THE YUKON ECONOMY
ITS POTENTIAL FOR GROWTH AND CONTINUITY

VOLUME VI   REFERENCE STUDY ON POWER

D. Wm. Carr & Associates Ltd.
Ottawa
July, 1968

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Yukon Power Survey

by

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Background study prepared for D. Wm. Carr & Associates Ltd. as part of the Yukon Economic Studies undertaken for the Department of Indian Affairs and Northern Development and the Government of Yukon Territory.

Ottawa

July, 1968

Cat. No.: R79-469/6

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YUKON POWER SURVEY

A. SUMMARY

This report comprises a survey of work which has been done to date on the production of electric power in the Yukon and is intended to gather together all the data obtained by various agencies and consultants and to delineate some guide lines for future work on power development in the Yukon. No new field work was done in the preparation of this report. It covers as much of the available information from a large number of different sources as could be discovered with respect to hydroelectric sites. In addition, a review of thermal power possibilities including gas, oil, coal, and nuclear developments was made. (1)

Up to the present, there have been a few small hydroelectric developments including a very early one near Dawson which operated until 1966, and the plants at Mayo and Whitehorse built in the 1950's by the Northern Canada Power Commission, who also operate diesel-electric units at widely scattered points. The Yukon Electric Company Limited operates two small hydroelectric plants in addition to a number of diesel-electric plants and these supply customers in various areas. (2)

To date, there is very little transmission of power over any considerable distances in the Yukon, but there is under construction the first large transmission line from Whitehorse to the Anvil Mines properties via Carmacks. There is also a transmission line from Whitehorse to Carcross. There is included in the report data on transmission line construction costs. (3)

Because the developments have been small and isolated, the cost of power everywhere in the Yukon is relatively high and at some of the smaller, more isolated points, it is so high as to make any considerable use of electricity prohibitively expensive. (4)

In the early stages of hydroelectric development such as is presently occurring in the Yukon, load forecasting is extremely difficult. The residential loads and loads from mining operations are about all that can be estimated on a reasonably accurate basis. In the survey, some 15 separate areas were considered and the summation of these indicates that the present total of 31 MW will grow to about 330 MW by 1980 and 560 MW by 1990. (5)

The hydroelectric potential in the Yukon is large. There are two difficulties in such developments, namely that the long, (6)

cold winters reduce flows and are conducive to the formation of frazil ice wherever there is open flowing water. The best solution to both problems is to provide relatively large storage volumes, preferably close to the generating stations. The Yukon River with its tributaries is the largest single potential source of hydroelectric power and on this river, consideration will have to be given to interference with the salmon runs. The Peel and Liard Rivers have large potentials and there is no problem with fish in these rivers.

Two schemes have been developed for the Yukon River, the major system scheme which would produce a capacity of some 6,000 MW at a cost of $2.5 billion and the modified system which would produce 3,450 MW at a cost of $1.6 billion. (7)

Recently, some 43 other sites on the tributaries of the Yukon River were investigated and the results indicate the possibility of generating power over a wide area but much of this would be relatively expensive. Developments on the Porcupine, Peel, and Liard Rivers have been investigated, although not in detail, and these indicate that some economical sites are available. As might be expected, all the more economical sites are of such size that a major investment would be required to provide power at reasonable rates. (8)

The pattern of development in the North, aside from the few hydroelectric plants that have been built, has generally been to generate power at the point of use by means of diesel-electric generators. This survey has included the possibility of further diesel-electric development and also the use of gas turbine generators. In addition, the possibility of generating power from the so far unproved coal deposits at Carmacks has been investigated and this appears to be an alternative to hydroelectric schemes. It is doubtful if nuclear power generating facilities would be economically feasible because the size of efficient nuclear units is too large for the load envisioned in the near future. (9)

The principal conclusions reached are as follows: (10)

(1) While present development of power in isolated areas which depends on diesel-electric generation is too expensive for large scale installations, the economics that may be brought about by the discovery of sizeable deposits of gas and oil in the area should be borne in mind.

(2) The use of nuclear power sources at the present time does not appear to be practicable. The load demand is too small to use the size of unit which at the present time is required for efficient nuclear power generation.

(3) The possibility of developing power from coal deposits at Carmacks looks attractive, but coal reserves there still have to be proved. If the coal reserves are as large as initial studies have indicated they may be, then it would seem reasonable to build a thermal plant if investigation indicates this can be done economically, and to increase its size by stages to the point where the load has built up sufficiently to warrant construction of one of the more economical hydroelectric developments. Then, the coal-fired steam turbine generator could be used as a reserve until sufficient load has been developed that further hydroelectric installations are warranted.

(4) Detailed investigation of the more attractive hydroelectric sites is needed to determine which will be the most economical.

(5) One of the keys to electric power development is a transmission grid and studies in detail of this are required. Such a grid will help both industries and settlement, which in turn will lead to general economic growth, including an increased demand for electric power.

(6) The best estimate that can be made at the present time is that new capacity of some 300 MW costing somewhere between $100 and $300 million will be needed by 1980.

(7) The above investigation and planning will help to make possible more uniform power rates which should aid economic growth.

Arising out of conclusions listed above, the following recommendations are offered: (11)

(1) A detailed study of transmission of power in the Yukon should be made.

(2) The coal reserves at Carmacks and the cost of mining them should be studied in detail.

(3) A study of generation of power from the coal deposits at Carmacks should be made.

(4) The most attractive hydroelectric sites should be investigated thoroughly so that reliable cost estimates can be made.

(5) Based on the studies recommended above, the setting up of a power rates structure for the whole area should be investigated.

(6) Continuing appreciations of new developments in the local oil and gas supplies as well as new developments in nuclear power engineering are needed.

(7) The best sequence of development should be evolved from the more detailed studies suggested above. It is tentatively suggested that a reasonably economical order would be to generate power from coal, increasing the capacity as required until some of the better hydro schemes could be economically integrated into the system.

B. INTRODUCTION

The exigencies of time and budget have resulted in this study of power development in the Yukon necessarily being limited to a great extent to a survey of work and investigations done in the past, synthesis of the results of such work and investigations into a systematically comprehensive and comprehensible report on data available, and as the result of this review, the delineation of some guide lines for further work that should be carried out to provide an orderly and economic plan for power development in the Yukon. (12)

Reports and studies that have been included in the present review are the Ingledow report on hydroelectric resources in the Central Yukon Territory, the Department of Northern Affairs and National Resources reports on the Yukon, Porcupine, Peel and Rat River regions, and the Werner-Gren British Columbia Development Company Ltd. report on the Liard River. Other sources have been referred to with regard to thermal power plants, transmission line costs, available fuel sources and potential mining development. (13)

It has not been possible to make any detailed investigation of hydroelectric power sites, but studies of information and the various reports available has made possible the summation of the information into a form where the most favourable schemes can be chosen to suit the situations which will arise. (14)

A review of the present knowledge of gas and oil possibilities has been made and the use of these sources of power in future development, as well as the possibility of using nuclear energy, has been considered. (15)

Known coal deposits and the associated cost of production have been used as a basis for including thermal power generation in future power development in the Yukon. (16)

A review has been made of costs of transmitting power and the effect of this on the relative merits of all power sources has been considered. (17)

C. PRESENT POWER DEVELOPMENT

1. History of Power Development in the Yukon

The first electrical generation facilities in the Yukon Territory were installed near Dawson by a mining company following discovery of gold in the Klondike in 1898. By 1935 these facilities were developed into a 10 MW hydroelectric plant on the north fork of the Klondike River and were operated until the end of 1966. The plant was a run of the river type with little winter capacity and supplied power principally for gold dredging operations in the summer months. In 1901 the Yukon Electrical Company Limited was incorporated to supply power at Whitehorse. This company now operates two small hydroelectric plants, totalling 1650 KW, and a 1200 KW diesel-electric plant in Whitehorse. (18)

In 1952 the Northern Canada Power Commission constructed a small hydroelectric plant on the Mayo River at Mayo to serve the mining communities in that area. The capacity of the Mayo plant was increased to 5.1 MW in 1958. Also during 1958, the Northern Canada Power Commission constructed an 11.4 MW hydroelectric plant on the Yukon River near Whitehorse to supply Department of National Defence installations there as well as to augment the Yukon Electrical Company system. From 1958 to 1967, the Yukon Electrical Company Limited expanded its electrical services to include most of the small communities in the Yukon. This power was generated by diesel-electric generating plants ranging up to 1700 KW capacity. During 1966, the Northern Canada Power Commission installed a 750 KW diesel-electric generating plant at Dawson City to replace the power formerly supplied by the Klondike River plant. In 1967 a 5600 KW diesel-electric plant was installed by Cassiar Asbestos Corporation Ltd. to service its new mine at Clinton Creek, some 48 miles northwest of Dawson City. (19)

2. Existing Transmission Facilities

Most of the electrical demands in the Yukon to date have been small and isolated from each other which has resulted in very little interconnection of load centers by transmission lines. At present, transmission lines join Whitehorse to Carcross (approximately 37 miles), Burwash Landing to Destruction Bay (approximately 8 miles), Watson Lake to Lower Post and Upper Liard (approximately 20 miles) and Mayo to Elsa, Calumet and Keno Hill (approximately 33 miles). Plans are presently under way to construct a 138 KV transmission line from Whitehorse to the new Anvil Mines property, a distance of approximately 225 miles. This transmission line would pass through Carmacks, 110 miles north of Whitehorse, the possible site of a future coal-fired steam electric plant or hydroelectric plant. (20)

3. Present Power Rates

Power costs to the consumers over most of the Yukon, with the exception of the Whitehorse and Mayo areas are governed by the operating costs of small diesel-electric installations. The monthly cost for a residential customer consuming 300 KWH in small centers serviced by diesel-electric generators, such as Haines Junction, Teslin, Destruction Bay and Beaver Creek, is $30.40. The monthly bills at larger communities served by diesel-electric generation, such as Watson Lake and Dawson, are $16.80 and $32.00 respectively. The monthly bill for a commercial customer consuming 2000 KWH on a 10 KW demand is $216.00 at Watson Lake and $211.10 at Dawson. Mayo and Whitehorse, both of which are supplied by hydroelectric power, have substantially lower rates. A residential customer consuming 300 KWH per month will pay $10.10 in Whitehorse and $12.00 in Mayo. A commercial customer consuming 2000 KWH per month on a 10 KW demand will pay $88.00 in Whitehorse and $75.10 in Mayo. (21)

D. PRESENT AND FUTURE LOADS

1. General

Present loads in the Yukon are widely scattered and are too small to warrant any power sources other than diesel-electric generators. The only exceptions to this are the Whitehorse and Mayo areas, where mines are being operated and reasonable population centers exist. (22)

The basis for estimating future loads is primarily on projected mining development. Table 1 of mine requirements has been used as a guide for this estimate. (23)

Table 1 MOST PROBABLE LOAD DEMANDS FOR MINING & MILLING OPERATIONS *

	Total Open Pit	Total Underground
200 tons per day	800 - 1200 KW	1200 - 2000 KW
500 tons per day	1200 - 2000 KW	2000 - 3000 KW
2500 tons per day	3000 - 3500 KW	3600 - 4500 KW
5000 tons per day	4500 - 6000 KW	6000 - 7500 KW
Average Load Factor		
	85% - 95%	80% - 90%

Power required by residential, commercial and municipal customers has been estimated as shown in Table 2. (24)

* Private communication from M.A. Thomas & Associates Ltd.
Vancouver, B.C.

