Whitehorse Rapids (Courtesy of YEC/YECL Archives)

This article is part of a series of publications on the Yukon's energy resources. It provides an overview of hydro development in the Yukon and the issues affecting its development. It is intended to encourage investment and to stimulate informed discussion among representatives of industry, government, and members of the community. Appendices of a more technical nature are available separately for each of the articles in this series. You can obtain copies of these appendices through the

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Hydro

Overview

Yukon rivers have provided hydro electricity since 1906. Currently, four utility-owned hydro electric facilities provide a total of approximately 76 Megawatts (MW) of power. In addition, there are three privately owned micro hydro facilities in the region, with one more due to be producing power soon. Past studies have shown that numerous sites could support new hydro developments. Facilities smaller than 20 MW are seen as the most likely to succeed; one study has identified thirty-three such sites.

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The largest single factor influencing electrical demand in the Yukon is the mining industry. For example, when the Faro mine is operating, it accounts for 40% of the Whitehorse-Aishihik-Faro system load. Utilities believe that the risk of mine closures is too high to justify building hydro plants that require pay-back periods, typically, of 50 years.

The main competition for new hydro electric developments is diesel electric plants. Hydro plants can have capital costs from three to ten times greater than diesel plants. However, hydro plants have a number of advantages over diesel plants, chief among them, a longer plant life, the fact that they use a local resource, and their non-variable fuel cost. Coal plants could also compete with hydro plants for generating base load power, provided an inexpensive, and steady supply of coal can be maintained.

New hydro developments will be required to undergo a more rigorous screening process than existing plants underwent. New projects will have to take into consideration the Canadian Environmental Assessment Act, Yukon First Nations' Final Agreements and the Development Assessment Process. New developments will also have to address environmental issues that were not considered in the past. The biggest environmental issues of concern deal with the impact of hydro developments on fish and wildlife and on the wilderness characteristics of the Yukon's undeveloped rivers and lakes.

The Resource

Yukon Hydrology

The Yukon is a land of rivers. Its five primary rivers drain an area, within the Yukon, of 418,000 km^2. The territory's largest river, the Yukon River, drains an area within the Yukon of 264,000 km^2. This area is 14% larger than the Fraser River drainage area in British Columbia. Flow volumes in Yukon rivers are less than in British Columbia rivers. Table 1 compares the average flow rate (discharge), drainage area and discharge per one thousand square kilometres (unit discharge) of the five primary Yukon rivers, with the three primary British Columbia rivers.

Table 1. Discharges and Drainage Areas for Yukon and British Columbia Primary Rivers

River	Average Discharge	Drainage Area (km^2) (m^3/s)	Unit Discharge (m^3/s /1000km^2)
Yukon Rivers			
Peel	387	49,000	7.9
Porcupine	326	55,400	5.9
Yukon	2,210	264,000	8.4
Alsek	204	16,200	12.6
Liard	377	33,400	11.3
BC Rivers			
Fraser	3,350	228,000	14.7
Peace	1,420	97,100	14.6
Stikine	643	36,000	17.9

Source: Water Survey of Canada, 1996.

Drainage areas and discharges of rivers describe one element of importance to hydro developers, namely the volume of water available to produce electricity. River flow patterns are another important element as they determine the time of the year a sufficient volume of water is available for producing electricity.

The Water Survey of Canada describes river flows in the Yukon as being affected by five main factors: precipitation, long winters, snowmelt, storage, and glaciers.

1. Precipitation

The Yukon is climatically classified as a semi-arid region. Snowfall varies from over 200 cm (200 mm rainfall equivalent) in the southwest to less than 80 cm (80 mm rainfall equivalent) in the arctic. Rainfall varies from 200 mm in the south to 100 mm in the arctic.

2. Long winters

The long cold season results in low flows in the late winter and peak flows in the early spring when the snow melts.

3. Snowmelt

Snow storage in the winter, followed by snowmelt in the spring, effectively redistributes six to ten months of precipitation into the brief snowmelt period.

4. Storage

The large lakes in the southern Yukon provide a significant amount of natural storage. This has the effect of moderating seasonal flows and storm flows. Northern streams have very little natural storage and so are more likely to have a high spring freshet and flash floods. Also, in the north, permafrost plays a role in limiting groundwater storage. This too contributes to faster run-off in northern streams.

5. Glaciers

The southwest Yukon is dominated by the St. Elias icefields. In addition, alpine glaciers are found at higher elevations throughout the Yukon. Glaciers tend to receive more water than the surrounding lowlands and provide the bulk of water to many river systems. Glacial systems release water later in the season, with peak runoff often delayed until late summer. Glaciers moderate annual precipitation patterns, in that they tend to grow in high snowfall years and withhold water from runoff. In low snowfall years, river flow is augmented by glacial melt water.

Hydro Plant Components

A hydro plant requires a combination of several major structures and equipment, to develop the necessary head, to transport the water, and to operate the plant.

Reservoir

One of the ways of developing head is to store water in a reservoir. The reservoir may also operate to provide flow regulation or long-term water storage.

Dams

Dams are used to divert flow into water conveyance structures or to develop reservoirs. These structures are commonly built of concrete, earthfill, rockfill, or earth and rockfill.

Intakes

The inlet for water to be carried to the power house may be a separate structure from either the dam or powerhouse. It may be integrated with a dam. The intake has trash racks, service gates and emergency gates.

Spillways

Spillways are provided to discharge flood flows that exceed the plant discharge capacity and reservoir storage capacity. The spillway is an important safety-related feature designed for the probable maximum flood. This flood is the maximum that is reasonably probable for that reservoir and drainage basin.

Water Conveyance

Water can be conveyed to the powerhouse by canals, pipe penstocks, lined or unlined tunnels, or formed passages in the integral dam and powerhouse. Combinations of these methods can also be used.

Power house

This houses the turbine-generator(s) and associated equipment.

Mechanical and Electrical Auxiliaries

The hydro plant will have a number of auxiliary systems. The most important are:

- A governor for speed control
- Water supply systems for equipment heat exchangers, and potable supply
- Building drainage pumps, including an oil separator
- Switch gear and service transformers
- Transformers and substation
- Communication and remote control system

Tail Race

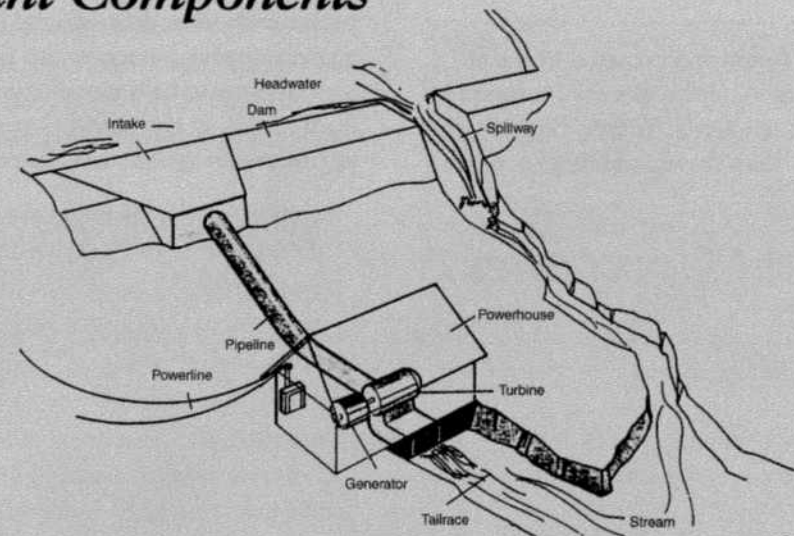
A canal or channel that directs water from the turbines back into the river.

