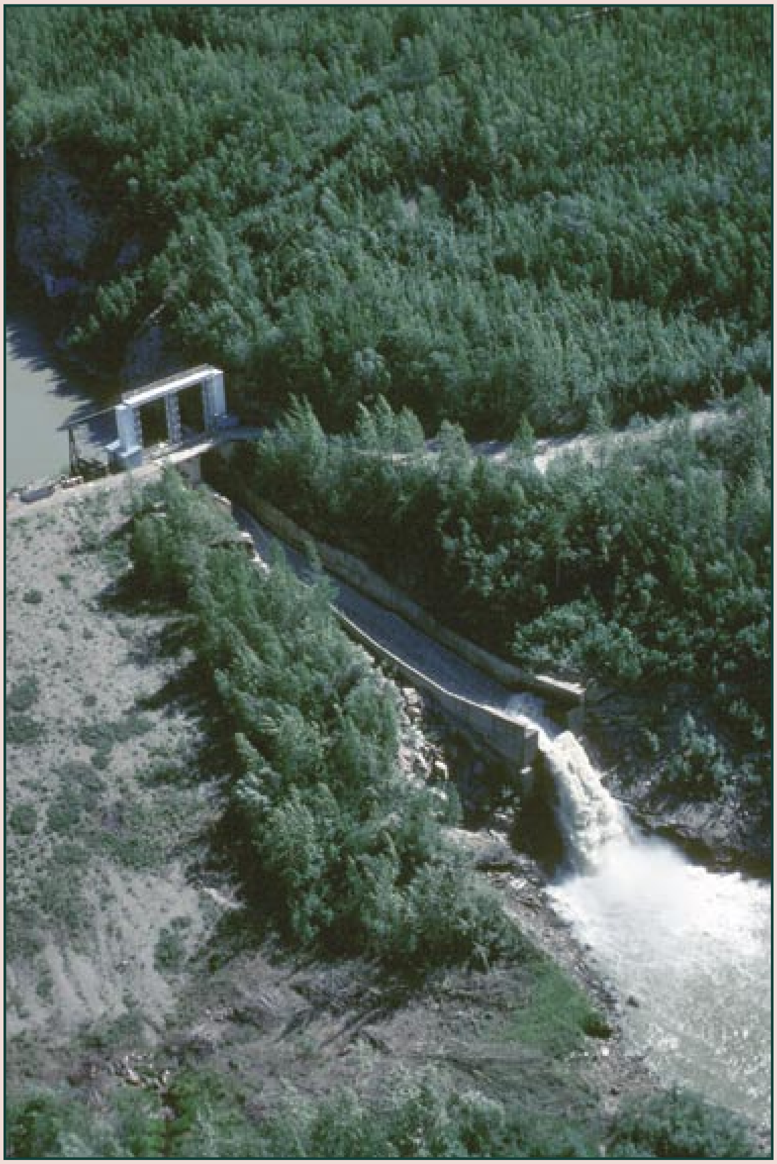
THE POWER OF WATER

The story of hydropower in the Yukon



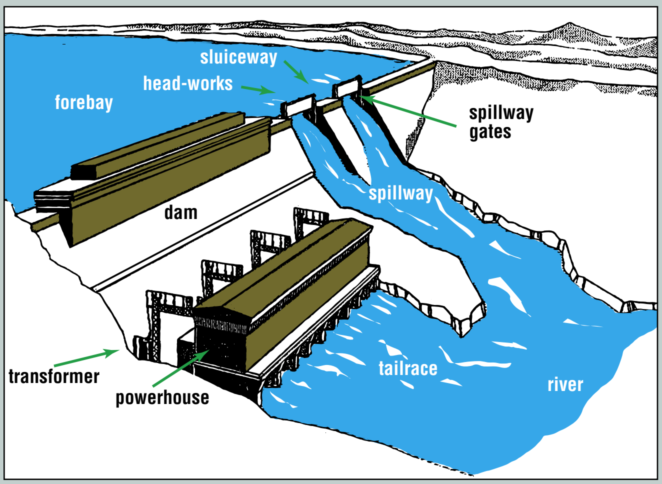
YUKON ENERGY

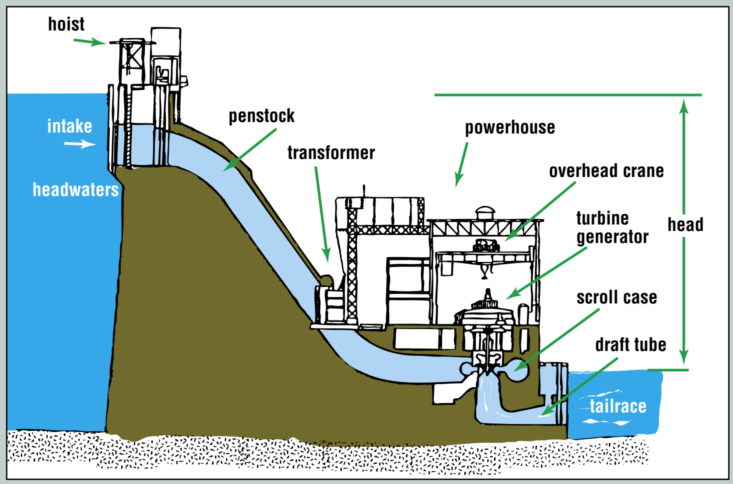
Yukon Development Corporation

energy solutions centre

Whitehorse Rapids Generating Facility, looking north towards the city of Whitehorse, 2000.

Schematic diagrams showing (left) parts of a hydroelectric generation station and associated facilities and (right) a larger-sized dam.





Both drawings adapted from December 1999 report of the Canadian Electricity Association

Facility	Owner	Summer/winter capacity	Turbine sizes and year built	Head	Control structures	Reservoir area	Features
Fish Lake	The Yukon Electrical Company Limited	1.3/ slightly <1.3MW	#1: 0.6 MW (1950) #2: 0.7 MW (1954)	#1: 128 m #2: 61 m	• storage control at Fish Lake outlet • head dams at Jackson Lake and Franklin Lake outlets	14 sq. km	• two turbines are located in separate powerhouses, one downstream of the other
Mayo Lake	Yukon Energy	5/5 MW	#1: 2.5 MW (1952) #2: 2.5 MW (1957)	32 m (Wareham)	• storage control at Mayo Lake • head dam is Wareham Dam	103 sq. km	• Mayo Lake dam is a timber crib dam, reconstructed in 1989 by Yukon Energy • usually only one turbine operating
Whitehorse Rapids	Yukon Energy	40/24 MW	#1: 5.8 MW (1958) #2: 5.8 MW (1958) #3: 8.4 MW (1969) #4: 20 MW (1985)	18 m	• storage control at Marsh Lake • head dam at Whitehorse Rapids	1,100 sq. km	• longest wooden fish ladder in North America
Aishihik Lake	Yukon Energy	30/30 MW	#1: 15 MW (1975) #2: 15 MW (1975)	175 m	• storage control at Aishihik Lake outlet • spill control dam at Canyon Lake	3,045 sq. km	• only multi-year reservoir storage on WAF grid • first underground hydroelectric facility north of the 60th parallel, in the western world

Major hydro facilities in the Yukon

Adapted from Economic Development report on hydro, March 1997

Cover photo: Wareham Dam, Mayo, Yukon (Yukon government)

YUKON HYDROPOWER

Placer mining on Miller Creek, 1894.