1. General (cont'd)

Table 2 TYPICAL RESIDENTIAL COMMUNITY DISTRIBUTION SYSTEM LOAD DEMANDS *

		Increase Allowance	
Population Range	Demand KVA/Residence	For Commercial Area	For Community Services, Street Lighting
50 - 100	2.0	15%	10%
100 - 500	1.8	15%	10%
500 - 1000	1.6	17%	8%
1000 - 5000	1.5	20%	7.5%
Over 5000	1.5	25%	5%

* Private communication from M.A. Thomas & Associates Ltd. Vancouver, B.C.

A four per cent load growth per year per customer has also been assumed. (25)

The following is an estimate of Yukon power requirements by settlement areas. Population increases due to projected mining and forest products have been taken into consideration. (26)

2. Beaver Creek Area

Beaver Creek is near the Yukon-Alaska border on the Alaska Highway, 280 miles west of Whitehorse. Other settlements in the area include Snag, a former Department of Transport installation, approximately 15 miles east of Beaver Creek and Koidern, approximately 30 miles southwest of Beaver Creek where the Alaska Highway crosses the White River. In the White River area, several mining companies are exploring copper-nickel prospects. (27)

Beaver Creek has been served by the Yukon Electrical Company Limited since 1963. Power is supplied by a 310 KW diesel generating station and the amount of power generated during the 1965 - 66 season was 576,000 KWH. (28)

2. Beaver Creek Area (cont'd)

If one of the nickel-copper properties presently being explored became a producing mine, new power generation facilities would be required, probably at Koidern. Assuming a 500-ton per day concentrator is installed, power requirements would be in the order of 3 MW for the mine and 2 MW for domestic and commercial loads. (29)

3. Burwash Landing Area

Burwash Landing on Kluane Lake is approximately 180 miles west of Whitehorse via the Alaska Highway. The nearby settlement of Destruction Bay is eight miles east of Burwash Landing. Copper and nickel deposits have been explored near Burwash Landing and at Quill Creek approximately 18 miles west of Burwash Landing. (30)

Destruction Bay and Burwash Landing are served by the Yukon Electrical Company Limited who operate a 500 KW diesel-electric generator at Destruction Bay. An eight-mile transmission line joins Burwash Landing and Destruction Bay. The amount of power generated in this area during the 1965 - 66 fiscal year was 756,000 KWH. (31)

A mine in the Quill Creek area may be developed by 1978 requiring 5 MW of power. By this time, the domestic and commercial loads in the area could reach 2 MW. (32)

4. Haines Junction Area

Settlements in the area include Haines Junction on the Alaska Highway, 98 miles west of Whitehorse; Dalton Post, approximately 50 miles south of Haines Junction on the Haines cut-off highway; Canyon Creek, approximately 20 miles east of Haines Junction; Aishihik at the north end of Aishihik Lake, approximately 40 miles east of Haines Junction. A number of copper properties are held south of Haines Junction and exploration work has been conducted on a copper property 20 miles west of Haines Junction. Exploration work has also been carried out on an asbestos property near Haines Junction. The 1966 census reported a population of 198 persons living at Haines Junction. (33)

Haines Junction is served by the Yukon Electrical Company Limited. Power is supplied by a 400 KW diesel-electric plant and 650,000 KWH were generated in 1966. (34)

4. Haines Junction Area (cont'd)

It is unlikely that the loads for the settlements in the area would ever warrant interconnection to a central station, but some interconnection might be practical if a hydroelectric plant was built on the Aishihik River and its power transmitted to Whitehorse or other load center. It has been estimated that power requirements at Haines Junction by 1980 will be 1 MW. If one of the mining properties near Haines Junction were developed, a total capacity of 4 to 5 MW would be required in the area. (35)

5. Whitehorse Area

Whitehorse, the capital of the territory, is the largest population center in the Yukon and is the northern terminus of the Whitepass and Yukon Railway. Other settlements in the area include Takhine, approximately 17 miles northwest of Whitehorse; MacRae, approximately seven miles south of Whitehorse; Carcross, 37 miles south of Whitehorse and Bennett on the Whitepass and Yukon line in British Columbia, approximately 25 miles south of Carcross. To the east of Whitehorse are the settlements of McClintock at the north end of Marsh Lake and Tagish at the south end of the lake. At the junction of the Atlin Lake road and the Alaska Highway, approximately 47 miles southeast of Whitehorse, is Jakes Corner, and further south in British Columbia is the settlement of Atlin on Atlin Lake. The 1966 census reports a population of 4771 in Whitehorse and 175 in Carcross. New Imperial Mines Ltd. have a producing mine seven miles west of Whitehorse and active development of properties in the Carcross area is being carried out by Arctic Mining and Exploration Ltd. and Venus Silver Mines Ltd. Other mining properties in the area being explored include a copper prospect on Laberge Lake, approximately 25 miles north of Whitehorse, and copper and antimony deposits 20 to 30 miles west of Carcross. (36)

Whitehorse is served by the Yukon Electrical Company Limited, who operate two small hydroelectric plants with a capacity of 1650 KW on Porter and McIntyre Creeks near Whitehorse, and two 600 KW diesel-electric units in Whitehorse. The Northern Canada Power Commission operates an 11,400 KW hydroelectric plant on the Yukon River, just south of Whitehorse. This plant supplies power to the Department of National Defence installations and the hospital at Whitehorse and to the Yukon Electrical Company Limited. Power is transmitted via a 23 KV transmission line from the Whitehorse Yukon Electrical Company Limited system to the New Imperial Mines Ltd., seven miles west, and to Carcross. Power is also (37)

5. Whitehorse Area (cont'd)

transmitted from Carcross to the Arctic Mining and Exploration Ltd. property, approximately six miles to the south. Plans are presently under way for the Northern Canada Power Commission to add 3500 KW of diesel electric capacity to the Whitehorse system by the fall of 1968, and 8000 KW of hydroelectric capacity to the Whitehorse Rapids plant by 1969. It is understood that a further 4500 KW of diesel-electric capacity will be added to the Whitehorse system by Northern Canada Power Commission in 1969.

The population of the Whitehorse-Carcross area makes up over 50 per cent of the total population of the Yukon. On the assumption that this ratio remains constant for future population increases for the territory it has been estimated that the total demand in the Whitehorse - Carcross area will be 32 MW by 1980. This includes a 7.7 MW allowance for New Imperial, Arctic, and Venus mines. (38)

The present and planned capacities of power generation sources at Whitehorse are as follows: (39)

	1967	1969	Beyond 1969
NCPC Hydro (Whitehorse Rapids Plant)	11.4 MW	19.4 MW	27.4 MW
NCPC Diesel	--	8.0 MW	8.0 MW
YECO Hydro	1.0 MW	1.0 MW	1.0 MW
YECO Diesel	1.2 MW	1.2 MW	1.2 MW
TOTAL	13.6 MW	29.6 MW	37.6 MW
Less Anvil Load		11.0 MW	11.0 MW
		18.6 MW	26.6 MW

The Northern Canada Power Commission have contracted to deliver 10 MW of power to the Anvil Mine site by 1969. Allowing for losses, this will reduce the generating capacity available to the Whitehorse system by about 11 MW. The Yukon Electrical Company Limited report that the Whitehorse system demand in 1967 - 68 was 12.1 MW and anticipate a peak demand of 18.2 MW (40)

5. Whitehorse Area (cont'd)

(excluding Anvil) by 1969.

The loads required by other small settlements surrounding the Whitehorse area are not known and are presumedly insignificant at the present time. (41)

6. Teslin Area

Teslin is midpoint on Teslin Lake, 114 road miles east of Whitehorse. To the northwest, near the north end of Teslin Lake, are the settlements of Brooks Brook and Johnsons Crossing at the junction of the Alaska Highway and the Ross River road leading to the north. Towards the east are the settlements of Swift River and Rancheria, approximately 60 and 80 miles respectively from Teslin. A silver-lead-copper prospect is being explored near the B.C. - Yukon border south of Teslin and silver-lead-gold prospects are being explored near Rancheria. Towards the north at Wolf Lake molybdenum claims are held. (42)

Teslin is served by the Yukon Electrical Company Limited, who operate a 450 KW diesel-electric generator there. During the 1966 - 67 fiscal year, 715,000 KWH were generated for a population of 231 persons. (43)

A 25 MW mining load has been forecasted for future mines in the Wolf Lake area by 1980. The development of these mines would result in a population increase of approximately 2500 in the Teslin - Wolf Lake area and the domestic and commercial power consumption would then reach 3.5 MW. Further east at Rancheria, a producing mine could add another 5 MW of demand to the system. (44)

7. Watson Lake Area

Watson Lake in southeast Yukon is at the junction of the Alaska Highway and the Ross River/Canada Tungsten development road leading to the north. Nearby settlements are Lower Post, approximately 20 miles south in B.C., and Upper Liard. Some work has been carried out on some lead-zinc mining properties 30 to 40 miles north of Watson Lake. (45)

Watson Lake, Lower Post and Upper Liard are served by the Yukon Electrical Company Limited, who operated a 1200 KW (46)

7. <u>Watson Lake Area</u> (cont'd)

diesel-electric generator plant at Watson Lake until 1966 and added a further 500 KW of capacity in 1967. The 1966 population of Watson Lake was 511 persons. The number of customers for the Watson Lake system has increased from 45 to 189 in the 1959 - 1968 period.

A large sawmill and timber preservative treatment plant have been forecasted for the Watson Lake area, which could require up to 1600 KW of power. These developments could increase the population of the area by 800 and a total load of 5 MW has been estimated for the system by 1980. If a mine were developed in the lead-zinc showings to the north, a further 5 MW load will be required. (47)

8. <u>Francis Lake Area</u>

The Francis Lake area is approximately 80 miles north of Watson Lake and can be reached by the Ross River/Canada Tungsten development road. A number of silver-lead-zinc properties and a copper property in the area are being explored. For purposes of this study, a future power requirement of 6 MW has been assumed for producing mine and resulting settlement. Further to the northeast, the Canada Tungsten mine operates just over the border in the Northwest Territories. This mine operates a 1500 KW diesel-electric plant. The 1980 power requirements at this location have been assumed to be 3 MW. (48)

9. <u>Ross River Area</u>

Ross River, at the junction of the Pelly and Ross Rivers, can be reached by roads from Watson Lake, Johnsons Landing and Carmacks. The community of Ross River is served by the Yukon Electrical Company Limited, but the capacity of the generation facility is not known. It has been assumed that the population and electrical demand are small. A number of silver-lead properties are held within an area 50 miles to the south of Ross River and active exploration is being carried out in at least one of these. A barite property is held approximately 25 miles to the west of Ross River and there are indications that an extensive zone of low grade copper may occur approximately 50 miles to the east. (49)

9. Ross River Area (cont'd)

For purposes of this report, a future mining load of 5 MW within 50 miles to the south or east of Ross River has been assumed. (50)

10. Vangorda Creek Area

The principal mining development in this area, which lies approximately 35 miles to the northwest of Ross River is the Anvil mine, which is presently under construction. Other lead-zinc properties in the area are being explored by Kerr Addison Mines Ltd. (51)

The Anvil reserves contain 63,000,000 tons of lead-zinc-silver ore and a 5500-ton-per-day mill is being constructed. Concentrates will be trucked to Whitehorse for shipment to Skagway by rail. (52)

The stage one development of the Anvil project will require 10 to 12 MW for the mine,mill and townsite. A transmission line from Whitehorse will deliver 10 MW of power to Anvil and it is understood that the Northern Canada Power Commission will install a 3500 diesel-electric plant at Anvil by 1970 or 1971. The transmission line from Whitehorse to Anvil will be 138 KV with 636 MCM ACSR conductors and is scheduled for completion in 1969. (53)