Transmission System

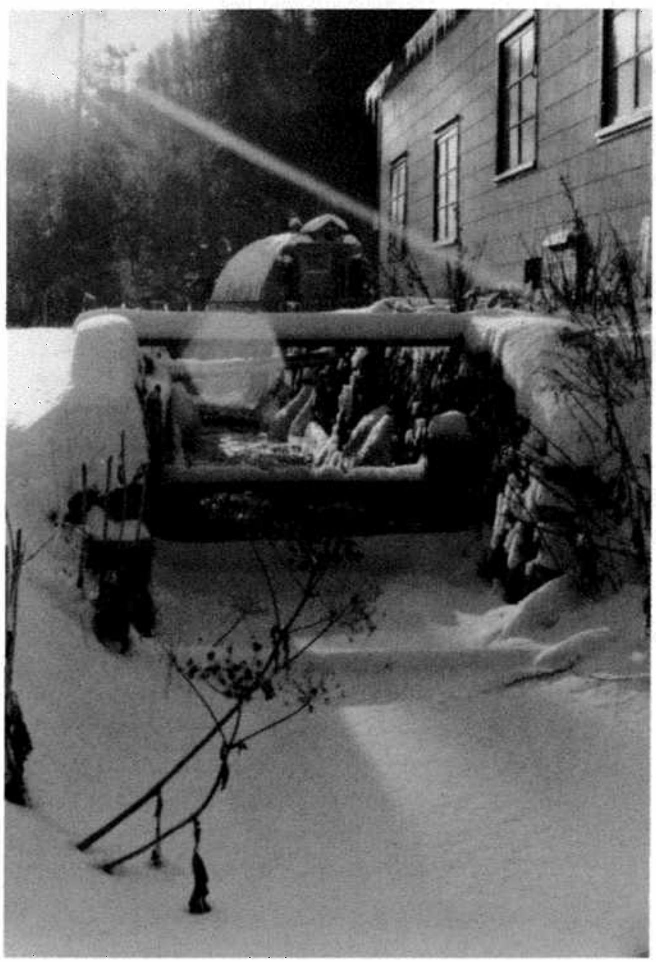
Transmission lines to distribute power and in the case of pump storage to receive power from the system.

Source: Dougherty, Gale B. Hydroelectric Power. Handbook of Energy Technology and Economics. 1983. Edited by Robert A. Meyers. Chapter 23 pp 999,1000.

Hydro Plant Components



Source: "Micro Hydro In Yukon Volume I"



Fish Lake Power House (Courtesy of YEC/YECL Archives)

Yukon Hydro Development

Yukon hydro development began with the construction of the Yukon Gold Company Ltd.'s 2.5 MW hydro plant in 1906. The plant was located on the Little 12 Mile River. It powered the company's dredges from 1906 to 1920. The company's competitor was the Yukon Consolidated Gold Fields Company. Yukon Consolidated operated a 5.4 MW hydro plant on the North Fork of the Klondike River from 1919 to 1935. In 1935 the company added another turbine to bring the plant's capacity up to 8.1 MW. This plant continued to operate until 1966.

In 1949 the Yukon Electrical Company Ltd. built its Fish Lake power plant. A second power plant was added in 1955, downstream from the first plant. Both power plants are still in operation. Together, they provide a total of 1.3 MW of capacity to the Whitehorse-Aishihik-Faro (WAF) grid.

The Fish Lake development is a run-of-river facility. The variation in flows from Fish Lake is moderated by the natural storage provided by Fish Lake, Franklin Lake and Jackfish Lake drainage basins. This makes the winter capacity of the plant only slightly less than the summer capacity.

In 1952, the Northern Canada Power Commission (NCPC) built the Mayo Hydro facility to supply electricity to Mayo and United Keno Hill Mines in Elsa and Keno. Regulated storage developed on Mayo Lake enabled the power plant on the Mayo River to operate at full capacity throughout the year. Five megawatts of capacity were generated by two, 2.5 MW turbines. When United Keno Hill Mines stopped mining in the area in 1989, the demand for power dropped from 4.5 MW to 1.5 MW. The Yukon Energy Corporation, which acquired NCPC's assets in 1987, now needs to run only one turbine most of the time.

NCPC built the Yukon's next hydro plant on the Yukon River, at Whitehorse Rapids in 1958. This plant was built to supply the rapidly growing demand for electricity in Whitehorse. The original plant had two turbines which generated a total of 11.6 MW. A third turbine was added in 1969, bringing the total capacity to 20 MW. Finally, in 1984, the fourth turbine was added to bring the total capacity to its current level of 40 MW.

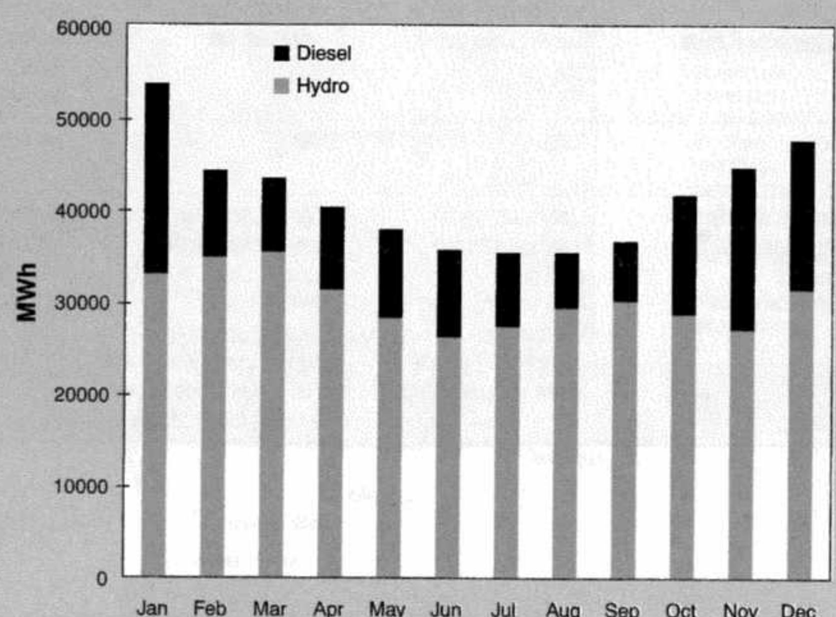
The Whitehorse Rapids plant is much more affected by seasonal variations in river flows than the Fish Lake and Mayo Lake plants. During the summer high flow months the plant's capacity is approximately 40 MW, but during the winter freeze-up it declines to an average of approximately 24 MW. This seasonal variation does not match the current demand pattern as shown in Figure 1. The demand for electricity is highest during winter when the stream flows are near their minimum.