Parks Canada, Anita Johns Collection, YT-11

The Yukon, with its mountainous terrain and wealth of rivers and lakes, is a hydro engineer's dream.

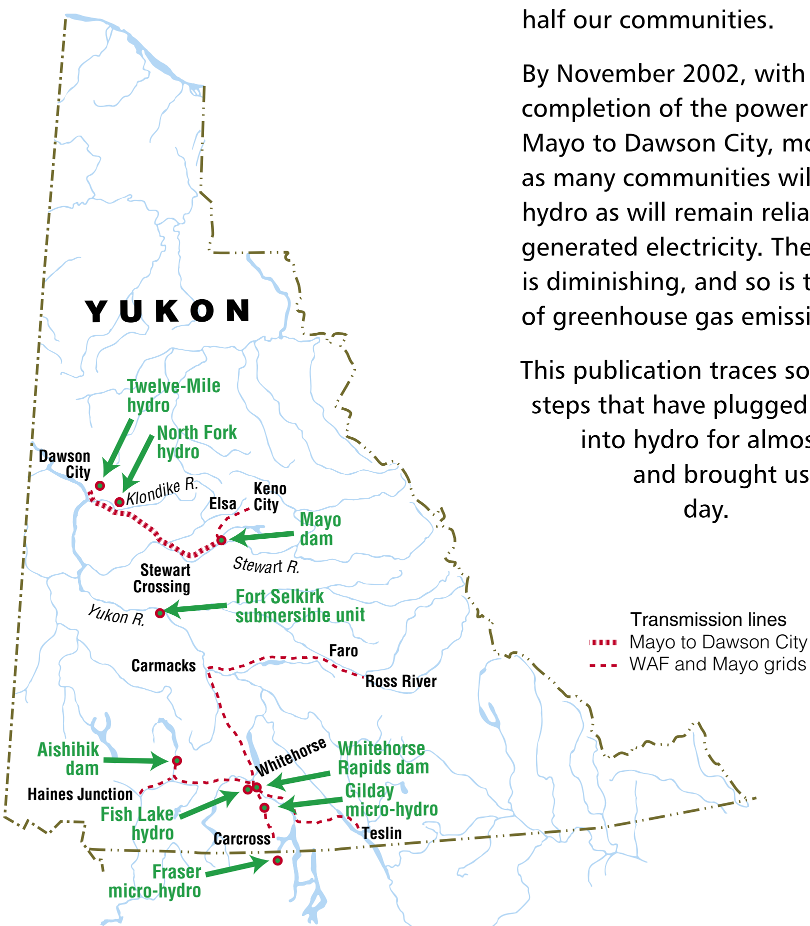
From the days of the Klondike gold rush, visionaries have imagined schemes to harness water. There was the Frobisher Project, which would have flooded Whitehorse, detoured the Alaska Highway and drained Yukon River headwaters into Atlin Lake and then through tunnels to Tulsequah on the Taku River to where a huge smelter was to be constructed. Or the Taiya project that would have tunnelled to tide water from Bennett Lake to make the Skagway, Haines and Juneau area the "industrial heartland of Alaska."

However, it's been more modest visionaries, driven by the demands of mining, who have built most of our hydro facilities.

Today, because of our isolation and relatively small electrical production, the Yukon is not part of the North American power grid. Instead, we have our own Whitehorse/Aishihik/Faro (WAF) system, which services about half our communities.

By November 2002, with the completion of the powerline from Mayo to Dawson City, more than twice as many communities will be served by hydro as will remain reliant on diesel-generated electricity. The role of diesel is diminishing, and so is the production of greenhouse gas emissions.

This publication traces some of the steps that have plugged the Yukon into hydro for almost 100 years and brought us to the present day.



Where it all began

Electrical power generation in the Yukon has almost always gone hand-in-hand with industrial development. In the Yukon, that has meant mining. So it is no surprise that our first hydropower plant was built in the Klondike.

During the 1898 Klondike gold rush, lone stampeders with shovels and a fever for gold tore apart the creek beds of the Klondike River watershed. Through shafts burned into the permafrost by hand-stoked fires, they winched gold-bearing ore to the surface and used the water of the creeks to wash it through their sluices. In 1898, an estimated $24 million in gold was taken from these creeks.

Within a year, crews of miners began to use newly developed industrial methods to accomplish the same goal. Steam points were driven to thaw the ground, while steam-operated, self-dumping hoists piled pay dirt on the surface and steam-driven pumps pushed water through the sluice boxes. Despite the technology, gold recovery declined as easy reserves were exhausted.

Thinking hydro

In 1898, A.N.C. Treadgold, a brilliant, Oxford-educated Brit, came to Dawson City as a special correspondent for *The Manchester Guardian* and *The Mining Journal*.

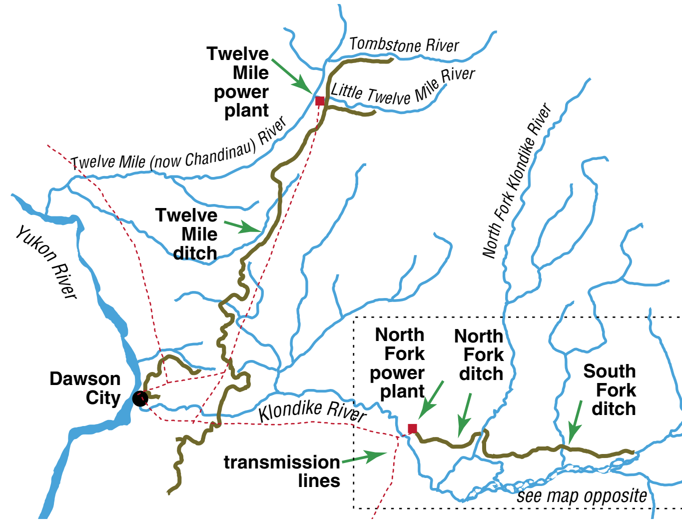
According to Lewis Green, writing in *The Gold Hustlers*, Treadgold realized that as creek bottoms were mined out, large quantities of water would be needed to mine and sluice the gold to be found higher up on the hills above the creeks.