The Anvil Mining Corporation will conduct a feasibility study for a smelter within five years of mine startup and if one is feasible, construction of the smelter would be within eight years. If a smelter were constructed, the anticipated load for the mine, mill and smelter will be in the order of 80 MW. Other mines in the area could require an additional 10 to 12 MW. By 1980, therefore, the total load in the Vangorda area could be 100 MW as follows: (54)

Anvil Mine	12 MW
Other Mines	12 MW
Smelter	68 MW
Population and Supporting Industries	20 MW
	112 MW

11. Carmacks Area

Carmacks is 110 miles by road north of Whitehorse and is near the junction of the Dawson and Ross River roads. Other settlements in the area are Montague, some 30 miles to the south, McCabe Creek and Minto, 35 miles to the north and Pelly Crossing, 66 miles to the north. (55)

Recent exploration of copper properties 30 to 40 miles northwest of Carmacks has been carried out as well as a silver-lead property some 100 miles northwest of Carmacks. Mt. Nansen Mines are constructing a 200-ton-per-day mill for a gold-silver mine approximately 30 miles west of Carmacks. This mine is providing its own power source by means of a diesel-electric generating plant. Nearby, a gold mine operated by Discovery Mines Ltd. terminated operations in 1966. Ten miles south of Carmacks is the Tantalus Butte coal mine, which produces 6000 to 8000 tons of coal per year for heating purposes, and has operated for a number of years. Estimates of coal reserves at this mine vary from 3,000,000 tons probable to 50,000,000 tons possible. (56)

The Yukon Electrical Company Limited serves Carmacks and Pelly Crossing with diesel-electric generators. The capacity of the plant at Carmacks is not known and the plant at Pelly is only 80 KW. The 1966 population at Carmacks was reported as 218 persons. The proposed 138 KV transmission line from Whitehorse to Anvil will pass through Carmacks, but it is not known if a Carmacks sub-station will be installed at present. (57)

Carmacks could be a suitable site for a coal-fired steam turbine-electric plant and groundwood pulp mill. If a thermal plant were developed at Carmacks, the coal mining operation would require 10 MW of power. The pulp mill would require 20 to 25 MW. An additional mining load of 10 MW has been forecasted for the area by 1983. Assuming a population of 5000 persons by 1983, it is estimated that the total load for the above noted developments in the Carmacks area will be 40 MW by 1980 and 52 MW by 1983. (58)

12. Mayo Area

Mayo, the principal settlement in the Mayo-Elsa-Calumet silver producing area is 254 road miles north of Whitehorse. Other settlements in the area include Stewart Crossing, 33 (59)

12. Mayo Area (cont'd)

miles to the southwest of Mayo at the junction of the Whitehorse-Dawson road and the Mayo road; Minto Bridge, approximately eight miles north of Mayo; Elsa and Calumet, approximately 26 miles northeast of Mayo and Keno Hill, approximately 33 miles northeast of Mayo.

Elsa, Calumet and Keno Hill are mining camps operated by United Keno Hill Mines Ltd. who also operate a 500-ton-per-day concentrator at Elsa. Average production at this mill was 485 tons per day in 1965 and 478 tons per day in 1966 until late in 1966 when the mill production was cut to 40 per cent of capacity due to low ore reserves and high operating costs. Further exploration work is being carried out by the company and an increase in the price of silver may permit an increase in production. Other silver properties in the area are also being explored. (60)

The average number of persons employed by United Keno Hill during 1966 was 496. The 1966 population of Mayo was 332, Elsa 395 and Calumet 377. (61)

Mayo is served by the Northern Canada Power Commission, who operate a two unit, 5.1 MW hydroelectric plant on the Mayo River, a tributary of the Stewart River. Power is sold to the mining company for its operations at Keno Hill as well as the settlements of Elsa and Calumet. Power is also sold to the Yukon Electrical Company Limited, who distribute power at Keno Hill. Total consumption by the mine, including Elsa and Calumet, in 1966 was 30.9 GWH. During the same period, the residential and commercial consumption at Mayo was 978,000 KWH, and at Keno Hill 114,000 KWH. Stewart Crossing is served by the Yukon Electrical Company Limited who operate a small diesel-electric generator there. (62)

The projected power requirement for the Mayo area is 12 MW by 1975. (63)

13. Dawson and Clinton Creek Areas

Dawson, 338 road miles northwest of Whitehorse, was a large mining boom town during the 1898 Klondike gold rush. Small placer mines in the area are still active, but the large placer dredging operation owned by Yukon Consolidated Gold Corporation closed (64)

13. <u>Dawson and Clinton Creek Areas</u> (cont'd)

down in December of 1966. Yukon Consolidated Gold Corporation operated a 15,000 HP run of the river hydroelectric plant on the north fork of the Klondike River, 26 miles from Dawson. Power fron this plant was used principally for operation of gold dredges and pumps. Some power was transmitted to Dawson for use in the company's machine shops and use by the Dawson utility. In 1966, 750 KW of diesel generating capacity was installed at Dawson by the Northern Canada Power Commission. The hydro-electric plant was de-commissioned and subsequently removed.

Other settlements in the area include McQueston, 80 miles (65)
to the southeast, Barlow; 60 miles to the southeast, Gravel Lake; 50 miles to the southeast, Granville; 40 miles to the southeast; Boundary on the Alaska border; 50 miles to the west, and Clinton Creek, 48 miles to the northwest. Clinton Creek is the site of a new asbestos mine which generates 5600 KW of power with its own diesel-electric plant. The 1960 population of Dawson was reported at 846.

Construction of a townsite for 600 to 700 persons is now (66)
under way near Forty Mile River, five miles from the Clinton Creek mine. Initial production will be 40,000 tons per annum, and is expected to increase to 80,000 tons per annum in the third year of operation. About 200 men will be employed in the operation. Reserves at the mine are estimated to be 23,854,000 tons. Four diesel units totalling 5600 KW were installed in 1967 for the initial production.

Near the Clinton Creek property lies an unknown tonnage (67)
of magnetite, which could be upgraded to a high iron content by pelletizing. This process would require about 70 MW of power. The establishment of such a development would be influenced considerably by cost of transportation and power.

Power requirements for the Dawson-Clinton Creek area for (68)
1980 have been estimated at 40.3 MW as follows:

Mine near Dawson	5.0 MW
Population and Supporting Industries	3.5 MW
Mines in Clinton Creek Area	25.0 MW
Population and Supporting Industries	6.8 MW
	40.3 MW

13. Dawson and Clinton Creek Areas (cont'd)

If an iron pelletizing operation came into production, (69)
an additional 80 MW of capacity would be required.

14. Old Crow Area

Old Crow is an Indian settlement on the Porcupine River (70)
north of the Arctic Circle. This settlement, which had a 1966 population of 217, can only be reached by air or river launch. It is served by the Yukon Electrical Company Limited, who operate a diesel-electric generator. Power rates are high at 15 cents per KWH for residential users and 25 cents per KWH for commercial users.

There is a lead-zinc deposit some 28 miles northwest of (71)
Old Crow but little activity is seen on this deposit until transportation facilities become available.

15. Snake River Area

A massive hematite deposit, estimated to contain over one (72)
billion tons of ore, is located near the Yukon-Northwest Territories border, approximately 105 miles northeast of Keno Hill, the closest road access.

If transportation and power costs made the development of (73)
a mine and pelletizing plant at this location feasible, the power requirements for this area could be in the order of 120 to 140 MW.

16. Macmillan Pass Area

A zinc deposit, estimated at 10,000,000 tons, is held in the (74)
Macmillan Pass area near the headwaters of the south Macmillan River, approximately 95 miles northwest of the Canada Tungsten mine, the closest road access. It is estimated that power requirements in this area, if the producing mine were developed, will be in the order of 15 to 20 MW.

Table 3 summarizes the 1980 and 1990 projected power require- (75)
ments for the territory.

TABLE 3: FORECAST OF FUTURE ELECTRICAL LOADS IN THE YUKON TERRITORY *

Center	Present Capacity	Projected 1980 Load	Possible Additional Capacity After 1980
Beaver Creek	310 KW	5 MW	
Burwash Landing	500 KW	7 MW	
Haines Junction	400 KW	5 MW	
Whitehorse, incl. Carcross	13.6 MW	32 MW	
Teslin, incl. Wolf Lake	450 KW	28.5 MW	
Rancheria	--	5 MW	
Watson Lake	1,700 KW	10 MW	
Francis Lake	nil	7 MW	
Canada Tungsten	1,500 KW	10 MW	
Ross River	200 assumed	5 MW	
Vangorda Cr. (Anvil)	--	112 MW	
Carmacks	400 assumed	40 MW	52 MW (1983)
Mayo	5.1 MW	15 MW	
Dawson	750 KW	8.5 MW	
Clinton Creek	5,600 KW	32 MW	112 MW (1990)
Crest	--		140 MW (1985)
Macmillan Pass	--	15 MW	
Total	30.5 MW (1968)	330 MW (1980)	562 MW (1990)

* Prepared by CBA. Engineering Ltd.

E. HYDROELECTRIC POTENTIAL

1. General Description

The Yukon Territory is that portion of the North American continent bounded by the 60th parallel on the south, the 141st meridian on the west and by the Mackenzie Mountains on the northeast. This area is sheltered from the Pacific Ocean by the St. Elias and the Coast Mountains along the Alaska Panhandle, and by the land mass of Alaska. Pacific air flowing over these barriers loses most of its moisture in precipitation on the western slopes of the mountains. The Yukon Territory is in general a semi-arid region. On the northeastern side of the territory, the Richardson and Selwyn Mountains in the Mackenzie Mountain Range impede the entry of cold Arctic air. The territory, therefore, enjoys a comparatively mild and dry climate. Since most of the winter precipitation is in the form of snow, stream flows reach a maximum in the summer months deriving most of the water from snow melt. Runoff varies between 7 inches and 16 inches. The maximum rate of flow in rivers occurs in the early summer months when the drainage area is comparatively low and in the later summer months when the runoff is derived from high mountains and glaciers. (76)

The Yukon Territory is drained by the following main rivers and their tributary systems: (77)

(a) The Yukon River in the southern part of the territory,

(b) The Porcupine and Peel Rivers in the northern part of the territory,

(c) The Alsek River in the southwest corner of the territory,

(d) The Liard River in the southeast corner of the territory.

In the far north, about a dozen small rivers drain into the Arctic Ocean.

The rivers in the Yukon Territory are subject to freezing over in winter and are generally ice covered, except in reaches where flow is swift and turbulent. Such places are productive of large quantities of frazil ice which are carried downstream in suspension and finally deposited on the underside of the ice cover in the form of hanging dams. The deposition of frazil ice (78)

1. General Description (cont'd)

on trash racks at power intakes can prove troublesome, and it is expected that this problem may be present in run of the river power developments on the rivers in the Yukon. It is, however, expected that there will be no problems caused by frazil ice in power projects incorporating storage reservoirs.