The next hydro development built in the Yukon was the Aishihik Lake plant in 1975. This was the last plant built by NCPC and the last plant built by a utility in the Yukon. The Aishihik Lake facility provides the only multi-year reservoir storage on the WAF grid. Natural storage is provided by Sekulmun, and regulated storage is provided in Aishihik and Canyon Lakes with the use of two dams, one at the outlet of Aishihik Lake and one at the outlet of Canyon Lake. During the winter months, when water flows are low, water is drawn from the reservoir and during the high-flow summer months the reservoir refills to an extent dependent on the inflows for that season. This allows energy to be produced in a pattern that suits Yukon demand.

During the 1980's, two micro hydro facilities were built by non-utility generators in the Yukon. These were built to supply power to the developers for their homes and businesses. A third micro hydro facility was built in Northern BC to supply power to the Yukon Government Highway camp in Fraser, BC. One other micro hydro plant was under construction in 1996, again to supply power for the developer's domestic use.

Taken together, the utility-owned hydro plants provide a total of approximately 76 MW of the 134 MW capacity provided by all the electrical power facilities in the Yukon (see Figure 2). Table 2 summarizes the Yukon's utility-owned hydro facilities. Table 3 summarizes the Yukon's non-utility-owned hydro facilities. BC's Fraser Micro Hydro plant is included, because its customer is the Yukon Government.

Figure 1. Yukon Electrical Load (1996)



Source: The Yukon Electrical Company Ltd., 1997

Yukon Electric Utilities

There are two electric utilities in the Yukon: the Yukon Energy Corporation and The Yukon Electrical Company Ltd. The Yukon Energy Corporation is owned by the Yukon Development Corporation which is, in turn, owned by the Yukon Government. YEC owns and generators most of the electricity in the Yukon and also owns distribution lines in the communities of Dawson, Mayo and Faro.

The Yukon Electrical Company Ltd. is a private utility owned by Alberta Power Limited, in turn, owned by Canadian Utilities of Alberta. YECL manages the Yukon's electrical system, including YEC assets, as well as its own assets under a management agreement. The purpose is to operate as a single integrated system at the lowest possible costs to rate payers. As well, YECL owns some of its own generating facilities and most of the distribution lines. Figure 2 shows the generating facilities in the Yukon, listed by company.

Table 2. Summary of Yukon Utility Hydro Facilities

Facility	Whitehorse Rapids	Aishihik Lake	Mayo Lake	Fish Lake
Owner	YEC	YEC	YEC	YECL
Seasonal Capacity (MW) Summer Winter	 40 24	 30 30	 5 5	 1.3 slightly < 1.3
Turbine sizes (MW) and year built	#1: 5.8 (1958) #2: 5.8 (1958) #3: 8.4 (1969) #4: 20 (1985)	#1: 15 (1975) #2: 15 (1975)	#1: 2.5 (1952) #2: 2.5 (1952)	#1: 0.6 (1950) #2: 0.7 (1950)
Cost ($000)	$300,000	$42,000 (1975$)	not available	$250 (1950 $)
Head (m)	18	175	32 (Wareham)	Plant #1: 128 Plant #2: 61
Control Structures	-storage control at Marsh Lake -head dam at Whitehorse Rapids	-storage control at Aishihik Lake outlet -spill control dam at Canyon Lake outlet	-storage control at Mayo lake -head dam is Wareham Dam	-storage control at Fish Lake outlet -head dam at Jackson Lake outlet -head dam at Franklin Lake outlet
Reservoir Area (square km)	1100	3045	103	14
Other	-longest wooden fish ladder in North America	-only multi-year reservoir storage on WAF grid -first underground hydroelectric facility north of 60th parallel in the western world	-Mayo Lake dam is a timber crib dam, reconstructed in 1989 by YEC -usually only one turbine operating now that United Keno Mines is not at full production.	-the two turbines are located in separate power houses, one downstream of the other.

Figure 2. Electrical Power Facilities in the Yukon.