By 1899, he was corresponding with Clifford Sifton, Canada's Minister of the Interior — the person responsible for regulating mining in the Yukon. Treadgold proposed a "big scheme" for mining the Klondike using hydropower and a system of ditches. To do that, he would need to control a lot of mineable ground.

With money from British backers, he bought up claims and sought a mining rights concession from Sifton so that he could attract more financing for hydroelectric and water developments.

On June 29, 1901, Treadgold was granted a concession, but within two years, it collapsed in controversy. His British financiers abandoned him.

Treadgold and his rival, Joe Boyle, holder of the Boyle Concession, still saw the need for water and hydropower. In 1903, they took a 14-day pack-horse trip up the Twelve Mile River and the North Fork of the Klondike in search of water sources. Treadgold returned with the idea of building a power plant at the Twelve Mile River.



Twelve Mile power plant

In the winter of 1905-1906, Treadgold attracted new money from the American Guggenheim family who were involved in mining and smelting in Colorado. With financing secured, he was able to begin work on the Twelve Mile River site.

That spring, Treadgold's engineers arrived at the site to survey for a plant. From the Little Twelve Mile River a ditch and flume would carry water to a power plant capable of generating 1,650 horsepower from an effective 650-foot head (the height difference between where water is drawn from and where it is used to power a turbine).

By August, steam shovels were digging the Twelve Mile ditch from the main valley above the plant site and crews were stringing transmission lines to the dredges in the gold fields. During the next winter, horse-pulled sleds freighted 3,000 tons of equipment and pipe to the site.

The Twelve Mile plant began producing power on May 28, 1907 and continued to operate during the dredging season — May to October or November — until it was shut down in 1920.

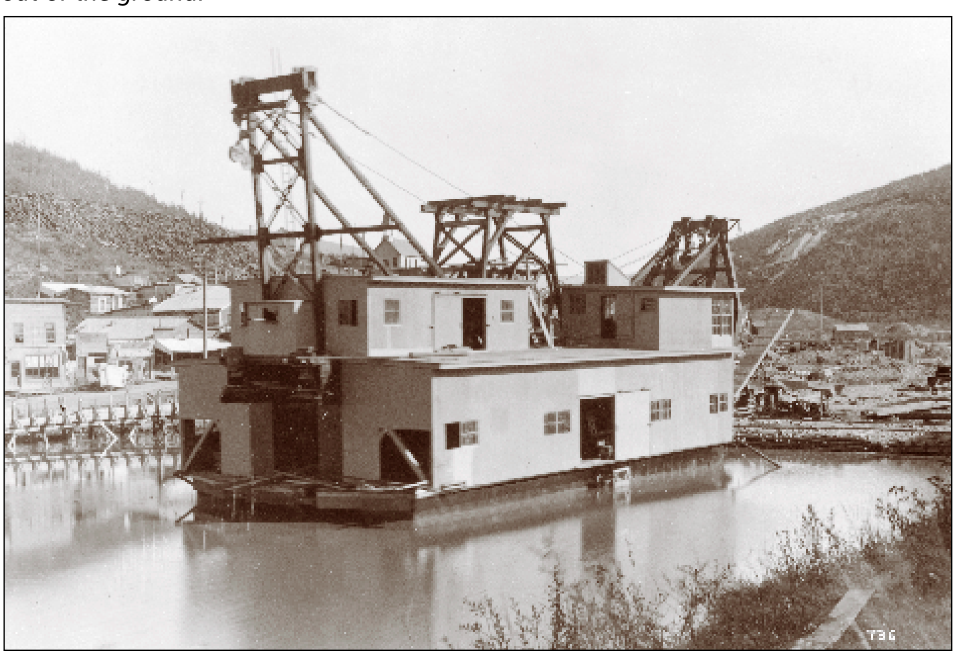
By 1908, Treadgold seemed to have had a falling-out with the Guggenheims. He was buying gold placer claims in competition with their Yukon Gold Company, apparently financed, again, by English backers. In June 1908, he acquired Dredging Lease Number 23 and once again needed power to work his ground.

North Fork power plant

In the summer of 1908, three Dawson City men, Grey, Dolan and Strong, who might have been working for Treadgold, acquired a water grant for a hydroelectric power plant on the Klondike River. A survey was made for a ditch from the North Fork to the Klondike plant site.

By the fall of 1909, a 20-person crew was working to satisfy water grant

Dredge no. 9, 1911. Dredges acted like conveyor belts with buckets to scoop gold out of the ground.



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conditions. Before breakup in 1910, 150 tons of supplies and equipment were freighted into the site. That summer, 300 workers and two steam shovels were building a six-mile long ditch and flume from the North Klondike River to the plant site. The plant it would supply was expected to develop 10,000 horsepower from an effective head of 228 feet.

Treadgold was on site that summer, supervising work that also included powerlines from the plant site to Hunker Summit and Dominion Creek, and to his dredge just east of Dawson City.

In February 1911, 700 tons of material, mostly steel pipe for the penstocks to the turbines, were freighted over the winter road. By that spring, a crew of 100 was putting the finishing touches on the plant.

By early summer, North Fork was supplying electrical power to nine dredges.

The North Fork plant was initially owned by Treadgold. But later, with the amalgamation of his Granville Mining and Joe Boyle's Canadian Klondyke Mining Company, the shares were turned over to Boyle, and Treadgold lost his second power plant.

For the next seven years Boyle controlled North Fork, even tying it into


Public Archives of Canada

Twelve Mile power plant flume under construction.

the Dawson City social calendar. Every Christmas, there was a dance out at the power plant for the high school students.