The Yukon River and its tributaries, including the Porcupine River, are used by salmon for spawning. The power potential of these rivers could be exploited only at risk to maintaining the life cycle of anadromous species of fish. The Peel and the Liard Rivers drain into the Mackenzie River, which flows into the Arctic Ocean, and do not contribute to the life cycle of the salmon. Any development on the Alsek River will be upstream of the Rainbow Falls at Aishihik and will not affect migration of fish below the falls. (79)

2. Yukon River Basin

With its source in Marsh Lake, the Yukon River drains an area of 130,000 square miles in Canada and falls 1290 feet in its course to the international boundary between the Yukon Territory and Alaska. Stream flow is typical of rivers fed from snow melt, and the yield is relatively low on account of the shielding influence of the mountain ranges flanking the drainage area. (80)

The hydroelectric power potential of the Yukon River and its tributaries has been investigated from the mid-forties to the present day, and many possibilities have been examined. (81)

Two alternative schemes of development for the main stem of the Yukon River and three major tributaries, the Teslin, Pelly and Stewart Rivers, and numerous schemes for development of hydroelectric power plants on the tributaries of the Yukon River, are currently available for consideration. (82)

The schemes for development of the main stem of the Yukon River are termed, "Major System Plan" and "Modified System Plan", in the reports of the Department of Energy, Mines and Resources, formerly the Department of Northern Affairs and National Resources. The Major System Plan provides for construction of ten dams on the main stem of the Yukon River, three on the Pelly (83)

2. Yukon River Basin (cont'd)

River, three on the Stewart River and one on the Teslin River, these rivers being tributaries of the Yukon. These dams would be used as follows: Two for storage only, four for storage and generation, and eleven for run of the river generation. The installed capacity of the Major System would be 6000 MW. It is estimated that the annual energy output would be about 37,700 GWH. The project capital cost would be in the order of $2,200,000,000 Pertinent details of the Major System Plan are shown in Table 4.

The Modified System Plan provides for diversion of an average flow of 21,000 cfs from the Yukon basin and power development on the main stem and tributaries of the Yukon River on a smaller scale than in the Major System. The development proposed for the Modified System comprises four dams on the main stem of the Yukon and three dams on each of the tributary rivers, Pelly and Stewart. Of these dams, one would be used exclusively for storage, three for storage and power generation and six would be run of the river dams for power generation only. (84)

With the Modified System the installed generating capacity on the mainstem and the tributaries of the Yukon River is 3,450 MW. It is estimated that the annual energy output would be about 20,000 GWH. The project capital cost of the Modified System Plan will be in the order of $1,400,000,000. (85)

Diversion would be from the headwaters of the Yukon River through the Coast Range mountains, either to the Taiya River near Skagway for the Yukon-Taiya generating system or to the Taku River near Tulsequah, B.C. for the Yukon-Taku generating system. Both these systems could be developed in stages. (86)

The cost of the Yukon-Taiya system in its final stage of development was estimated in 1965 to be in the order of $1,058,000,000 and will produce annual firm energy of 25,200 GWH. The Yukon-Taku system in its final stage of development is estimated to cost $1,239,000,000 and to produce annual firm energy of 21,300 GWH. (87)

The cost figures indicated in the above mentioned projects are based on 1965 estimates. (88)

Data on the Yukon Modified System Plan and the Yukon diversion plans is shown in Tables 5 and 6. (89)

2. Yukon River Basin (cont'd)

In the summer of 1967, a resources survey of the central Yukon Territory was carried out by T. Ingledow & Associates Limited. This survey covered the whole of the Yukon basin excluding potential development on the main stem of the Yukon River. Forty-three sites were surveyed superficially, the power potential at each site evaluated, and the approximate cost of the development estimated. Table 7 gives pertinent information regarding the 43 sites investigated. (90)

In the absence of detailed data in respect to the sites, certain assumptions were made in evaluating power potential and in estimating cost. While the evaluations may not be accurate, they serve as a basis of comparison of the projects covered by the survey. The assumptions were as follows: (91)

(a) The minimum size of development investigated was 5 MW.

(b) The load factor was to be 60 per cent.

(c) Each site was considered separately, receiving no benefit from any upstream potential development.

(d) The maximum drawdown was to be the lesser of 50 feet or one third height of the dam, where powerhouses were sited at the storage dam.

(e) Dams were to be concrete gravity or rock fill, depending on site conditions, standard cross-sections and volume curves being used for computation of quantities.

(f) Spillway dams were to be of concrete gravity section fitted with vertical lift steel gates.

(g) Intake gates were sized on the basis of velocity of five feet per second through openings. Tunnels were assumed circular and concrete lined and sized for velocity of six feet per second. Penstocks were sized for velocity of 12 feet per second with thickness being a function of the diameter.

(h) Powerhouses were sized and priced from empirical data, relating quantities per installed horsepower to head on plant. This data is based on approximately 100 actual plants.

2. Yukon River Basin (cont'd)

(i) In view of the preliminary nature of the investigations and designs, a contingency item of 25 per cent of the direct cost was included in order to arrive at the total direct cost.

(j) Indirect costs were assessed at six per cent for engineering and administration and 12 per cent for interest during construction.

(k) Annual charges were assessed at eight per cent of total costs, and allowed for an interest rate of six per cent.

3. Porcupine and Peel River Basins

Proposals for development of the hydro power potential of the Porcupine River and the Peel River are interdependent. These two drainage basins will therefore be considered together. The Porcupine River has its origin in the Ogilvie Mountains, draining an area of 23,500 square miles in Canada into the Yukon River in Alaska. There is an available head drop of about 300 feet in the river's 370-mile northwestern course. Since there is an available head drop of almost 1,000 feet in the Rat River on the eastern side of the Richardson Mountains Divide, a much greater power potential exists in a plan for diverting the available water into the Rat River than in utilizing this water on the main stem of the Porcupine River. (92)

The Peel River drains the northern slopes of the Ogilvie, Wernecke and Selwyn Mountains, an area of 28,600 square miles. The Peel River proper flows eastwards for 120 miles to its confluence with the Snake River, and then continues in a northerly course for about 150 miles to Fort McPherson in the Northwest Territory. The main stem of the Peel River has a total drop of about 1,250 feet. (93)

There are two possibilities for development of the power potential in these two rivers. The one is for a conventional plan of development by building storage dams across the rivers and generating power at the damsites. The other is a plan for damming the Porcupine and Peel Rivers at the Porcupine Canyon site and Bell River site on the Porcupine River, and at the Aberdeen Falls site on the Peel River, and diverting the water into the Rat River over the McDougal Pass for power generation at Fish Creek and Rat Canyon sites. (94)

3. <u>Porcupine and Peel River Basins</u> (cont'd)

The latter development could be phased over five stages, and it was estimated in 1965 by the Department of Energy, Mines and Resources to be capable of ultimately producing 10,000 GWH of annual firm power at a capital cost of about $1,000,000,000. The former development plan, viz. the conventional development plan, is estimated to be capable of generating 1,500 GWH of annual firm energy at a capital cost of about $180,000,000 on the Porcupine River, and 2,700 GWH of annual firm energy at a capital cost of about $290,000,000 on the Peel River. (95)

4. <u>Liard River Basin</u>

The Liard River, originating on the eastern slopes of the Pelly Mountains, follows a southeasterly course to about the 60th parallel. On entering British Columbia near the 129th meridian, the river follows an easterly course to the 124th meridian, and then flows northwards into the Northwest Territories, and finally northeast until it meets the Mackenzie River near Fort Simpson. The drainage area of the Liard River and its principal tributaries, the Francis, Hyland, Smith and Coal Rivers in Yukon Territory, is about 16,000 square miles. (96)

The power potential of the Liard River and its major tributaries has been assessed, largely from superficial inspection of potential power sites, by Associated Electrical Industries (Canada) Ltd. for the Werner-Gren British Columbia Development Company. The power potential has been assessed on the basis of (i) an integrated development of the whole watershed, in which maximum utilization of the hydraulic resources of the catchment is assumed, and (ii) optimum development as isolated individual projects. The power potential of the integrated development is estimated at 7.4 million horsepower from the main stem of the Liard River, and the tributaries in Yukon Territory, viz. the Hyland, Francis, Coal and Smith Rivers. The power potential of the optimum piecemeal development is estimated at 4.5 million horsepower from the sites on the main stem of the Liard River, and from the tributaries in the Yukon Territory. Most of the possible damsites on the Liard River and its Yukon tributaries lie in close proximity to the 60th parallel and the Alaska Highway. The most favourable sites on the main stem of the Liard River are about 250 miles north from the Portage Mountain Dam on the Peace River and about 350 miles east from Whitehorse. A possible damsite on the Liard River, about 100 river miles upstream of Fort Liard, is under (97)

4. Liard River Basin (cont'd)

investigation at present. Figures of costs given in the Associated Electrical Industries report are not detailed enough to ascertain exactly what they represent and are therefore not quoted here.

5. Pacific-Arctic Coast Drainage Areas

The southwest corner of the territory drains to the Pacific Ocean via the Alsek River. A small potential damsite is located on the Aishihik River, a tributary of the Alsek River, and is included in Table 7. (98)

The few rivers flowing northwards into the Arctic Ocean drain comparatively small drainage areas. During winter, the rivers are frozen and stream flows are very small. Power developments on these rivers would require storage in order to firm up the winter flows. (99)

6. Hydroelectric Plant Costs

The estimated costs of the hydroelectric projects covered in the Ingledow report (see Table 7) appear to be suitable for evaluating the relative merits of the different sites examined under their investigation, but should not necessarily be used for direct comparison with cost estimates for thermal power development. Further detailed investigations on some of the more attractive sites may result in modifications to the estimate. (100)

A review of hydroelectric plant costs since 1900 is shown on Charts 1 to 5. These costs have been averaged out and a projection to 1970 is shown. On the assumption that hydroelectric plant costs will be 20 per cent higher in the Yukon than in the United States and comparable sites to those already developed can be found, costs of hydroelectric power in the Yukon could be in the following order: (101)

	Cost per Installed KW at Interest Rate			
	5%	6%	7%	8%
Installations 0 - 50 MW	$660.00	$672.00	$684.00	$696.00
Installations 51 MW - 100 MW	$594.00	$605.00	$616.00	$627.00
	Cost of Energy at 60% Load Factor-Mills/KWH			
Installations 0 - 50 MW	8.9	10.1	11.3	12.6
Installations 51 MW - 100 MW	8.0	9.1	10.2	11.4

TABLE 4 *

YUKON RIVER DEVELOPMENT

MAJOR SYSTEM PLAN

Project	Dam Height Feet	Installed Capacity Megawatts	Usable Storage Thousands Acre Ft.
Yukon River Main Stem			
Miles Canyon	120	--	6,596
Whitehorse Rapids	65	54	
Hootalingua	190	259	
Big Salmon	200	301	
Five Finger Rapids	250	455	
Wolverine	250	476	
Britannia	200	459	
Ogilvie	250	896	4,645
Dawson	140	571	
Boundary	240	1,006	
Teslin River			
Swift River	180	158	4,120
Pelly River			
Detour	210	--	1,001
Granite Canyon	325	254	3,692
Bradens Canyon	220	180	
Stewart River			
Fraser Falls	290	347	4,481
Independence	350	431	
Porcupine	180	223	
Total		6,070	24,535

Annual Firm Energy Potential at Site	37,700 G.W.H.
Project Capital Cost	$2.2 Billion
Unit Cost of Energy at Site	3.7 Mils per kwh
Unit Cost of Energy at Load *	5.6 Mils per kwh

* assumes that 90% of the energy will be delivered to Tulsequah, B.C. and 10% used in the Whitehorse area

* Position Paper, Power Development on the Yukon River Department of Northern Affairs and Natural Resources, **Water Rights Branch**

TABLE 5 *

YUKON RIVER DEVELOPMENT

MODIFIED SYSTEM PLAN

Project	Dam Height Feet	Installed Capacity Megawatts	Usable Storage Thousands Acre Ft.
Yukon River Main Stem			
Britannia	220	240	
Ogilvie	250	560	4,645
Dawson	140	437	
Boundary	240	783	
Pelly River			
Detour	210	--	1,001
Granite Canyon	325	254	5,762
Bradens Canyon	220	180	
Stewart River			
Fraser Falls	290	347	4,843
Independence	350	430	
Porcupine	180	223	
Total		3,454	16,251

Annual Firm Energy Potential at Site	20,000 G.W.H.
Project Capital Cost	$1.4 Billion
Unit Cost of Energy at Site	4.3 Mils per KWH
Unit Cost of Energy at Load *	6.3 Mils per KWH

* Assumes that 90% of the energy will be delivered to Tulsequah, B.C. and 10% will be used in the Whitehorse area.