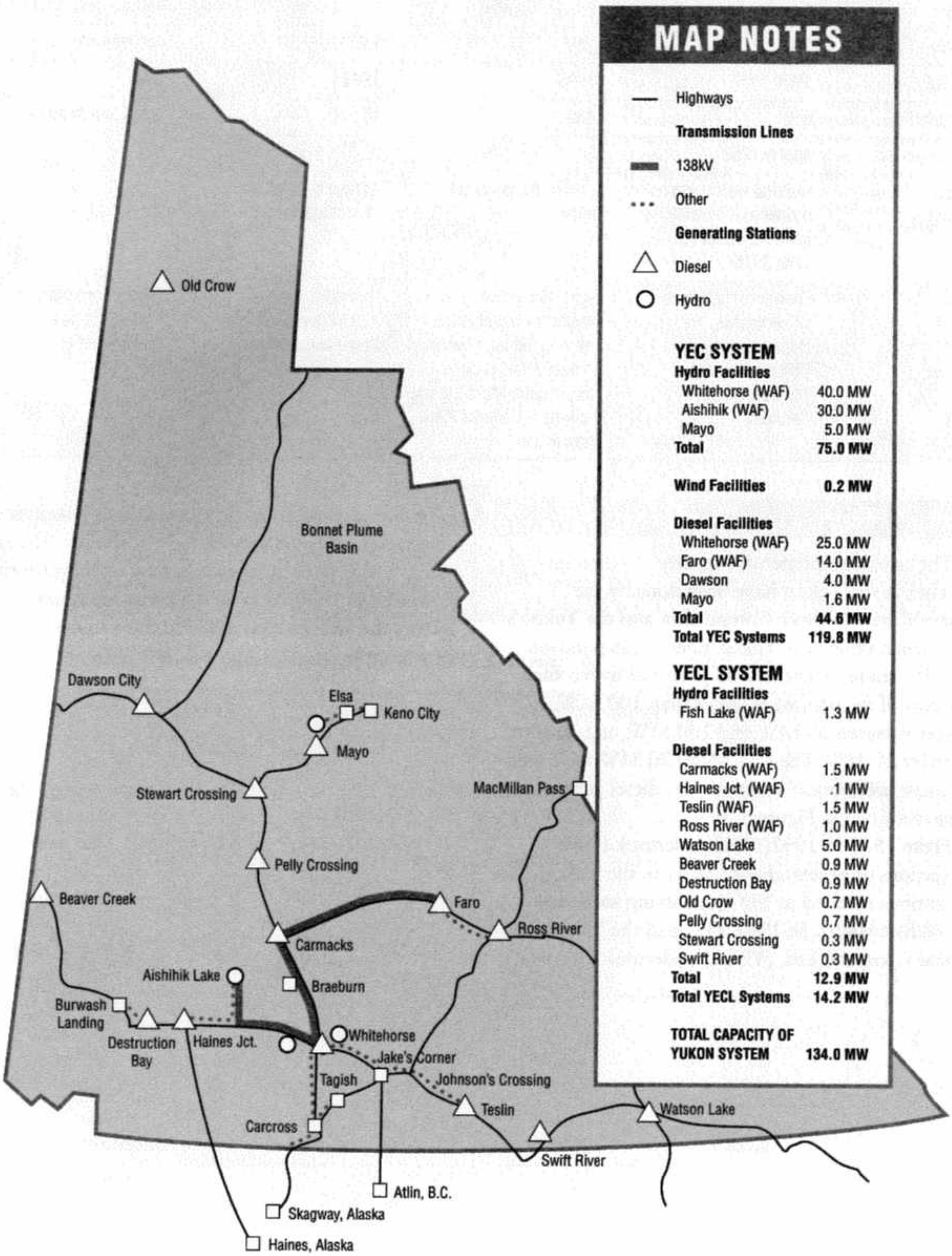


Table 3. Summary of Yukon Non-Utility Hydro Facilities

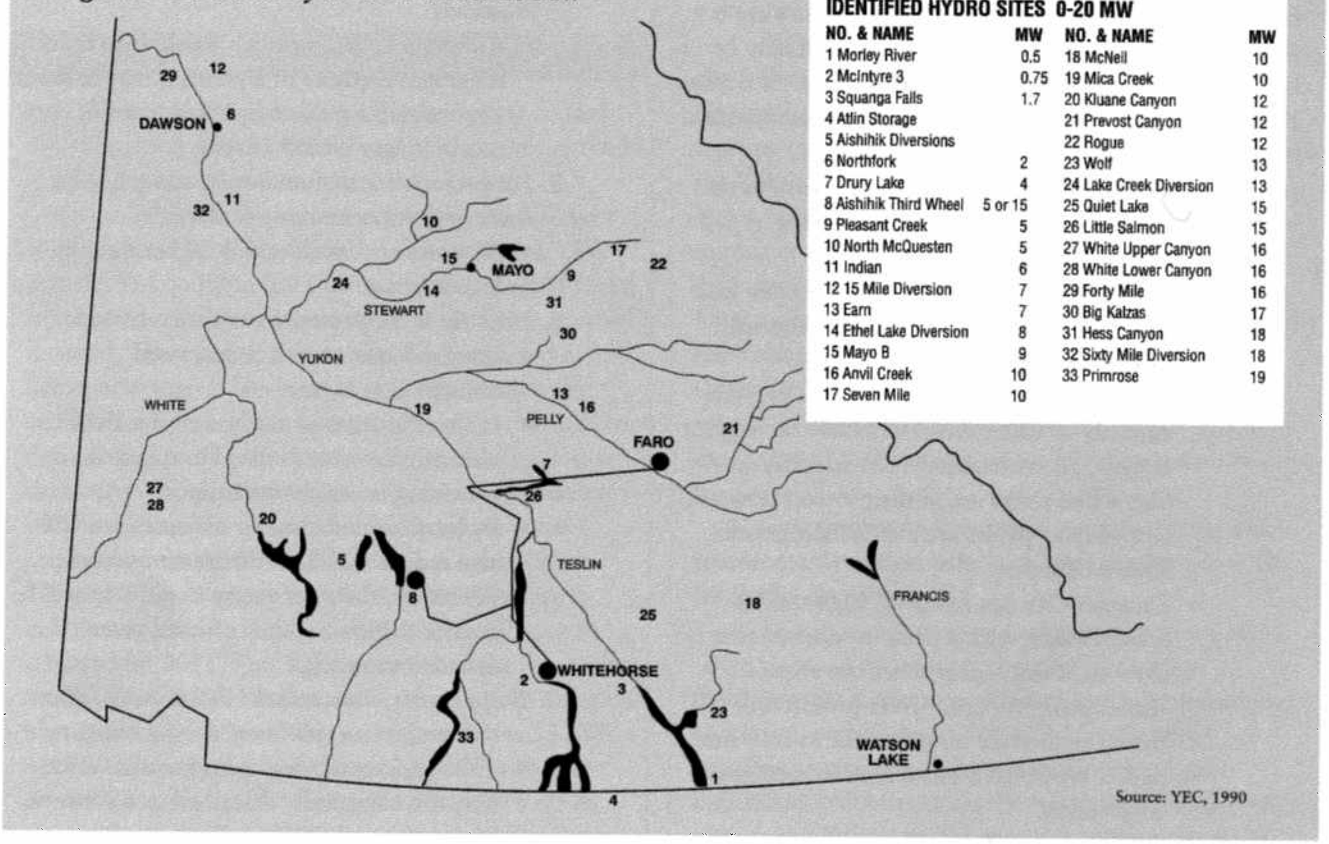
Facility	Fraser Micro Hydro	Rancheria Micro Hydro	Gilday Micro Hydro	Berdahl Micro Hydro
Owner	New Era Engineering Corp.	Beverly Dinning	Doug Gilday	Ron Berdahl
Capacity (kW)	250	155	1.6	not available
Year Built	1990	1990	1986	1996
Cost ($000)	550	400	15	under construction
Head (m)	approx. 250	38	9	
Control Structures	-natural weir (terminal moraine) for penstock intake at outlet of Lake 3575	-1 weir for penstock intake	-2 flow control dams -1 storage dam	
Other	-customer is Yukon Government, Department of Community and Transportation Services	-provides power year round for travel lodge -during winter, flow is reduced and back-up diesel generators are used. -owner installed a 2 km power line	-provides approx. 720 kWh/month for home and workshop	-under construction -intake will be at Gilday's outlet.

Potential Hydro Development

The most comprehensive studies of potential hydro sites in the Yukon have been done by the Northern Canada Power Commission and the Yukon's crown owned utility, the Yukon Energy Corporation. The NCPC studies identified 82 potential hydro sites. Thirty-two of the sites were larger than 100 MW, 17 sites were between 20 MW and 100 MW, and 33 sites were under 20 MW. The sites under 20 MW were seen as the most economical alternative to diesel generation and are identified in Figure 3.