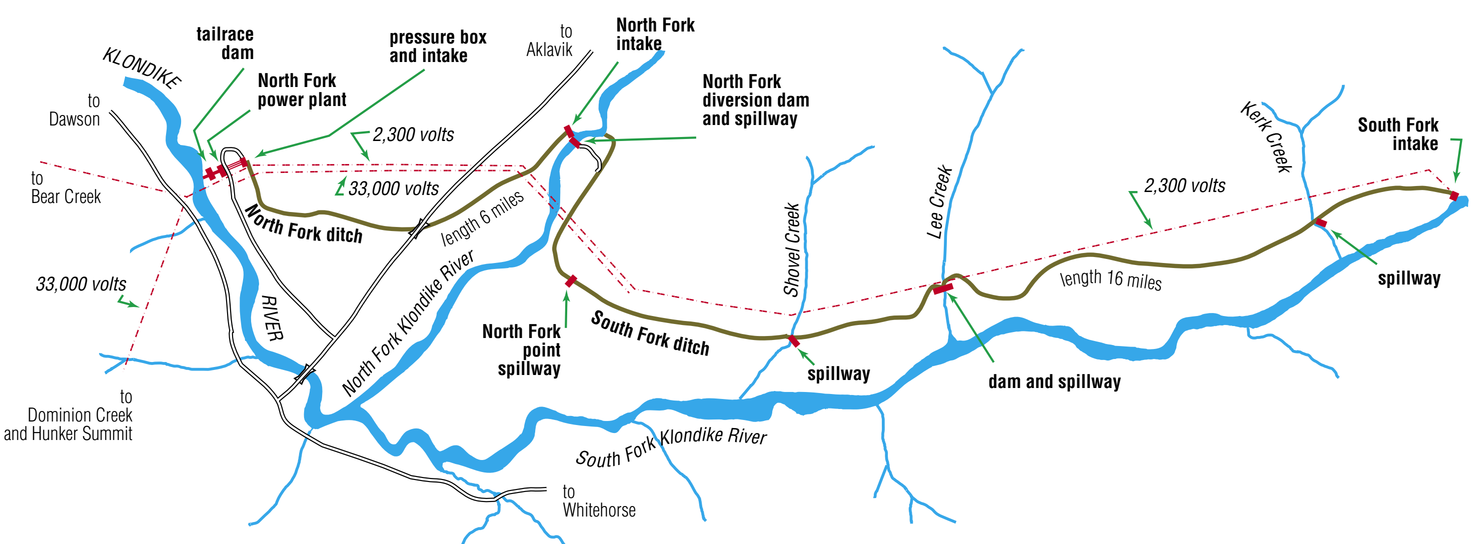
In 1920, Joe Boyle's Klondike mining empire collapsed. And in March 1922, Canadian Klondyke Power Company assets became part of the New North West Corporation Limited.

In 1923, Treadgold began another attempt to consolidate Klondike mining and power interests. Over the next two years, the Treadgold Company acquired operating control of earlier consolidations, including New North West, in a blur of stock and cash transactions.

On Treadgold's return to the Klondike in 1925, he visited his North Fork Power Company hydroelectric plant. An operator at the plant reported that Treadgold acted like an excited schoolboy on his visit, saying, "And to think that I lost the whole thing for 15 years."

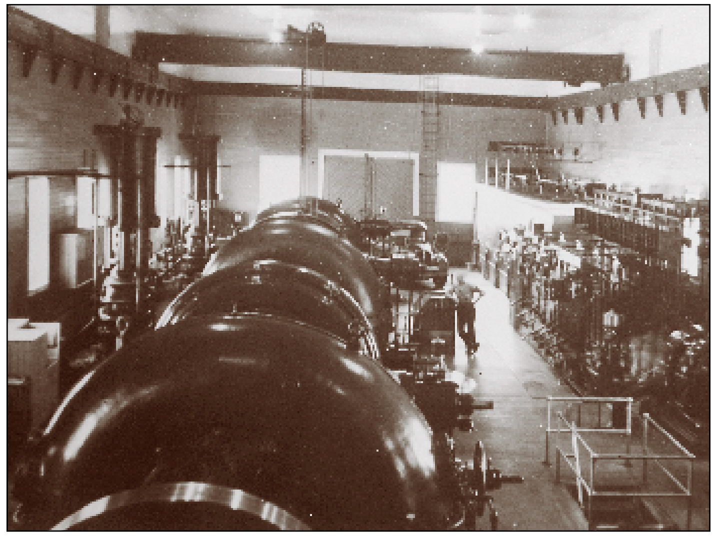
In 1928, the new holdings became known as Yukon Consolidated Gold Corporation Limited.

Always the visionary, Treadgold soon began planning for a new ditch from the South Fork Klondike River to the North Fork intake. However, by the time it was completed in 1935, and



Adapted from December 1931 general plan

Yukon Archives, Finnie Coll. 81/21, #274 pho 140



Yukon Archives, Butterworth Coll. 9558

Powerhouse at North Fork, (left) 1922 and (right) interior, 1913. In 1935, the building was extended to house a third unit.

another 5,000-horsepower turbine was added, he had again lost the plant.

A Yukon Consolidated Gold Corporation Limited lawsuit had stripped him of all his Klondike interests, including the North Fork plant. He fought the judgement in the courts until the early 1950s, by which time he was well into his 80s. He never again won back his Klondike dream.

Technical challenges

During its initial year, the North Fork plant ran well until freeze-up. In late October, frazil, or slush ice, formed in the canal and jammed the feed to the plant, putting it out of commission that winter.

In 1912, under Boyle's management, a solution was developed. During the first cold weather, the canal was kept full, at a constant level, so that ice could form on the top. Once a thick ice coating was in place, the water level in the ditch was returned to normal and protected from freezing by electric heaters. This allowed the plant to run year-round, although power to the dredges was restricted during the freeze-up period.

In January 1934, water in the North Fork dropped so low that there was little to supply the plant. At the same time, temperatures plunged and the ditch burst. It was late February before repairs could begin, and mid-April before the plant was again operating.

In the meantime, the Dawson City thermal electric plant burned 24 cords of wood a day. A wood crew worked 16 hours a day in temperatures down to 66 below to keep it fed.

End of an era

The North Fork plant operated until 1966, when the last Yukon Consolidated Gold Company dredge shut down. A number of studies have been undertaken over the years to explore the feasibility of re-activating the North Fork plant. All have recommended against it, largely because of the difficulty of maintaining power production through the winter months when demand is the highest.

(left) North Fork diversion dam and spillway. (right) South Fork intake. Both from August 1982.

Yukon Energy

Yukon Energy

FISH LAKE – BUILDING WHITEHORSE'S FIRST HYDRO PLANT

All photos for Fish Lake, courtesy of YECL

#1 Hydro tailrace with rock wall and gardens created by workers at the site.

One of the pioneers of hydro in the Whitehorse area is John Scott, now in his 90s and still living in his house on Hawkins Street. In 1935, when he was a mining engineer at the Treadwell-Yukon Mine at Keno Hill, he married into a family that ran an electrical utility company. His bride, Dorothy Phelps, was the daughter of Willard Phelps, the Whitehorse lawyer who had handled the incorporation of The Yukon Electrical Company Limited (YECL) and was a major shareholder.