* Position Paper, Power Development on the Yukon River Department of Northern Affairs and Natural Resources, Water Rights Branch.

TABLE 6 *

YUKON RIVER DEVELOPMENT

CUMULATIVE DATA FOR YUKON-TAIYA DIVERSION

Completed Stage of Development	Diversion flow c.f.s.	Capital Cost $ Millions	Annual Firm Energy at Site G.W.H.	Unit Cost of Energy Mils per KWH At Site	At Load
1	6,200	316	8,000	2.4	2.9
2	11,200	690	14,100	3.0	3.4
3	21,000	1058	25,200	2.6	3.0

Assumes 90% of energy delivered to industrial centre at Haines, Alaska, and 10% used in the Whitehorse area.

CUMULATIVE DATA FOR YUKON-TAKU DIVERSION

Completed Stage of Development	Diversion Flow c.f.s.	Capital Cost $ Millions	Annual Firm Energy at Site G.W.H.	Unit Cost of Energy Mils per KWH At Site	At Load
1	6,600	268	4,400	3.7	4.6
2	6,600	405	7,200	3.4	4.2
3	11,600	736	10,100	4.4	5.0
4	11,600	839	12,300	4.1	4.7
5	21,400	1125	17,300	4.0	4.5
6	21,400	1239	21,300	3.5	4.1

Note: Additional development at Sinwa site would produce a total annual firm energy of 23,500 G.W.H.

Assumes 90% of energy delivered to Tulsequah, B.C. and 10% used in the Whitehorse area.

* Position Paper Power Development on the Yukon River Department of Northern Affairs and Natural Resources Water Rights Branch

YUKON POWER SURVEY

TABLE 7*

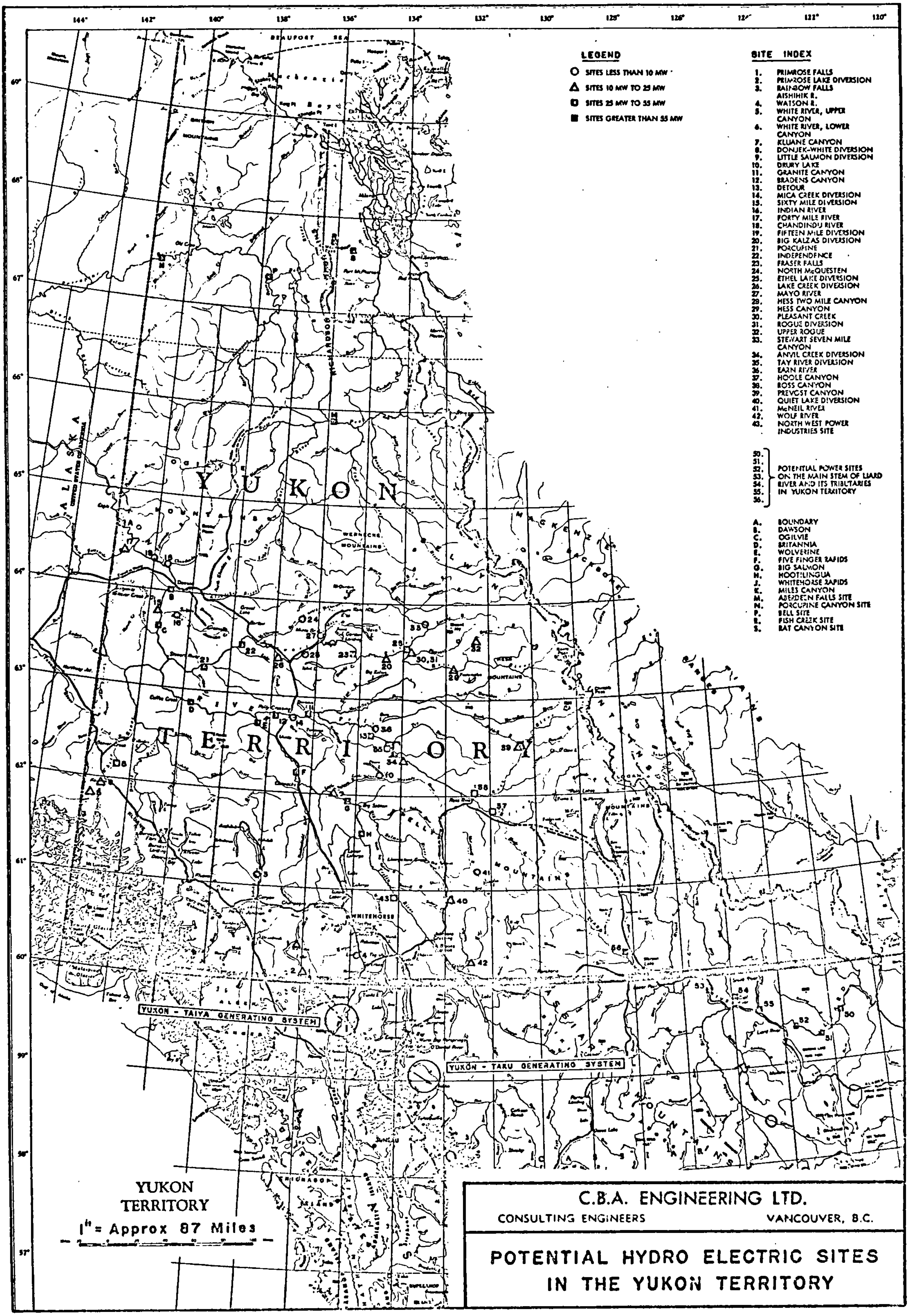
INVENTORY OF POTENTIAL SITES

Site Number	River	Location or Description	Installed Capacity (megawatts)	Annual Firm Energy GWH	Capital Cost x $ million	Annual Cost x $ million	Cost of Capacity $ per kw	Cost of Energy mills per kwh
1 & 2	Primrose							
	Alternate I							
	Stage 1	Rose Lake dam, tunnel to powerhouse on Kusawa Lake	17.2	93	27.4	2.19	1590	23.6
	Stage 2	Add storage dam at Primrose Lake	+ 8.6 = 25.8	+ 53 = 145	+ 5.7 = 33.1	+ .46 = 2.65	+ 8.6 at 663 = 1280	+ 53 at 8.7 = 18.3
	Stage 3	Add pipeline from Primrose dam to powerhouse on Rose Lake	+ 8.6 = 34.4	+ 35 = 180	+ 6.8 = 39.9	+ .54 = 3.19	+ 8.6 at 790 = 1160	+ 35 at 15.4 = 17.7
	Alternate II							
	Stage 1	Primrose Lake dam with tunnel to Takhini Lake	19.0	100	16.2	1.30	854	13.0
	Stage 2	Rose Lake dam with tunnel to Kusawa Lake	+ 13.8 = 32.8	+ 73 = 173	+ 20.0 = 36.2	+ 1.60 = 2.90	+ 13.8 at 1450 = 1100	+ 13.8 at 21.9 = 16.8
3	Aishihik	Rainbow Falls	7.0	36.6	4.47	0.36	643	9.8
		Note: Up to 9.7 MW could be installed at approximately the same cost per kilowatt hour						
4	Watson	near Annie Lake	2.7	14.2	≈ 12	≈ 0.96	≈ 4450	>50
5	White	Upper Canyon	16.0	84.1	25.0	2.00	1560	23.8
6	White	Lower Canyon	16.0	84.1	42.2	3.38	2640	40.3
		Note: Installed capacity and costs are independent of Upper Canyon scheme						
7	Kluane	Kluane Canyon	11.8	62.2	10.4	0.83	880	13.4
8	Donjek	Diversion to White	43.0	226	157.6	12.6	3660	55.8
9	Little Salmon	Diversion to Yukon	12.0	63	23.5	1.88	1952	29.8
10	Drury Lake	Little Salmon Lake	4.3	22.8	5.22	0.42	1210	18.3
11	Pelly	Granite Canyon	333	1750	200.6	16.1	602	9.2
12	Pelly	Bradens Canyon	112	588	94.5	7.56	843	12.9
13	Pelly	Detour (load factor 60 percent)						
		a) Detour alone	83	435	80.2	6.42	965	14.8
		b) Detour with regulation at Pelly Lakes	111	585	89.6	7.16	808	12.2
		c) Detour with regulation at Hoole Canyon and Pelly Lakes	119	625	84.0	6.72	706	10.8
14	Mica Creek	near Pelly Crossing	9.8	52	15.7	1.25	1600	24.1
15	Sixty Mile	near 50 Mile Creek	17.5	92	32	2.56	1830	27.8
16	Indian	Ophir Creek	6.3	33	16.4	1.32	2610	39.9
17	Forty Mile	near Bruin Creek	15.7	82	18.4	1.47	1170	18.0
18	Chandindu	near mouth	5.8	31	27.0 Dam only	2.16	-	>70
19	Fifteen Mile	near mouth	6.7	35	15.8	1.27	2360	36.2
20	Big Kalzas Lake	Diversion to Stewart	17.0	89	26.5	2.12	1560	23.8
21	Stewart	Porcupine	83	- - - - - - - - - - - - - Not economic without upstream regulation - - - - - - - - - - - - -				
22	Stewart	Independence	288	- - - - - - - - - - - - - Not assessed because of size and location - - - - - - - - - - - - -				
23	Stewart	Fraser Falls	233	1220	162.8	13.0	699	10.7
24	N. McQuesten	Diversion to McQuesten	5.0	26	19.2	1.53	3740	59.0
25	Ethel Lake	Diversion to Stewart	8.5	45	7.68	0.61	903	13.6
26	Lake Creek	Diversion to Stewart	13.0	68.0	19.2	1.54	1475	22.6
27	Mayo	"B" Site, downstream of existing plant	8.8	46.0	7.56	0.60	860	13.1
28	Hess	Two Mile Canyon	53.1	280	48.0	3.84	905	13.7
29	Hess	Hess Canyon	17.8	93.6	28.6	2.29	1610	24.5
30	Pleasant Creek	near mouth	5.3	28.0	16.1	1.29	3040	46
31	Rogue	Diversion to Pleasant Creek						
		a) Without storage on Rogue	5.3 + 1.7 = 7.0	28.0 + 8.8 = 36.8	--	--	--	--
		b) With Rogue storage	5.3 + 11.4 = 16.7	28.0 + 59.6 = 87.6	16.1 + 29.4 = 45.5	1.29 + 2.35 = 3.64	+ 11.4 at 2580 = 2720	+ 59.6 at 39.4 = 41.3
32	Rogue	Includes storage and diversion dam	11.8	62.2	34.4	2.76	2900	44.3
33	Stewart	7 Mile Canyon	9.8	51.0	15.7	1.26	1600	24.6
34	Anvil Creek	Diversion to Pelly	10.0	52.5	13.1	1.05	1310	20.0
35	Tay	Diversion to Pelly	31.0	163	43.3	3.47	1400	21.3
36	Earn	Diversion to Pelly	6.6	34.6	14.0	1.12	2130	32.5
37	Pelly	Hoole Canyon						
		Stage 1 - no upstream storage	12.7	66.7	16.0	1.28	1260	19.2
		Stage 2 - add Pelly Lake storage plus one extra unit	+ 12.7 = 25.4	+ 66.7 = 133.4	+ 10.4 = 26.4	+ 0.83 = 2.11	+ 12.7 at 820 = 1040	+ 66.7 at 12.4 = 15.8
		Stage 3 - third unit	+ 12.7 = 38.1	+ 66.7 = 200	+ 3.60 = 30.0	+ 0.29 = 2.40	+ 12.7 at 286 = 788	+ 66.7 at 4.4 = 12.0
38	Ross	Ross Canyon	33.6	177	50.3	4.03	1500	22.8
39	Ross	Prevost Canyon	11.7	61.5	14.6	1.17	1245	18.9
40	Quiet Lake	Diversion to Nisutlin						
		a) Lake only	7.0	37	14.8	1.18	2110	32
		b) Including Rose River diversion	15.0	79	28.3	2.27	1890	28.8
41	McNeil Lake	East Peak	9.5	50	12.5	1.00	1315	20.0
42	Wolf	Diversion to Nisutlin	13.0	68	25.3	2.02	1940	29.7
43	Teslin	NWPI Site	36.3	190	28.7	2.30	790	12.1