From 1988 to 1992, YEC undertook four investigations of potential hydro sites in the Yukon. The investigations resulted in YEC identifying some new potential hydro sites. In 1992 YEC and the Yukon Electrical Company Ltd. (YECL) undertook a Capital Planning process. After developing load forecasts, the companies analyzed various supply options. The most viable hydro options, as determined by this process, are presented in Table 4. Table 4 also includes some of the factors the utilities considered in their analysis of the various options.

Figure 3 - Potential Hydro Sites Under 20 MW



Source: YEC, 1990

Table 4. Potential Hydro Projects Assessed by YEC/YECL during the 1992 Capital Plan

Project Option	Installed Capacity (MW)	Dependable Capacity[1] (MW)	Deliverable Annual Energy[2] (GWh)	Installed Costs ($000)	Annual O&M ($000)
Over 30 GWh/year					
WAF: Surprise Lake	8.5	6.7	48.0	40,600	1,800
WAF: Moon Lake	8.5	7.4	44.9	44,200	1,800
WAF: Wolf River	4.8	4.3	37.6	38,600	391
20 to 30 GWh/year					
WAF: Drury Creek	2.6	2.8	24.8	21,200	271
WAF: Orchay River	4.0	3.0	26.6	23,400	285
Dawson: North Fork	4.0	3.7 (summer peak) 0.8 (in winter)	21.0	22,400	324
10 to 20 GWh/year					
WAF: Morley River	2.0	1.6	16.0	13,800	212
WAF: Lapie River	2.0	0.3	10.5	7,000	157
WAF: Squanga Creek	1.8	0.6	10.7	9,800	180
5 to 10 GWh/year					
WAF: McIntyre Creek #3	0.7	0.6	5.5	5,000	30
5 GWh/year or less					
WAF: Aishihik 3rd Turbine	5.0	5.0	5	5,000	30

Notes:
1. Dependable capacity is the average capacity available during system peak. System peak occurs in the winter in the Yukon, except in Dawson City where it occurs in the summer.
2. Deliverable energy reflects system loss adjustments related to plant location.
3. All projects have an economic life of 50 years.

Source: *YEC/YECL 1992 Resource Plan Supply Side Binder A*, p88, Table 6.5

Each of the hydro facilities analyzed by the utilities had a number of other issues considered, apart from the factors shown in Table 4. These issues are not necessarily unique to the projects studied and may be of interest to potential investors in other projects as well as those studied by YEC and YECL. They are summarized in the nine questions that follow.

Hydro Facility Development Issues for Yukon Plants:

1. *Will the plant be capable of generating at full capacity over the peak load period?*
   - For most places in the Yukon the peak load period is in the winter months. Currently, much of this peak is met by diesel generators. Hydro plants that can provide capacity to offset diesel will have the biggest benefit. However, the winter months are also when rivers are at their lowest flow and run-of-river plants are experiencing their lowest capacity.
   - Dawson City has relatively high tourist-season loads, with a peak in summer that is close to, if not higher than, the annual winter peak. A run-of-river project will therefore provide more benefit to Dawson than it would to a more typical northern community.
2. *Is there storage capacity from season to season?*
   - If the plant could operate at reduced capacity during the summer, and if storage capacity is available, water could be stored for winter use. This would provide a way of generating more electricity during the winter peak demand.
3. *Do upstream lakes provide natural storage as well as a potential to develop further storage?*
   - Natural storage refers to the drainage basin characteristics that allow water to be stored with minimal, or no control structures. A large lake, or a network of smaller lakes can provide natural storage. Natural storage is important in increasing the firm power of run-of-river facilities as well as storage facilities. It provides for natural regulation of rivers which gives more stable river flows.
4. *Can the project be developed in stages, in order to reduce the up-front capital investment required?*
   - Although such a strategy would also reduce the initial capacity of a plant, it may make it a more viable project by spreading out costs over a longer period of time.
5. *For projects located on border waters, what taxes and water rentals are there?*
   - BC costs are considerably higher than the Yukon costs.
6. *How far is the project from the consumers?*
   - Long distances result in increased transmission losses.
   - Projects located on the end of the WAF transmission system may be of benefit in providing transmission support.
   - Projects located close to a major load will also reduce losses on the transmission line. Therefore, their net energy capability will be greater than would be expected given their installed capacity.
7. *If applicable, how will the detrimental effects of this project on spawning fish be mitigated?*
   - This was one of the environmental effects that was repeatedly described as a concern in the 1992 YEC/YECL Resource Plan.
8. *If applicable, how will conflicts with recreational users be mitigated?*
   - This may be of particular concern if the project will be developing an otherwise undeveloped river or lake, or reducing flows, to the extent that a portion of a river is impassable by boat.
9. *Would the project be located on areas posing potential land ownership problems?*
   - Not all Yukon First Nations have Final Agreements for their land claims. Developers should take this into consideration early in the planning process to avoid future conflicts.
   - Consideration must also be given to other users such as trappers, hunters, tourism operators, and recreational users.

Economic Issues

Market Potential

The main markets for hydro developers in the Yukon are the utilities. Additional hydro capacity could offset diesel generation on the Yukon Energy Corporation's WAF grid, where diesel is used to meet peaking demand. It could do the same for both YEC and the Yukon Electrical Company Ltd., off-grid in the isolated communities, where diesel is used to supply all demand. The opportunity on the WAF system may be better now than it has been in the past, because the utilities have a number of diesel generators that will be decommissioned in the next several years. This means that unless the demand decreases, new energy sources will be required to replace the old diesel generators.

Based on the 1992 YEC/YECL Capital Plan's "low case" forecast, at least 13 MW of new supply may be required by 2000. A further 12 MW may be required by 2011. This forecast assumed the Faro mine would close in 1995 and no new mines would come on line. Under the utilities' "high case" scenario, 35 MW of new capacity may be required by 2001 with new capacity continuing to be required after that year. In this scenario, the Faro mine was assumed to remain open beyond the forecast period and new mines were forecast to open in Dawson and Mayo. As well the Sa Dena Hes mining project in Watson Lake was assumed to continue until 2010.

Whether or not these forecasts are accurate, they show that there will most likely be some increase in electrical demand, beyond what can be met with existing facilities. They also show how demand varies in the Yukon, based on mining activity.

Another potential market for hydro developers is mining companies. In the past, new mines located off-grid generated their own power using oil or diesel. Exceptions to this were the hydro plants operated by the Yukon Gold Company Ltd. and the Yukon Consolidated Gold Fields Company. Table 5 shows operating and potential mines for the Yukon and how much power they require, as well as the expected mine life.

Government highway maintenance camps and remote tourist lodges offer a smaller market potential for hydro developers.