In 1948, Scott and his brother-in-law, John Phelps, started discussing the possibilities for hydroelectric power in Whitehorse. Since 1901, the town's electricity had been generated by thermal and, later, diesel power plants.

According to John Scott, Phelps had already looked at several possibilities for a hydro site, but had not found anything that would work or was available.

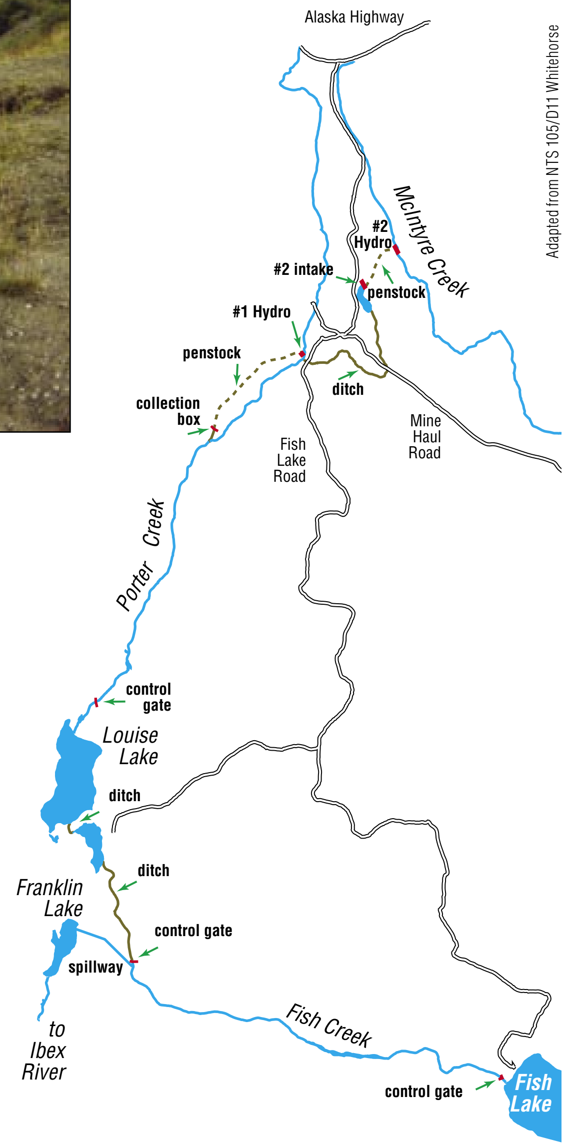
Scott had seen small hydroelectric plants in Juneau, Alaska. He had also read geological reports that suggested that at one time, Fish Lake had drained into the Yukon River by way of Porter Creek, rather than through Fish Creek into the Ibex River as it did then. He thought that if the flow could be re-directed to the old way, there might be enough water and head for hydroelectric generation on Porter Creek.

That winter, after studying all the contour maps they could find, the two men skied and snowshoed the area. They concluded that their proposal looked feasible so Scott resigned from Yukon Consolidated Gold Company in Dawson City. With the approval of Willard Phelps and a budget of $60,000, they went ahead.

The next summer, Scott and a school principal, Larry Todd, walked the ground and surveyed the area. According to Scott, "We did no drilling, permeability soil tests or any other such foolishness. We managed to obtain a few water measurements, but they only gave us a vague idea of the volumes available."

Phelps leased land for the plant from the Pueblo Mine north of Whitehorse and bought a Pelton wheel hydro plant from the Engineer Mine near Ben-My-Chree on Tagish Lake. It was a two-nozzle machine with 24 buckets that could drive a generator producing 2,300 volts and 100 amps. They took the plant apart and barged the equipment and its wood stave pipe pieces to Carcross. The following winter, it was trucked into Whitehorse and hauled up to the old Pueblo Mine site.

Louise Lake discharge, upstream side.



Building begins

In 1949, the same year Scott and Phelps applied for a water licence, they began construction. They pushed roads into Fish Lake, Louise Lake and up Porter Creek from the Pueblo Mine. They dug a ditch more than a kilometre long from Fish Creek to Louise Lake. To deal with 200 metres of permafrost, Scott says, "We made huge piles of bush and trees…four or five hundred feet long, set fire to them and thawed our way down to grade. It took three fires."

To cut through the glacial moraine — the ridge of gravel — at the head of the Porter Creek valley, they let loose the water in Louise Lake above it. They dumped silt into the lake to seal the gravel in the moraine and, with a Cat, made a starting cut across the top of it. Scott says he took a break to eat. By the time he wandered back, enough cutting action had happened that he would have lost the bulldozer if he'd been ten minutes later!

A wooden collection box was built about half a mile above the plant site to funnel water into the penstock. Work crews sorted through the wood stave pipe pieces and reassembled what could be used at the top end, lower pressure part, of the penstock. Ed Jacobs, who later ran Jacobs Industries in Whitehorse, worked with John Phelps to weld the steel pipe that would carry the water the rest of the way from the collection box to the powerhouse. At the same time, a foundation was put in for the #1 Hydro powerhouse.

In March 1950, the Yukon Hydro Company Limited was incorporated. By that spring, the Pelton wheel and generator had been cleaned up and bolted into place at the powerhouse. Finally, in May, #1 Hydro plant began operation.

Ninety Years North, the history of YECL by Allen Wright and Flo Whyard, recounts a C.D. Taylor story of a government inspector who visited the site "after

Reservoir above #2 Hydro showing intake shack.

the company put in its application for water rights, in order to determine the feasibility of the plant. He looked around and asked, 'What's all of this?' The operator explained that it was a plant, which was running and providing power. 'Oh, well, then,' the inspector said. 'It must be feasible.'"

In 1954, #2 Hydro plant was built on McIntyre Creek and a 650-horsepower, British-made Gilkes turbine and Westinghouse generator were installed. It used the outflow from #1 Hydro.

