics
	Type of Channel:
4	Braided
3	Braided Transitional to Straight
2	Braided Transitional to Meandering
2	Straight
1	Meandering
0	Expanded
	B. River Gradient
	Gradient:
1	.001 - .09 m/km
2	.1 - .19 m/km
3	.2 - .29 m/km
4	.3 - .39 m/km
	C. Type or Number of Tributaries
	Description:
5	Three or more large gravel bed tributaries and five or more small gravel bed tributaries.
4	Three large gravel bed tributaries and no or a few small gravel bed tributaries.
3	One to two large gravel bed tributaries and many small gravel bed streams.
2	One to two large gravel bed tributaries and a few or no gravel bed tributaries.
1	No large gravel bed tributaries, but several small gravel bed streams.
0	No gravel bed tributaries.
	D. Cummulative Ratings (total of points from A, B and C)
	Rating:
1 - 4	Low
5	Low to Moderate
6 - 7	Moderate
8	Moderate to High
9 - 13	High

Table 7. Mackenzie Riverbed Borrow Potential for Each River Zone

River Zone (km)	River Regime Rating[1]	Upland Borrow Deposits[2] Sand (m^3)	Sand & Gravel (m^3)	Fisheries Activities[3]	Potential for River Borrow Sources
I (0-26)	Low	None		D F M (Moderate)	Low
II (26-60)	Low	None		D F M (Moderate)	Low
III (60-107)	Moderate	None		D S R M (Moderate)	Borehole data (Drawing 4.1) suggests Moderate-High potential between km 75 and 100.
IV (107-130)	Low	None		D M (Low)	Low
V (130-300)	Low	Some Near Trout & Redknife Rivers		M D (Moderate)	Low-Moderate between km 170 and 299.
VI (229-300)	Low	None		D M	Moderate near Jean-Marie Creek (km 270), otherwise low.
VII (300-410)	Low	Unlimited	2,000,000	M D S	Moderate between km 310-330, otherwise low.
VIII (410-520)	High	Unlimited	<500,000	D M S R (Moderate)	High near McGern Island (km 490-520) Camsell Bend (km 460)
IX (520-580)	Moderate-High	Unlimited	>67,000,000	D M	High near Wrigley River (km 580) and River Between Two Mountains (km 539)
X (580-665)	Moderate-High	Unlimited	>56,000,000	D M (High)	High near Ochre River (km 605) and Blackwater River (km 664)
XI (665-714)	High	Unlimited	>65,000,000	M S R (Low)	High
XII (714-828)	Moderate	Unlimited	>36,000,000	D M S R (High)	Moderate between km 725 and 780, high near Fort Norman (km 825)
XIII (828-946)	High	>40,000,000		M D E S R (High)	High (proof is at Norman Wells) (km 905)
XIV (966-1017)	Moderate	15,000,000	$5\text{-}25\times10^6$	S R M (Moderate)	High near Sans Sauk Rapids, moderate between km 966 and 1000
XV (1017-1087)	Moderate		>2,000,000	M R S (High)	High between km 1017-1030, low beyond
XVI (1087-1098)	Low		Limited	M (Low)	Low
XVII (1098-1261)	Low	Some large and many small deposits		D S R M (High)	Moderate near Tieda River (km 1163), Loon River (km 1136) and Hare Indian River (km 1105), low between km 1140
XVIII (1261-1438)	Low-Moderate	Unlimited	$12\text{-}115\times10^6$	M D S R (Moderate)	Moderate near Thunder River (km 1299), otherwise low
XIX (1438-1475)	Low		2,000,000	M S D (High)	Low to moderate below Arctic Red River (km 1454), otherwise low

Note: (1) From Table 7.2
(2) From Table 5.1
(3) From Appendix B, Symbols are:
D - Domestic Fisheries, F - Sport Fisheries,
S - Spawning Areas, R - Rearing Areas, M - Migratory Routes
Where high level of sensitivity is known, it is indicated by underlined symbol (e.g., D)

Table 8. Mackenzie River Sections Where River Bed Granular Resources Development May be Feasible

River Section (km)	River Bed[1] Potential	Upland[2] Reserves	Prospects[3]
50 - 75	Moderate to High	None	Good
75 - 100	Moderate to High	None	Good
250 - 300	Moderate	None	Fair
300 - 325	Moderate to High	None	Good
400 - 425	Moderate	Some to None	Fair
450 - 475	Moderate to High	None	Good
475 - 500	High	Some to None	Fair to Good
700 - 725	High	Fine Sand	Fair to Good
775 - 800	Moderate	Fine Sand	Fair
850 - 875	Moderate	Some to None	Fair
1000 - 1025	High	None	Very Good
1025 - 1050	High	None	Very Good

1. River Bed Potential: Interpreted probability that suitable material can be found.
2. Upland Reserves: Extent of previously identified land sources.
3. Prospects: Subjective assessment of prospects for success by dredging.