An expansion of the existing transmission grid could improve the market potential for hydro development. A grid expansion to more communities and mines within the Yukon would make more customers accessible to hydro developers. A grid expansion which connects the territory's grid to grids outside the Yukon would give Yukon developers the potential to export hydro electric power.

Table 5. Potential Yukon Mineral Projects

Property Name	Distance From Grid	Mine Life (years)	Power Required (MW)	Annual Energy Required (GWh/year)	Project Impact on Yukon Communities
Producing Mines					
Brewery Creek	Elsa 133 km	8	3.0	12	Employ - 100 people - adds a maximum of 219 new people to Dawson City, population increased by 10%
Mount Nansen	Carmacks 60 km	6	2	6.2	Employ - 65 people Camp Housing, Whitehorse, Carmacks
Potential Mines					
Carmacks Copper	Carmacks 45 km	8	7.2	50	Employ - 90 to 136 people - expect a gradual influx of 44 positions to Carmacks (124 people, 40 dwellings) - influx of 200 people into Whitehorse, 68 dwellings (direct and indirect jobs), 0.9% population increase - estimate 10–15 hired from outside Yukon

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Table 5. Potential Yukon Mineral Projects - *continued from previous page*

Property Name	Distance From Grid	Mine Life (years)	Power Required (MW)	Annual Energy Required (GWh/year)	Project Impact on Yukon Communities
Casino	Carmacks 129 km	12	38 (est.)	283*	Employ - 500 people Camp Housing
Division Mountain	Braeburn 25 km	15 (est.)	2–4	22*	Employ - 100 to 200 people
Dublin Gulch	Elsa 25 km	10	2 (summer) 5.3 (winter)	28.9**	Employ - 179 to 205 people
Grizzly and Grum (Underground)	Connected	12–14	12 (est.)	90*	Employ - 250 to 300 people Reside in Faro
Grum (Open Pit)	Connected	6	22	170	Employ - 450 people Reside in Faro
Ketza River	Ross River 50 km	2	3	12	Employ - 75 to 100 people Camp Housing
Kudz Ze Kayah	Faro 230 km	11	8.8	41.5	Employ - 200 people
Minto	Carmacks 88 km	12	2.5	13	Employ - 76 people - expect 49 jobs (79%) and indirect jobs (total 125) from Whse., - 12 jobs (15%) from Carmacks, - 8 jobs (10%) from Pelly Crossing, - 4 jobs (5%) from Faro, - 50% of those jobs from Whse. will be taken Whse residents, the other 50% will move from other Yukon communities. - Whitehorse is the staging point.
Mt. Skukum/ Skukum Creek	Carcross Road 40 km	4	3	12	Employ - 80 to 100 people Camp Housing, Whse, Carcross
Sa Dena Hes	Watson Lake 58 km	4	6.2	25–30	Employ - 81 people Camp Housing, Watson Lake
Tulsequah Chief	64 km NE of Juneau, AK	9	9	67*	Employ - 200 people Crews flown from Vancouver or Smithers
Keno Hill	Connected	3	2.0 to 3.5	24	Employ - 160 people Camp Housing
Wellgreen	Aishihik 200 km	12	35 mine/ Smelter	261*	Employ - 400 to 500 people

Notes: * Estimate based on 85% load factor. ** Estimate based on 75% load factor
These are potential mines only, based on current mining activity.
This is not a comprehensive list and does not imply that production will commence at these sites.
Source: *Economic Development, 1996.*

The Competition

Yukon utilities measure the viability of hydro electric generation against diesel electric generation. Diesel plants have been seen by Yukon utilities as the lowest cost and lowest risk way of providing for load growth incrementally, in an environment of fluctuating loads. Diesel generators are less capital intensive than other options, easier to size to meet the load, and reliable. They are also removable and transferable, when no longer required to generate power for a particular use. Diesel generators' main disadvantage is their variable fuel costs.

Base load diesel generators typically have a capital cost of approximately $1000 per kilowatt. The capital cost for hydro plants can range from three to ten times as much. On the other hand, hydro plants have a number of advantages that allow them to compete with diesel plants:

- Hydro plants have a life time that is approximately three or more times as long as diesel generators.
- Hydro plants have a non-variable fuel cost (of zero).
- Small hydro plants can provide for load growth incrementally. (Note that the plants shown in Table 4 are all under 10 MW in capacity.)
- Hydro plants produce energy from a local resource.
- Hydro plants do not emit the air pollutants associated with burning fuel.

Although there are currently no coal power plants in the Yukon, coal plants could also compete with hydro plants for generating base load power, provided an inexpensive, and steady supply of coal can be maintained. The capital costs for coal plants are less than for hydro plants — typically from two to five times that of a base load diesel plant. Coal plants have a life time that is comparable with hydro plants. The Yukon hosts considerable coal reserves and various mines have used coal for process heat. The Energy Resources Branch has included a publication on Coal, in this series on the Yukon's Energy Resources.

Market Stability

Hydro plants are long-term, capital intensive projects. Therefore, the size and long-term stability of the market are key concerns for developers. Customers such as highway maintenance camps or travel lodges may require relatively small amounts of power (under 1 MW) for long periods of time. This may make a micro hydro development attractive.

Mines, on the other hand, may require large amounts of power (the Faro mine accounts for 40% of the WAF system load when it is fully operating) for shorter time periods. Utilities in the Yukon are reluctant to build hydro facilities to meet load growth based on a cyclical mining industry. The reason is that the Yukon's electrical system is isolated from the North American grid because there is no cross-border transmission line connection. As a result, a hydro facility that becomes surplus to system needs due to mine shut-downs remains surplus until new mining loads come on line. This results in the remaining customers being required to pay significantly higher power rates to cover the costs of maintaining the facility. There is no opportunity to sell the surplus on the open market. Utilities see the risk of mine shut-downs as too high for them to build plants that require the long pay-back periods of 40 - 60 years required for hydro plants.