Technical problems

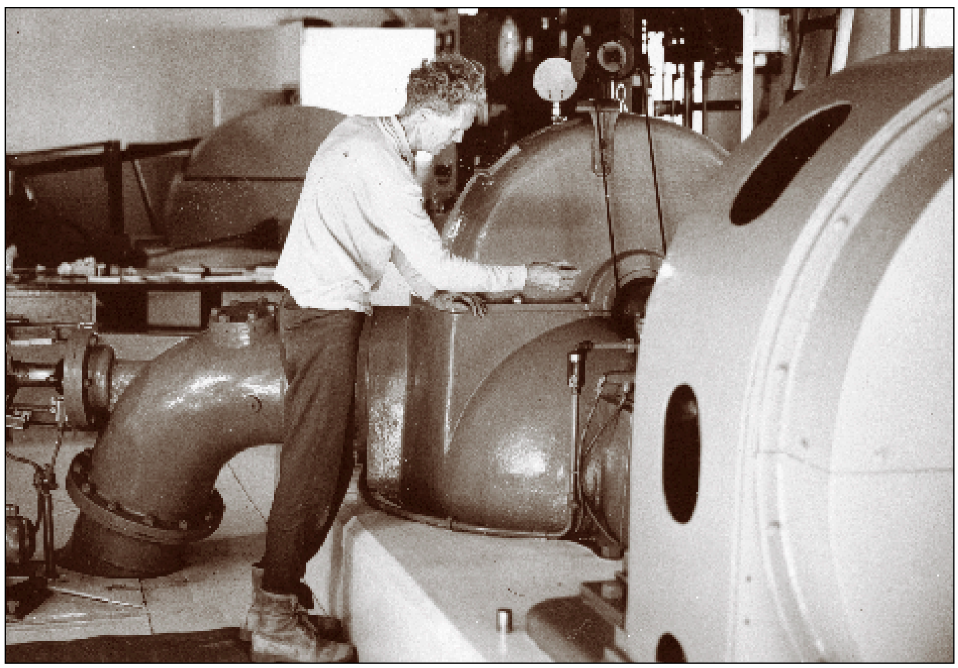
The major technical concern at the new plant was, in John Scott's words, "whether we could keep the small flow of water available to us moving through open ditches in the extreme weather conditions we anticipated."

In her memoirs, Dorothy Scott recalled, "I think back on those first years with sheer horror. Frazil ice and ditches that leaked at 2 a.m. became our life…as did beavers…that dammed up the water supply."

In the end, the frazil ice was dealt with in the same way as at North Fork: the ditch feeding the plant was kept high during freeze-up so that the slower water velocity allowed a protective ice layer to form.

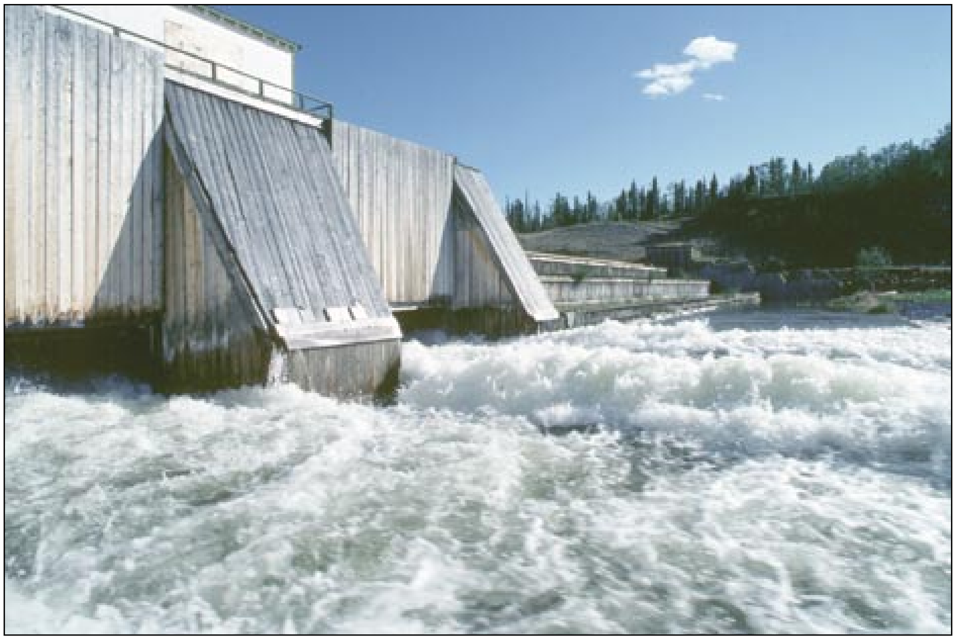
Some years were dry and low water flows limited power generation. To deal with this, silver iodide vaporizers were used to seed the clouds, John Scott said. "They worked, too. Except that the clouds always seemed to drop their loads over the Grey Mountain area instead of in our watershed."

Today, #1 Hydro and #2 Hydro have largely overcome these difficulties and continue to feed power into the Yukon power grid.



(top) View of the #1 Hydro site. (middle) Paul Sparks working on the equipment at #1 Hydro, 1972. In the background is the original Pelton wheel from the Engineer Mine and in front is the Wilkes turbine with the Westinghouse generator in the very front. (bottom) Dorothy and John Scott, 1972.

MAYO – INVESTING IN HYDRO


Yukon government

In the middle of the 20th century, as more attention became focused on resources in the north, governments realized that one of the obstacles to industrial development was the cost of power. Diesel electric generation offered the most flexible and portable power for northern mines, with relatively low capital costs. However, imported fuel was an ongoing drain, diesel plants needed regular overhauls and mine operators wanted cheaper power.

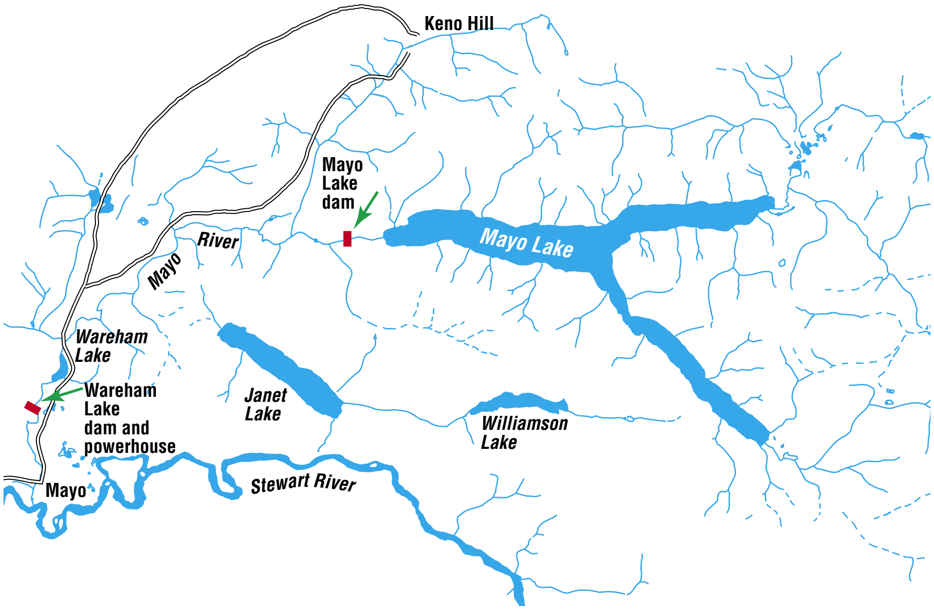
That led to pressure on the Canadian government to help supply electricity to the north. As a result, the North West Territories Power Commission (NWTPC) was created in 1948. Its mandate was "to facilitate the construction and operation of power plants for mining and other interests and to encourage the development of mining properties."