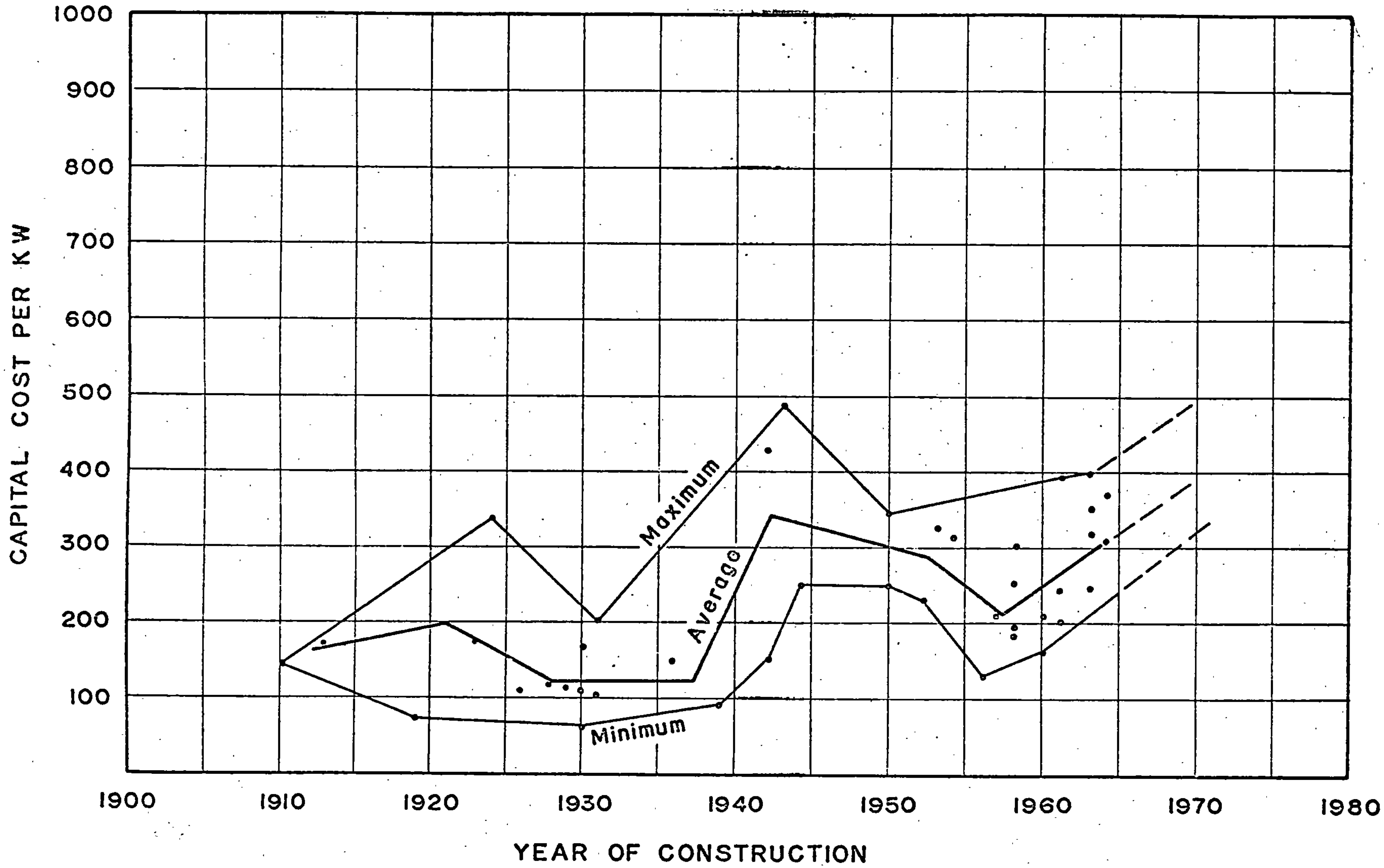
NOTE:

1. Installed capacity is calculated assuming a 60 percent load factor
2. Firm energy is calculated from power available 100 percent of the time
3. Annual cost is 8 percent of capital cost
4. Costs do not include cost of transmission

* T. Ingledow & Associates Limited - Hydroelectric Resources Survey of the Central Yukon Territory.

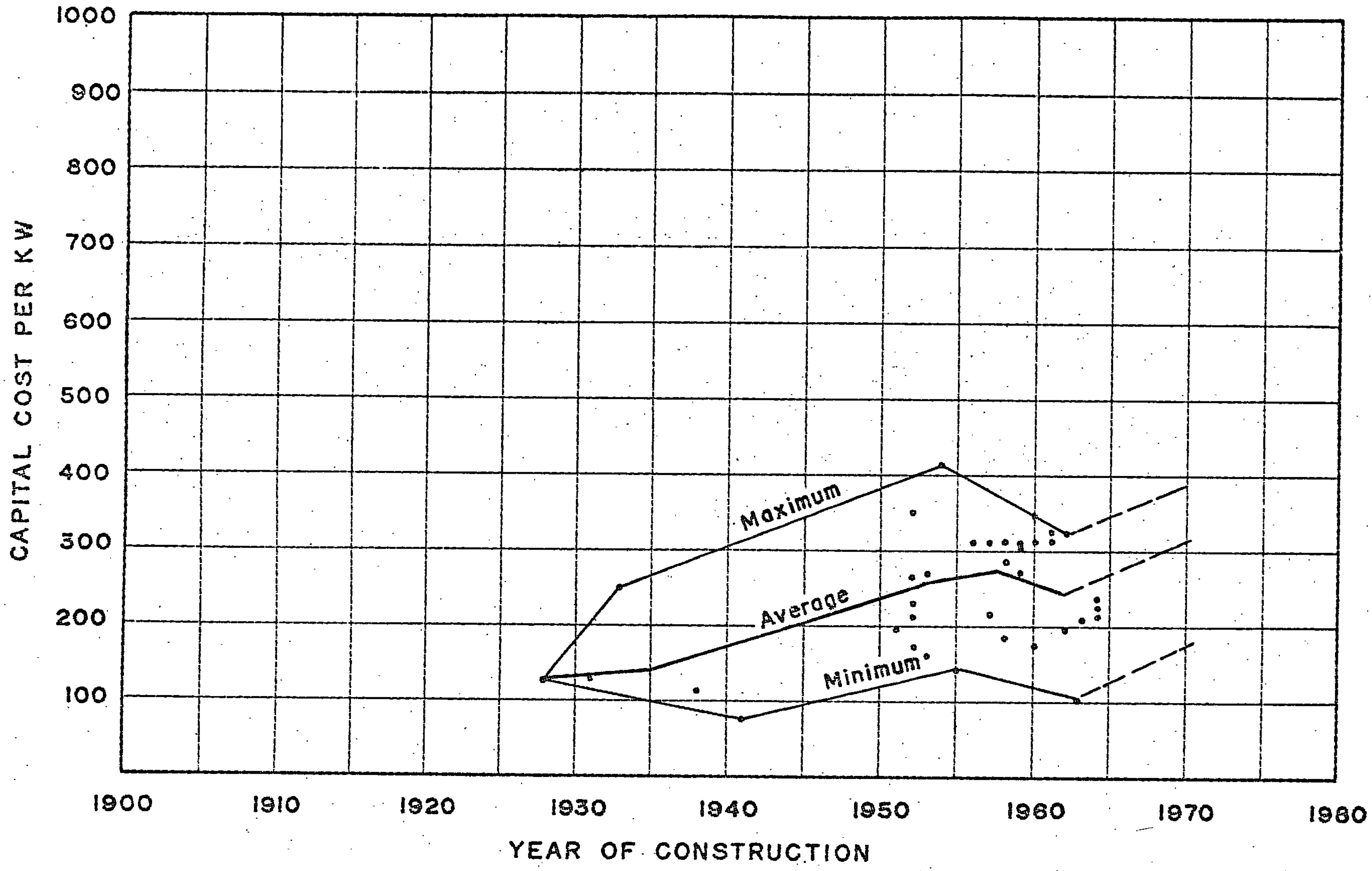


LEGEND
SITES LESS THAN 10 MW
SITES 10 MW TO 25 MW
SITES 25 MW TO 55 MW
SITES GREATER THAN 55 MW
SITE INDEX
1. PRIMROSE FALLS
2. PRIMROSE LAKE DIVERSION
3. RAINBOW FALLS AISHIHIK R.
4. WATSON R.
5. WHITE RIVER, UPPER CANYON
6. WHITE RIVER, LOWER CANYON
7. KLUANE CANYON
8. DONJEK-WHITE DIVERSION
9. LITTLE SALMON DIVERSION
10. DRURY LAKE
11. GRANITE CANYON
12. BRADENS CANYON
13. DETOUR
14. MICA CREEK DIVERSION
15. SIXTY MILE DIVERSION
16. INDIAN RIVER
17. FORTY MILE RIVER
18. CHANDINDU RIVER
19. FIFTEEN MILE DIVERSION
20. BIG KALZAS DIVERSION
21. PORCUPINE
22. INDEPENDENCE
23. FRASER FALLS
24. NORTH McQUESTEN
25. ETHEL LAKE DIVERSION
26. LAKE CREEK DIVERSION
27. MAYO RIVER
28. HESS TWO MILE CANYON
29. HESS CANYON
30. PLEASANT CREEK
31. ROGUE DIVERSION
32. UPPER ROGUE
33. STEWART SEVEN MILE CANYON
34. ANVIL CREEK DIVERSION
35. TAY RIVER DIVERSION
36. EARN RIVER
37. HOOLE CANYON
38. ROSS CANYON
39. PREVOST CANYON
40. QUIET LAKE DIVERSION
41. McNEIL RIVER
42. WOLF RIVER
43. NORTH WEST POWER INDUSTRIES SITE
50.–56. POTENTIAL POWER SITES ON THE MAIN STEM OF LIARD RIVER AND ITS TRIBUTARIES IN YUKON TERRITORY
A. BOUNDARY
B. DAWSON
C. OGILVIE
D. BRITANNIA
E. WOLVERINE
F. FIVE FINGER RAPIDS
G. BIG SALMON
H. HOOTALINQUA
J. WHITEHORSE RAPIDS
K. MILES CANYON
M. ABERDEEN FALLS SITE
N. PORCUPINE CANYON SITE
P. BELL SITE
R. FISH CREEK SITE
S. RAT CANYON SITE
YUKON TERRITORY
ALASKA
BEAUFORT SEA
WERNECKE MOUNTAINS
WHITEHORSE
YUKON - TAIYA GENERATING SYSTEM
YUKON - TAKU GENERATING SYSTEM
YUKON TERRITORY
1" = Approx 87 Miles
C.B.A. ENGINEERING LTD.
CONSULTING ENGINEERS
VANCOUVER, B.C.
POTENTIAL HYDRO ELECTRIC SITES IN THE YUKON TERRITORY