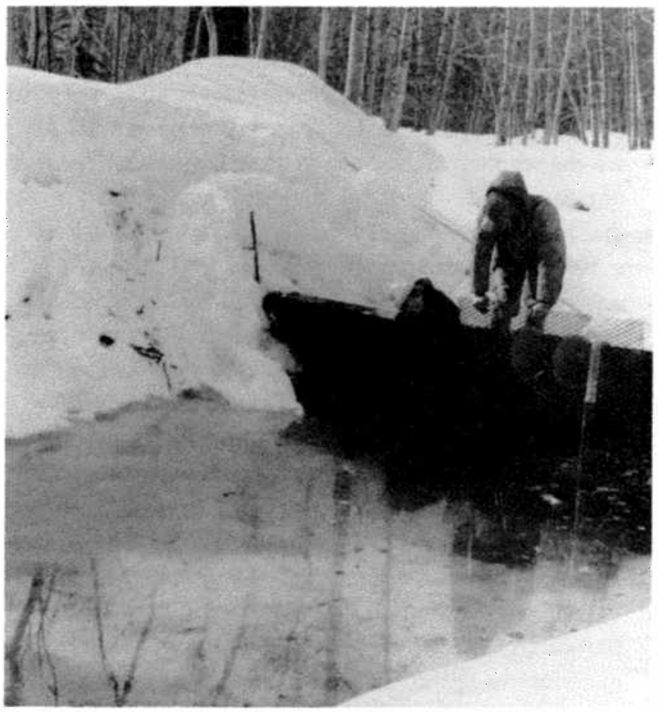
In 1993, soon after the YEC/YECL Capital Plan was developed, the Faro mine closed. This event reduced the demand for electricity to the extent that the impetus for developing new power was temporarily gone. With the reopening of the mine in 1995, the demand increased to the point where the electrical system was again operating at full capacity. A "Supply Option Review" process was initiated by the utilities in 1996. Like the 1993 Capital Plan, this review will be greatly influenced by mining operations in the territory. It will be particularly affected, once again by the Faro mine, which announced a reduction in operations in November 1996.

Non Utility Generation

Up until 1995, only franchised utilities could generate electricity for sale in the Yukon. The *Public Utilities Act—1986* was amended in 1995 so that non-utility generators (NUGs) could also sell power. They may sell power to a single customer or a franchised utility. The Act states that a transmission line is allowable only if it "does not duplicate any existing or planned facilities of any public utility."

For NUGs wishing to connect to the existing grid, the main customer will likely be the utility that owns that grid. Market stability may not be as big a concern for NUGs, if they can negotiate a "take-or-pay" arrangement with the utility. In such an arrangement, the utility would agree to buy power from the NUG at a levelized price, regardless of end-user demand.

Currently, neither YEC nor YECL has entered into take-or-pay arrangements. However, YEC issued a request for "expressions of interest" from non-utility generators in September 1996. The utility is interested in using NUG power as a supply option in its Supply Option Review. YEC's preference will be for NUGs with a proven ability to produce power reliably, at a cost less than diesel generation. The utilities' operation and maintenance costs to generate power with existing diesel plants is approximately $0.09 - $0.11 per kWh. If a new diesel generator needs to be installed, then the costs rise to approximately $0.11-$0.13 per kWh.



Gilday's Micro Hydro - Intake Weir and Head Pond (Courtesy of Doug and Cindy Gilday)

Regulatory Issues

Regulatory Regime

In the early years of hydro development in the Yukon, there was no requirement for formal feasibility studies, nor environmental assessments. One of the original developers of the Fish Lake Hydro plant, John Scott, wrote in his memoirs:

> *"In those days you just went ahead and did what was required. You never had to bother with fire permits, land use regulations, ecological studies and so forth, and we caused no harm."*

None of the existing utility hydro developments were built under the current regulatory regime. The last project to be built by a utility was the Aishihik plant. NCPC began building the Aishihik Lake project before the Federal Government's Environmental Assessment Review Process (EARP) was enacted in 1974. This process was replaced by the Canadian Environmental Assessment Act in 1992. In 1994 the Yukon First Nations Umbrella Final Agreement became effective, and the Yukon Development Assessment Process is currently being developed. These three initiatives will affect future hydro-electric developments in the Yukon and may affect existing developments undergoing relicensing.

Canadian Environmental Assessment Act (CEAA)

CEAA enables the Federal Government to assess the environmental, and to a lesser extent, the social and economic impacts of resource development on Federal lands. CEAA is also used when the Federal Government proposes a project, financially supports a project, or regulates a project (such as by issuing a water license). CEAA attempts to document the environmental effects of a proposed project and determine the need to mitigate these effects, to modify the project plan, or to recommend further assessment. CEAA does not apply on First Nations Settlement Lands.

Yukon First Nations Final Agreements

Individual First Nation Agreements flow from the Yukon First Nations Umbrella Final Agreement. Among other items, these agreements detail how resources may be developed on land that is owned by each First Nation. For example, members of a First Nation may require a share in a hydro-electric development on their traditional territory. The details differ for each agreement, and not all First Nations have their Final Agreements completed. Therefore developers must become familiar with the First Nation having a claim in the territory where they propose a development.

Development Assessment Process (DAP)

The Development Assessment Process was negotiated and agreed to as part of the Yukon First Nations Umbrella Final Agreement. It is intended to provide a comprehensive and integrated way to assess resource development in the Yukon. DAP will consider social, economic, and environmental impacts, as well as the impacts on the heritage and culture of Yukon First Nations people. Unlike CEAA, it will apply to developments on Territorial (Commissioner's) lands and settlement lands, as well as Federal (Crown) land. DAP is intended to replace CEAA for development assessment in the Yukon.When passed, DAP will become law in the Yukon.

NUGs Generating for Private Use

Non Utility Generators (NUGs) may generate power to supply their own demand, or they may generate power for sale. *Micro Hydro in Yukon Volume II: A Guide to the Regulatory Process* was prepared for the Department of Economic Development in 1985. It gives a detailed description of what is involved for NUGs developing a micro hydro facility for their own use. A summary is provided below. For those wishing more detail, a copy of the guide can be obtained through the Energy Resources Branch of the Yukon Government. The guide covers the following steps.

1. Preparation of background information
2. Water use licensing application process
3. Land tenure application process
4. Land use permit application process
5. Other government agencies

Step 1. Preparation of background information

The first step of the process helps determine the feasibility of the project. If this step is done thoroughly, it minimizes delays later in the process. This step includes a search of potential property ownership conflicts through a land title search, mineral claim search, Yukon First Nations Land Claims area search and registered trapline search. If no land title conflicts are found then this step can be continued with an assessment of the site's suitability for development. The data collected from the assessment is also necessary to obtain water use and land use licenses. The site assessment should include a site reconnaissance, site data collection, project planning and consultation with affected parties.

Step 2. Water use licensing application process

The second step is required for anyone using inland waters in the Yukon. The Yukon Territory Water Board issues water use licenses after a formal review process has been successfully completed. This step involves filing an application along with the data gathered in the first step. The site will be inspected during construction and operation to ensure that the license conditions are met.

Step 3. Land tenure application process

The third step is necessary if the project is to be developed on Crown Land or Commissioner's land. Crown land is administered by the Department of Indian Affairs and Northern Development and Commissioner's land is administered by the Yukon Government's Lands Branch. This step involves filing an application, followed by a full review process.

Step 4. Land use permit application process

A Land Use Permit is necessary before construction can begin. A land use permit authorizes a person to carry out a specific land use operation at a specified place, during a stated period of time, and subject to conditions designed to protect the environment. It is issued by the Department of Indian Affairs and Northern Development. Again, an application must be filed, along with the relevant background information gathered during step one. Land use inspections will be done by DIAND during construction and operation to ensure that the permit conditions are being met.