E.W. (Ted) Humphrys, now retired and living in Ottawa, was the first engineer for the commission.

According to Humphrys, Ventures Limited, the company that owned the Giant Mine, was so happy with the results of using hydro at its mine in the Northwest Territories, that it began to investigate hydro options for its United

(below) Mayo storage dam under construction, May 1952, and (above) in 1988.


All photos of construction of Mayo dam, courtesy of Yukon Energy



Adapted from November 1949, location map

Keno Hill Mine north of Mayo in the Yukon.

It lobbied the federal government for help, and in March 1949, the *North West Territories Power Commission Act* was amended to allow NWTPC to extend its activities to the Yukon.

In 1950, W.G. Stewart surveyed the Mayo area and identified the Mayo River as a suitable prospect for hydro development. NWTPC contracted Montreal Engineering Company, which had designed many northern projects, to conduct feasibility and engineering investigations for a power plant with a target capacity of 2,500 to 3,000 kW. The result was a proposal for a generating facility at Wareham Lake on the Mayo River just north of Mayo, and a control structure where Mayo Lake drained into the river.

David Duguid, now retired and living in Chemainus, B.C., was a junior engineer on the project. His job was to oversee the work at the Mayo storage dam. A Scot, with electrical and civil engineering degrees from Edinburgh University, he served in the Royal Electrical and Mechanical Engineers during the war, immigrating to Canada in 1947.

Mayo was his first experience of northern Canada. He describes it as very difficult, "a cultural shock, you might say," and remembers watching oldtimers, there since the gold rush, down water glasses full of over-proof rum.

Duguid says that in northern Canada, a number of factors make hydro developments very costly: small scale; high transportation and construction costs; and distinct northern factors such as permafrost and frazil ice. On top of this, NWTPC needed to balance construction costs against anticipated demands. If the primary power demand was to be from a mine, as was the case at Mayo, when the ore was exhausted, the load and customer would disappear and the remaining ratepayers would have to pick up the cost. As a result, Duguid says, the commission and Montreal Engineering built safe, reliable products without a lot of frills. "We couldn't afford to build Cadillacs and had to build Chevrolets."

Mayo Lake storage dam

The design for the Mayo Lake storage dam called for a five-metre high rock-filled timber crib dam. The large surface area of the lake allowed for the simple construction of a cofferdam, or temporary dam, across its outlet to allow construction to proceed on the downstream side. Local Stewart River timber was used for the cribbing and facing material.

During construction, permafrost was discovered at the abutments where the cribbing was to be joined with the shore. Since rigid structures built on permafrost can tilt and fracture if it thaws, Montreal Engineering amended the design to use earth-fill for the abutments. If there was settling, this fill would slump to conform without losing its structural integrity. Steam points were used to allow steel sheet-piling to be installed at the junction between the earthen abutments and the spillway.

David Duguid, Ted Humphrys and Steve Arbutina at Steve's cabin at Mayo Lake.

David Duguid

Despite an anticipated life of 15 years, the Mayo storage dam has lasted more than half a century, with frequent inspections and a major reconstruction in 1989. Duguid thinks that it's likely that long, cold winters contributed to the longevity of the cribbing. The original construction in 1951 cost $500,000; the reconstruction cost was about $5 million.

Cofferdam under construction at Wareham dam, October 1951.

Wareham Lake dam

Downstream, at Wareham Lake, engineers constructed a 32-metre high earthen dam with a concrete spillway. The intake structure fed water to a 2,500-kW power plant turbine through a tunnel to the powerhouse below the dam.

During the summers of 1951 and 1952, crews erected 69-kV transmission lines to tie the plant to Mayo and United Keno Hill Mines in Elsa and Keno. The plant was officially commissioned in November 1952.

In 1957, a second unit was installed in the powerhouse, bringing the plant's generating capacity up to 5,150 kW. The plant was now capable of producing an average of up to 43 GWh of electrical energy per year. That was enough power to supply all the mines and communities on the Mayo grid, using a renewable energy source.

According to David Duguid, at the time the Mayo dam was built, no environmental studies were required. A keen freshwater angler himself, he regretted that the healthy run of spring salmon on the Mayo River was brought

Near disaster

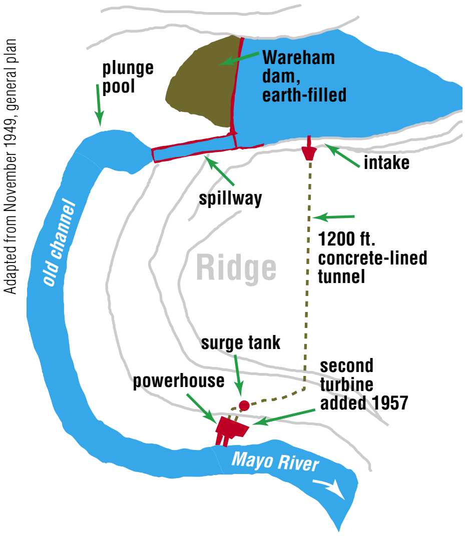
In 1951, while surveying at Wareham Lake, David Duguid found that the ground over the penstock tunnel at the powerhouse site was shifting — sometimes as much as one inch per day. His colleagues dismissed his readings.

Only when the timbers supporting the penstock tunnel walls and roof cracked and split, did they call in the geologists. They found that a huge slab of rock over the tunnel was shifting downhill along a fault line.

As a result, the tunnel was abandoned and the powerhouse was shifted 200 feet upstream.

Main blast at new powerhouse excavation with abandoned tunnel entrance in foreground, August 1951.

(right) View of construction of the concrete-lined diversion tunnel at the Wareham dam, November 1951.
(below) General diagram showing tunnel route through the ridge.



to a stop at the Wareham Lake dam. He recalls that most of the salmon were big fish, 20 pounds or more.