HYDRO ELECTRIC PLANT CONSTRUCTION COSTS
IN THE UNITED STATES
101 - 200 MW GENERATING CAPACITY

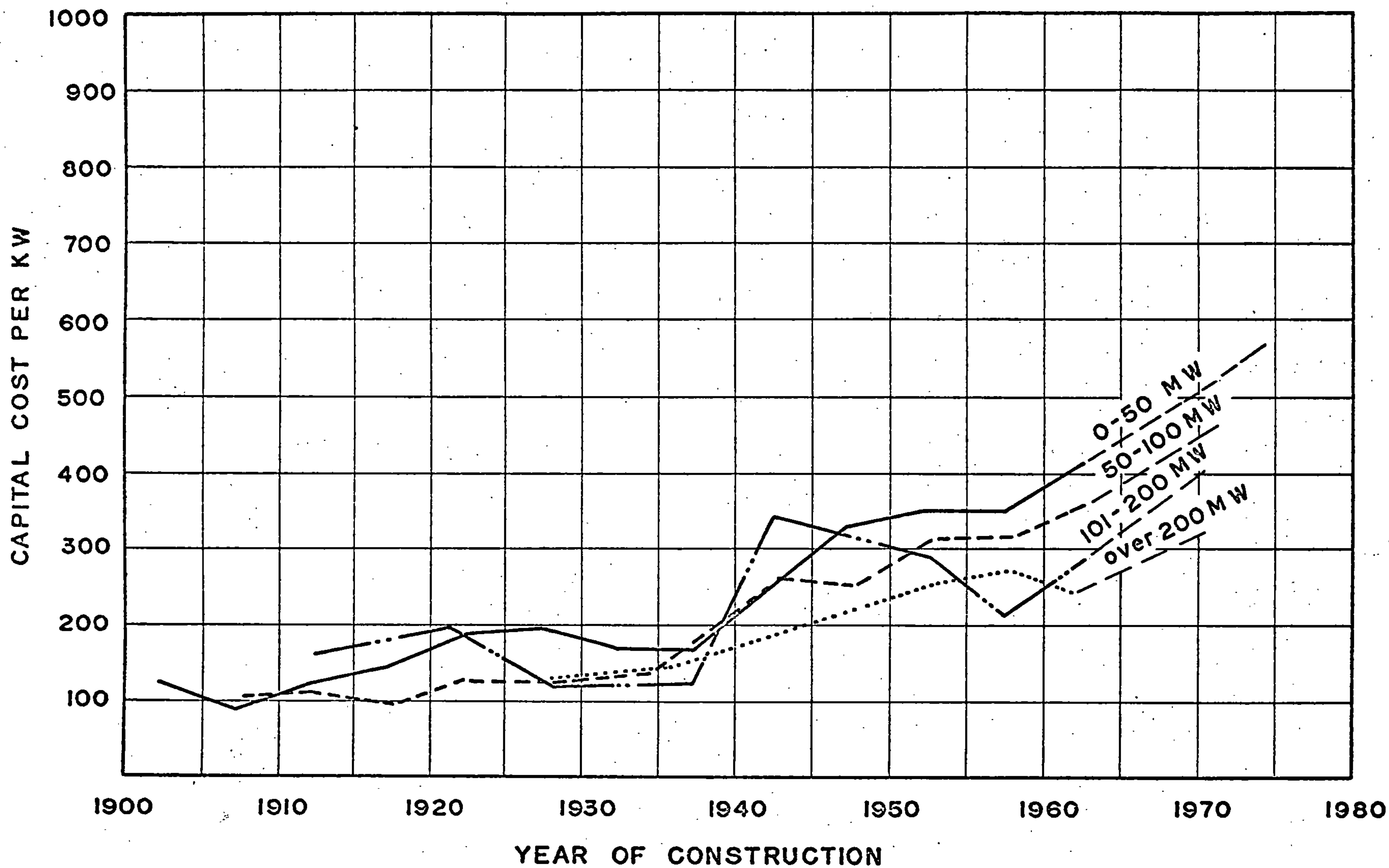
CHART 3



35

HYDRO ELECTRIC PLANT CONSTRUCTION COSTS
IN THE UNITED STATES
OVER 200 MW GENERATING CAPACITY

CHART 4



HYDRO ELECTRIC PLANT CONSTRUCTION COSTS
IN THE UNITED STATES

CHART 5

F. THERMAL POWER GENERATION

1. General

The cost of providing diesel power at the mine site is usually a small part of the total cost of the project. The cost of power produced by diesel-electric generators at the mine will approximate 25 mils with diesel fuel at 25 cents per gallon. This will compare favorably with most sources of power which can be purchased in the Yukon. It is to be expected that as a power distribution grid is developed in the Yukon and reliable power becomes available at competitive rates mining companies will draw their power from the grid and will discontinue generation with their own plants. (102)

2. Short Term Demand

If the annual rate of growth of load in the Yukon continues or rises it appears that a deficiency of generating capacity will occur in 1969 or shortly thereafter. The only power generating equipment which can be brought into production within a short period after decision to proceed is either diesel or gas turbine. A minimum time of three to four years should be allowed to construct a coal fired steam turbine plant. Depending on the size and complexity, a hydroelectric generating station will require five to seven years to complete. (103)

3. Cost of Thermal Power

Preliminary cost estimates indicate that it may be feasible to supply power to the Whitehorse-Anvil power line by means of a coal fired steam turbine generator located at Carmacks. It appears from a review of reports currently available that none of the potential hydroelectric power sites in the Yukon could be developed to produce power in the quantities required in the near future at a lower cost than power which could be developed by a coal fired steam turbine plant located at Carmacks. (104)

4. Coal Reserves and Cooling Water

In order that a coal fired thermal plant be considered an adequate reserve of suitable coal in the Carmacks area must be proven, and estimates made of the cost of this coal at the plant. To support the installation of a 25 MW coal-fired thermal station at Carmacks with additional capacity being installed over the years to develop 100 MW or more will require reserves of some 10 million tons of coal. (105)

4. Coal Reserves and Cooling Water (cont'd)

The minimum flow of the Yukon River at Carmacks i.e. 4800 cfs. March 1952, is adequate to provide cooling water for a thermal plant exceeding 100 MW. A 25 MW coal fired steam turbine station located at Carmacks would require a staff of 20 men. In addition the labour to mine and deliver 700 to 1000 tons of coal per week would be required. (106)

5. Gas Turbines

Gas turbine plants in complete packaged units and having an output of approximately 15000 KW have now been developed by several manufacturers in which all the components and equipment necessary for the operation of the generating set are provided. The generating station consists of three major components: the gas turbine unit, the generator unit and the control unit. The units are housed in weatherproof enclosures complete with heating, lighting and ventilation. The fuel storage tanks equipment foundations and transformers are not provided by the manufacturers. Each component is assembled into a package which can be transported by rail. (107)

Gas turbines can be supplied in sizes ranging from 7.5 MW to 15 MW and are suitable for base load or peaking service. If operated on base load the units are de-rated so that the period between overhauls becomes more than 20,000 hours. (108)

Two manufacturers have stated that their 14,000 KW (peak rating) gas turbine unit can be supplied for less than $1,000,000 and delivered in approximately 12 months. (109)

The gas turbine has a reasonable degree of portability which could be of value in the Yukon where load growth may not occur at a uniform rate. Waste heat boilers to recover the heat in the exhaust gases can be added to a gas turbine installation. If a demand for low pressure steam, such as for district heating exists, a very substantial reduction in the cost of fuel can be made. (110)

The gas turbine is suitable for remote, automatic operation. Consideration should be given to a gas turbine unit for use as stand-by capacity for diesel plants or to firm the capacity of existing or future hydroelectric stations. (111)

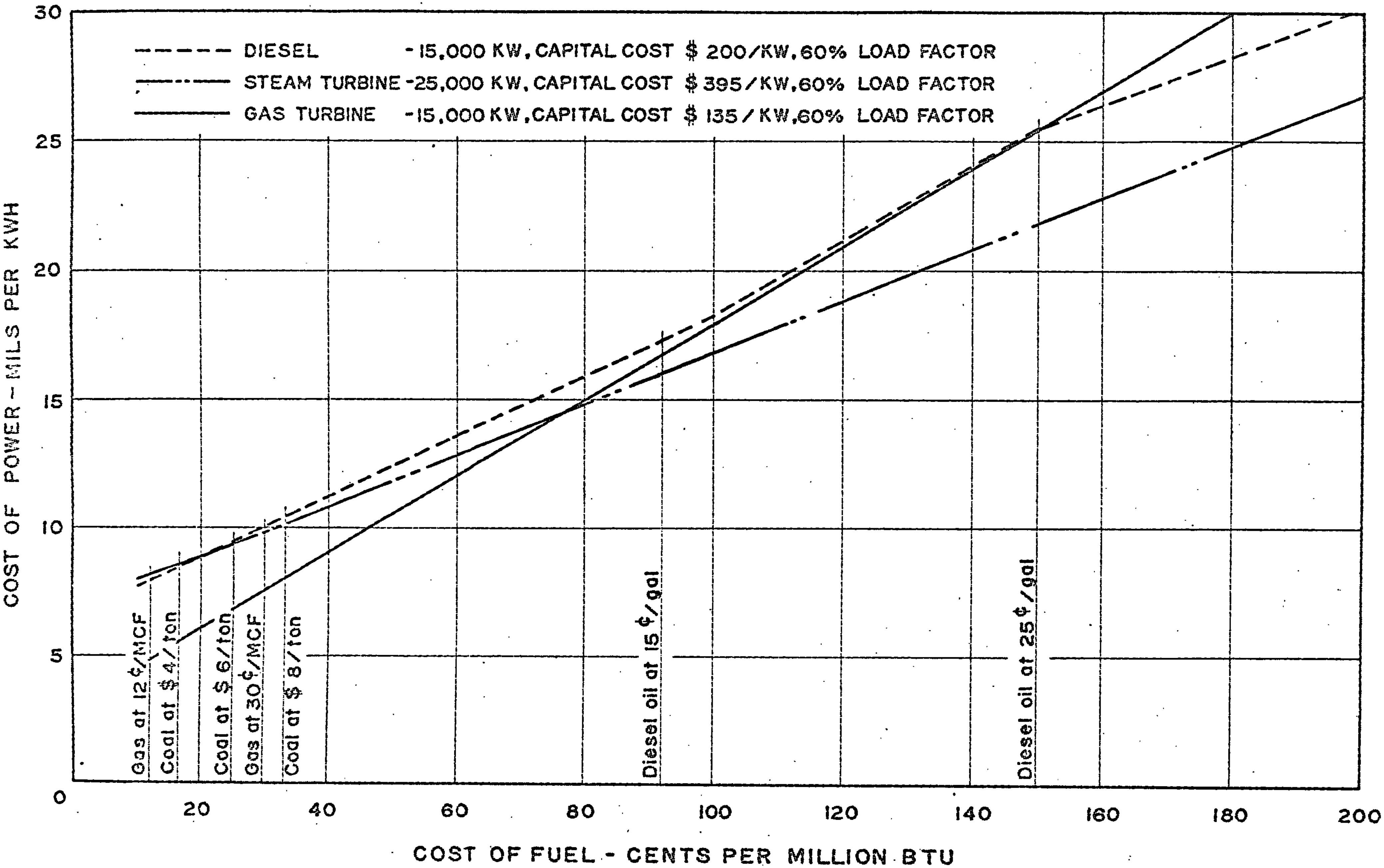
6. <u>Diesel Engines</u>

Diesel electric generating units will continue to provide power for small loads in the Yukon since they are a comparatively low cost, rugged, dependable source of power. When the savings in fuel costs which can be made by waste heat recovery for heating or process steam are taken into consideration a diesel-electric generator can furnish power at a very competitive rate. In general it is not economically sound to transmit power from diesel-electric generators except for short distances. In some cases it may be desirable to connect existing diesel-electric stations to a transmission line to firm other generating stations. (112)