Step 5. Other government agencies

Other government agencies that may need to be contacted are as follows:

- the Federal Department of Fisheries and Oceans, if there are potential effects on fish, fish passage and fish habitat;
- Transport Canada, if a navigable watercourse is to be affected;
- DIAND, for a quarrying permit, if aggregate or building material is to be obtained from a source off-site; and
- First Nation governments, if applicable.

Each project will be different; however, a general time frame for the whole process to be completed is approximately two years.

NUGs Generating for Sale

For NUGs that wish to sell the power they generate, the process is similar to the one described above. However, there are a few more issues that they must consider, beginning with the first step: as with any commercial venture, the feasibility study should include a market analysis. This analysis should consider the economic issues described earlier in the paper.

If a NUG sells its power to a utility, the Yukon Utilities Board will be involved, through review of the contract cost. The YUB is the body that approves the rates utilities charge for their service to Yukon customers. Since a utility's rates may be affected by buying power from a NUG, the YUB has the mandate to review the contract's financial effects and decide whether the cost should be passed on to rate payers.

Utilities

When utilities decide to develop a hydro site, they follow a similar process to a NUG in developing the facility. They do a detailed feasibility study, and go through the water use, land tenure and land use permitting processes. The study costs and the development will also have to be approved by the YUB, at an appropriate time, to assess its impact on electrical rates.

Environmental Issues

The Yukon Perspective

Hydro electric facilities can have a significant impact on the watershed in which they are placed. Storage facilities, in particular, can affect the hydrology, geomorphology, wildlife, and aquatic life of the lakes, rivers and shore lands. In the Yukon, these impacts raise a number of issues — some which offer opportunities for hydro development and others that present challenges.

Hydro developments provide the opportunity to generate energy using a local, renewable resource. This means that a smaller amount of petroleum product may need to be imported, so more money stays in the Yukon. Displacing imported fuels with local resources has consistently been a goal of Yukon Governments.

Hydro electric energy is also seen by many as a "clean" source of power, in that it does not involve the air pollution associated with burning fuel. When a hydro plant displaces diesel generators, or other forms of power production involving hydrocarbon combustion, it also displaces the greenhouse gas emissions and other air contaminants that come from that combustion. The main greenhouse gas it displaces is carbon dioxide. However, biogas from organic decay in new reservoirs contains methane, which is a more potent greenhouse gas than carbon dioxide.

The biggest challenge to new hydro developments in the Yukon could come from the fact that so many of

Wareham Dam (Courtesy of YEC/YECL Archives)

Yukon rivers are wilderness rivers, because so little of the Yukon has been developed by humans. This was not much of a concern for past developers in the Yukon, but the public's concern for wilderness areas has been rising. This affects both storage and run-of-river hydro developers. According to the *1995 Yukon State of the Environment Report,* approximately 80% of the Yukon is wilderness, compared to 41% of all of North and Central America and 3% of Europe. Thus, the Yukon is viewed internationally as an important wilderness area. As well, 9% of the territory has some form of protected status, such as a park, wildlife area, managed resource protected area, or has Canadian Heritage River Status. Opposition to developing an otherwise undeveloped river can come from conservation groups, First Nations people who have traditionally used and continue to use the area, recreational groups and the tourism industry.

Another challenge faced by hydro developers in the Yukon comes from the impacts of hydro facilities on fish and wetlands. The impacts include blocking fish migration routes, flooding or drying shallow spawning waters and flooding or drying wetlands important to migrating water fowl and aquatic mammals.

Impact on fish

The following impacts have been documented in the *1995 Yukon State of the Environment Report*, for each of the Yukon's utility-owned hydro facilities.

- Mayo River (Wareham Dam) - Salmon blocked from migrating upstream to Mayo Lake. No fish ladder.
- Aishihik Lake - Eliminated East Aishihik River rainbow trout population; suspected reduction of whitefish age classes in Aishihik Lake. Resource studies ongoing.
- Whitehorse Rapids - Juvenile fish mortality resulting from passage through hydro turbines or spillway. Fish ladder since 1959. Hatchery since 1984.
- Fish Lake - Dam rebuilt or replaced several times. Barrier to fish migration in past. Impact on fish unknown. Fishway installed.

Canyon Lake Spill Structure (Courtesy of YEC/YECL Archives)

As can be seen, mitigation measures, such as fish ladders, fishways and fish hatcheries have been taken at some of the facilities. New developments will be much more likely to proceed , when a careful assessment of the potential impacts has been made and well-planned mitigation measures have been proposed.

Impact on wetlands

According to the *1995 Yukon State of the Environment Report*,

> *"The greatest human impact on wetlands in the Yukon has been from hydroelectric development. ....The hydro dam at Whitehorse and the control dam downstream from Marsh Lake have significantly altered the high water regime upstream on Marsh, Tagish and Bennett Lakes. The most noticeable change is that wetlands on those lakes, noticeably McClintock Bay, Lewes Marsh, Tagish Narrows and Nares Lake, have extremely high water in the fall until after freeze-up, rather than a decline after a mid or late-summer peak. This has probably reduced the value of these wetlands for waterfowl during fall migration."*

The report goes on to note that this has also had a detrimental effect on muskrats, an important species for local trappers.

In recent years, the Aishihik Hydro facility has received considerable attention due to its potential effects on species that rely on the drainage basin's wetlands. YEC, with technical advice from the Champaign and Aishihik First Nations, the Territorial and Federal Governments, and other stakeholders is currently undertaking a series of studies on the affected area. The goal of the studies is to improve understanding of the effects of the facility so that it can be relicensed in a manner which considers all project benefits and consequences. The experience gained from this facility may be useful for planning future developments.

Credits

Prepared for the Cabinet Commission on Energy

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Glossary of Energy Terms

Kilowatt (kW) — 1000 watts - The amount of power available from a stream with a flow of one litre per second, with a head of 100 m.

Megawatt (MW) — 1000 kW

Kilowatt hour (kWh) — The amount of energy used in one hour. A 100 watt lightbulb consumes one kWh of electricity in ten hours.

Reader Survey

Please take a few minutes to answer the following questions so that we can better meet your needs for information about energy resources in the Yukon. Please return it to us at: Yukon Economic Development, Box 2703, Whitehorse, Yukon, Y1A 2C6

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___ Alternative Technologies

Did you find the information useful?

Has this issue improved your understanding of the Yukon's hydro resource?

Would you recommend this publication to your colleagues?

Are there any other topics you would like to see covered in later publications?

Appendices available with this issue are:

___ Appendix A YEC/YECL Resource Plan, Supply Side Binder A
___ Appendix B Micro Hydro in Yukon Volume II

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