7. <u>Nuclear Power</u>

The development of nuclear generating stations has now progressed to the point that on site power can be produced for 5 to 6 mils per KWH by stations having 500 MW output. The cost of power generated by fossil fuel fired plants is greatly influenced by the distance of the station from the fuel source and the cost of transporting fuel whereas transportation is a minor factor in the cost of nuclear fuel. Provided that sufficiently large loads develop the negligible transportation costs of nuclear fuel can greatly reduce any inter-area differential in power generation costs, thus making possible increased economic development in areas where power costs are relatively high. Of considerable interest is the very competitive position of power generated on site by a nuclear plant to hydroelectric power transmitted over long distances. (113)

Chart 6 indicates the estimated cost of power for various types of thermal plants. (114)



THERMAL ELECTRIC POWER COSTS

CHART 6

G. TRANSMISSION OF POWER

A transmission grid should be planned for the Yukon before any sizeable power sources are developed. The scope and time available for this report does not allow such planning to be undertaken. The data shown in Tables 9, 10 and 11 has been compiled to be used as a guide for estimating delivered power costs. (115)

Much of the cost of a transmission line is the preparation and clearing of the right-of-way. It is estimated that 40 to 60 per cent of the total cost of a transmission line is in field labour costs. (116)

If oil or gas-fired thermal electric plants are proposed, consideration should be given to locating the plant at the load center and piping the fuel to it, rather than locating the plant at the fuel source and transmitting electric power to the load center. For larger pipelines, gas and oil can be transmitted at a competitive price to electric transmission. A pipeline could also provide substantial benefits to other fuel consumers, such as heating, commercial and industrial. (117)

Mention should also be made of recent advances in long distance transmission. High voltage lines using 735 KV AC and 500 KV DC have been, or are being constructed. These lines are capable of transmitting in excess of 1000 MW and, with a high load factor, may prove to be feasible in developing large blocks of power in northern British Columbia or the Yukon for transmission to the more heavily populated areas to the south. (118)

TABLE 9 *

SELECTION OF MOST SUITABLE TRANSMISSION VOLTAGES (in KiloVolts)

POWER LOAD TO BE TRANSMITTED IN MW	Distance in Miles: 10	20	40	80	160	320
5	25	33	66	66	66	NF
10	33	66	66	132	132	NF
20	66	66	66	132	132	NF
40	66	66	132	230	230	NF
80	132	132	132	230	230	345
160	230	230	230	230	345	345
320	230	230	230	345	345	345

NOTE:
"NF" indicates not normally feasible.

* Private communication M.A. Thomas & Associates Ltd.

TABLE 10 *

VOLTAGE LEVELS IN KV

CAPACITY OF STATIONS MW	33	66	132	230	345
0					
5	50	60	95	NA	NA
10	80	90	125	NA	NA
20	NA	110	145	175	NA
40	NA	NA	190	220	NA
80	NA	NA	290	310	360
160	NA	NA	NA	460	500
320	NA	NA	NA	NA	800

TYPICAL TERMINAL SWITCHING AND TRANSFORMATION STATION COSTS - THOUSANDS OF DOLLARS

* Private communication M.A. Thomas & Associates Ltd.

TABLE 11 *

MW CAPACITY		Voltage in KV				
		33	66	132	230	345
5 MW	LC	11	14	NA	NA	NA
	MC	13	16			
	HC	15	20			
10 MW	LC	12	14	22	NA	NA
	MC	14	17	26		
	HC	18	22	30		
20 MW	LC	14	16	24	NA	NA
	MC	16	20	30		
	HC	22	24	36		
40 MW	LC	NA	18	25	35	NA
	MC		26	33	45	
	HC		32	42	55	
80 MW	LC	NA	NA	30	35	45
	MC			40	45	55
	HC			45	55	65
160 MW	LC	NA	NA	NA	45	50
	MC				55	65
	HC				65	80
320 MW	LC	NA	NA	NA	NA	100
	MC					120
	HC					140

TABLE OF TYPICAL TRANSMISSION LINE COSTS/MILE IN THOUSANDS OF DOLLARS

NOTES:

1. "NA" - means not applicable.

2. Labor content of power line construction generally varies from 60% for low voltage light conductor lines with relatively heavy timber clearing costs for the required right of way to 40% for prefabricated towers, high voltage insulation and heavy conductored lines with relatively light timber clearing from the right of way.

3. In the above tabulation, "LC" refers to light construction conditions, ie. easy access, light clearing, and minimum sized conductors; "MC" refers to medium construction conditions, ie. good access, medium clearing, and mid size conductors for the voltage involved, "HC" refers to heavy construction for difficult access areas heavy clearing and large size conductors.

* Private communication M.A. Thomas & Associates Ltd.

H. CONCLUSIONS

It would be well to preface this section of the report with a few general remarks to delineate the background on which they are based. A great deal of investigation has been done on power sources in the Yukon by various agencies in the past. Because of the vast area of the country and the abundance of hydro-electric development possibilities, these investigations have necessarily, and quite properly, been in most instances of preliminary nature and generally limited to a superficial examination without any extensive subsurface investigation or detailed site selection work being done. Costs are therefore based on many imponderables and are bound to be approximate. The general economic development of the Yukon has so far been largely on an ad hoc basis and the pattern of power development has naturally followed this line to a very considerable extent. Thermal power generation has been limited to internal combustion engines which serve relatively small loads at isolated points. The growth of power demands is now increasing to a point where consolidation of some of these isolated demands warrants a much more extensive study of the transmission of power from larger production centres. (119)

The following conclusions are offered as being what can logically be deduced from all the data studies: (120)

1. Power from gas and oil cannot now be produced on an economical basis except in small amounts at isolated points. The possibility of large supplies of either product being developed in the future must be kept in mind and when such sources are a proven actuality they must of course be fitted into their proper place.

2. The state of development of nuclear power at this moment makes it possible to produce extremely large quantities of power economically but the load demands in the Yukon are not yet sufficient to warrant consideration of such installations. The most economical use of nuclear stations requires that they be coupled with large hydroelectric sources for peaking purposes and such a system pre-supposes a fully integrated transmission and distribution grid. The lack of very large loads and a large transmission grid makes the use of nuclear energy in the Yukon an impossibility at the present time. Future improvement in smaller nuclear plants coupled with the growth of power loads and production in the Yukon will lead to an eventual situation where use of nuclear energy may well be economical, but prediction of the time when this will occur is difficult. It now appears to be at least ten years away.

3. Generation of power from the coal deposits at Carmacks appears to be a sound alternative to hydroelectric development. Before such development can be confidently undertaken the reserves of coal available must be proved sufficient. Assuming that they are, the normal course of development could probably best be:

(a) To build the necessary size of thermal station to cover the imminent shortfall of power, with provision for extension.

(b) When extension of the thermal plant has led to development of a plant of such a size that it is comparable to some of the more economical hydroelectric developments, the best of these should be constructed, thus returning the thermal station to its role of reserve for future load growth. This process then can be repeated producing an orderly development. The economic advantage of such a procedure should perhaps be noted here. The capital investment in a thermal plant is relatively low and is a direct function of the capacity of the plant. When the point is reached at which replacement by a hydroelectric development is economical, the investment in the hydroelectric development will immediately produce a return and the operating costs of the thermal plant, which are the largest proportion of its production cost, will be reduced in proportion to the production required. There is also the added advantage of having alternative power sources. At current rates of interest power development with relatively low "sunk costs" would appear to be highly advantageous.

4. Hydroelectric power resources in the Yukon are very large. Nevertheless, in common with such resources everywhere it is axiomatic that the production of cheap power depends on implementing relatively large developments. These involve investment of large sums of money on which the return from power sales is in the beginning small. Sufficient investigation has already been done to indicate the more economical hydroelectric developments, but the nature of these preliminary investigations, coupled with the fact that some of them were done a considerable time ago, leads to the conclusion that the best sites should be re-explored

in more detail and more accurate cost estimates obtained.

5. Orderly development of suitable power facilities in the Yukon requires that an extension of the transmissions grid be undertaken early in the program. It is recognized that this involves sizeable capital investment in the near future and a continuing program of expenditure. However, past experience elsewhere in Canada, and indeed in the world, shows that the availability of power is an effective agent in producing power demands and a well planned transmission and distribution network is an integral part of a developing power supply.

6. The system of setting power rates on an ad hoc basis generally is discouraging to new commercial developers. An integrated power system with more or less uniform rates should provide a better climate for the general growth of commercial enterprises in the Yukon. It is recognized that in the case of large mining operations power costs represent a fairly small factor in overall production costs, but if the local processing of mining products is to be achieved in the future, with all its attendant advantage, the production of much larger amounts of economical power will be essential. The advantages of a well-planned power program in making these power resources readily and assuredly available, are obvious.

7. The increase in electrical load in the Yukon, projected to 1980 will require new generating capacity of up to 300 MW. Until such time that a pattern of development of generating stations is developed and a transmission grid is established, it is difficult to predict costs with accuracy. It is to be expected that an expenditure of not less than $100 million and up to $300 million will be required to meet the projected electrical demand of 300 MW by 1980. The value of the labour required to construct the generating stations for the projected electrical demand is estimated to be not less than $35 million and as much as $100 million.

I. RECOMMENDATIONS

Once more, the limitations of time and budgetary means are (121)
acknowledged in respect to making specific recommendations. The following steps appear to be the logical result of this study:

1. A detailed study of a comprehensive power generation and transmission system geared to the pattern of industrial growth should be made.

2. A policy for widely applicable relatively uniform power rates should be developed.

3. A specific investigation of the Carmacks coal deposits should be made to obtain:

    (a) An accurate estimate of coal reserves.

    (b) An accurate estimate of coal production costs.

4. A detailed preliminary study of the installation of a thermal plant at Carmacks should be made.

5. Several of the more economical hydroelectric sites should be investigated in detail and preliminary plans developed on which to base accurate cost estimates updated as to present construction costs and the effect of current interest rates.

6. A plan for continuing appreciations of the effect of new discoveries of fuels in the form of coal, oil and gas should be carried on and the development of techniques for using nuclear energy should be monitored.

Respectfully submitted,

C.B.A. ENGINEERING LTD.

K.A. Henry, P. Eng.
Executive Vice-President.

GLOSSARY

M.W. = megawatt = 1000 Kilowatts. a measure of power

K.W. = Kilowatt = 1000 watts. a measure of power

K.V. = Kilovolts = 1000 volts. a measure of potential

Load Factor = Rates of energy consumed to that which might have been consumed if the peak demand represented a constant load.

K.V.A. = Kilovolt ampere = 1000 amperes - a measure of power

M.C.M. = Thousand circular mils - a measure of wire size.

A.C.S.R. = Aluminum conductor steel reinforced power cable.

Frazil ice = Ice which forms in turbulent super-cooled water in very thin plates and which will deposit on hydraulic intake structures, causing blockage.

Trash Rack = A device, usually a series of bars, which prevents trash entering water passages to hydraulic equipment.

G.W.H. = 1,000,000 K.W.H.

Mils = 1/10 cent.

Acre feet = The volume of water which covers one acre to a depth of 1 foot (i.e.) 43,560 cubic feet.

Drawdown = The distance in feet that the level of a reservoir is reduced below its maximum level.