Unlike some hydro plants in the Yukon, the Mayo system has never experienced water shortages, largely because of the huge, regulated storage capacity of Mayo Lake. In fact, since the closure of United Keno Hill Mines in 1989, almost 80 percent of generating capacity has been spilt over the Wareham Lake dam. Even when operating at full capacity, water is usually spilled from early spring until November.

During the 1990s, work was done on the Wareham dam and plant, and transmission lines were upgraded. Currently, a transmission line is under construction from Mayo to Dawson City. It will allow the Mayo dam's excess power to displace Dawson City's diesel-generated electricity. This could reduce greenhouse gas emissions by up to 16,800 tonnes per year.

(left) Placing core material at Wareham dam; looking downstream from the right abutment, July 1952. (right) David Duguid's work on the Mayo hydro project included surveys to see if a rise in lake levels would affect the few cabins and placer workings on Mayo Lake. He found that the most efficient way to take levels was from the streambeds.

David Duguid

WHITEHORSE RAPIDS – HYDRO FOR A CITY

All photos of construction of Whitehorse dam, courtesy of Yukon Energy

Looking northwest towards the area being cleared for the powerhouse. The city of Whitehorse is on the right, November 1956.

In 1952, the North West Territories Power Commission, encouraged by the success of the Mayo project, sought federal approval to examine possible hydropower resources in the Whitehorse area. At first, permission was deferred because a mining company, Ventures Limited, through a subsidiary, Northwest Power Industries Limited, was investigating the feasibility of the Frobisher Project, the proposed major hydropower development on the Yukon River and its head-waters.

However, by 1955, that scheme was off the table and there was a growing need for power in Whitehorse. At the time, two parallel systems were operating. The Yukon Electrical Company Limited (YECL) continued to supply downtown customers, and the Department of National Defence (DND) operated a diesel plant to supply the airport, Camp Takhini, Hillcrest, Marwell and parts of downtown. DND was considering the addition of a 1,000-kW diesel unit to meet anticipated air force needs, as well as those of the planned Whitehorse hospital.

YECL, seeing potential for corporate growth, lined up $2.5 million in financing to build at a Primrose Lake site identified by John Scott. The project died when the company learned that NWTPC was interested in supplying the Whitehorse market.

NWTPC, which became the Northern Canada Power Commission (NCPC) in 1956, had begun to study possible options. In addition to diesel, it looked at the possibility of a thermal plant near Carmacks, as well as hydro sites at Primrose Lake and on the Yukon River above Whitehorse. Because of uncertain coal reserves, Carmacks was ruled out, as was Primrose Lake after drilling results indicated poor conditions for dam foundations. Both

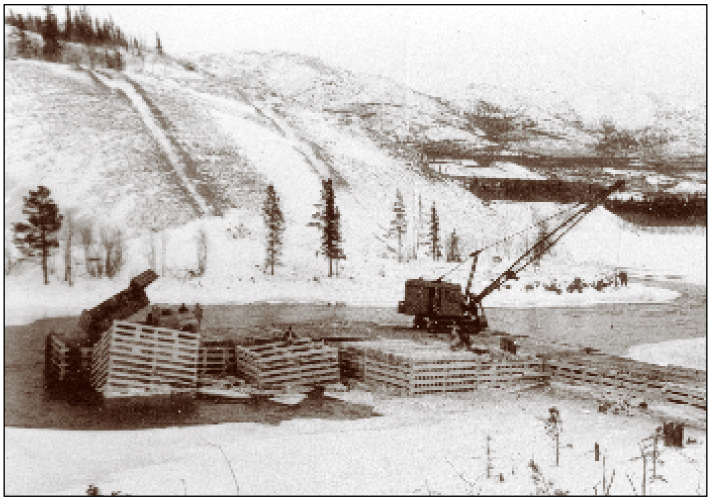
Lewes dam

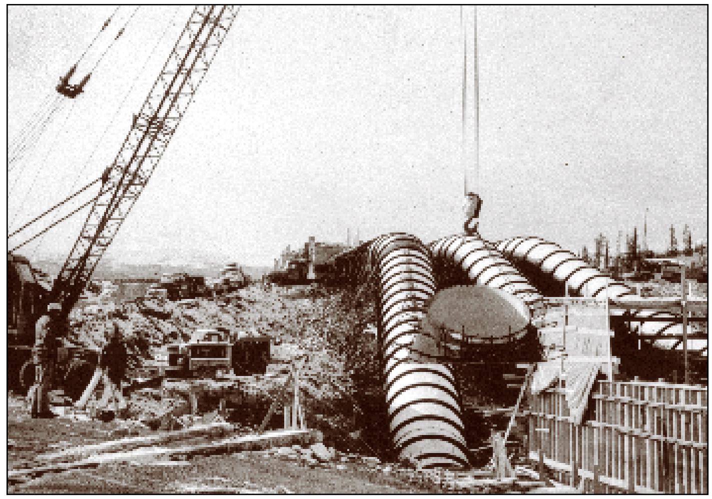
Yukon government

In the early 1920s, White Pass built the Lewes dam, just downstream from the Yukon River Bridge on the Alaska Highway, about 11 kilometres below the outfall of Marsh Lake. It was used to hold back the lake waters so that ice downstream on the Yukon River could be flushed with a pulse of water at spring break-up. As a result, navigation on the river could begin two to three weeks earlier than usual.

During the 1950s, as the Klondike Highway was extended north to Mayo and riverboat traffic declined, the Lewes dam fell into disrepair. Part of the dam was demolished in 1964 to allow boat traffic to pass.

In 1969, the dam began its second life as a water control structure when the Northern Canada Power Commission rebuilt it. Then, in 1974, a completely new structure was installed at this location, featuring 30 gates, a fish passage, and a boat lock to allow small craft to move up or down stream. The cost of construction was $3 million.





(left) Filling crib #18 with rock on the first cofferdam, looking east, 1957. (right) Penstock sections in position. The third penstock allowed for future installation of a third turbine and generating unit should power requirements justify the cost.

projects would also have required expensive transmission lines to Whitehorse.

At the time, one concern about a Whitehorse-Yukon River site was that the hydro capacity was likely to far exceed the future market for power, making it a very expensive project.

But by 1956, the Whitehorse Rapids site became affordable when it was clear that more generating capacity could be used to power electric boilers at the hospital.

Building begins

In the fall of 1956, construction began on an earth-filled dam, the sluiceways and an intake structure with three penstocks. Included was a fish ladder and barrier dam, required by an agreement with the Department of Fisheries and financed by a direct grant from the Government of Canada.

Timber was cleared from 250 acres above the dam site. The 14-metre high dam would create Schwatka Lake, almost a kilometre wide and 10 metres deep at the centre.

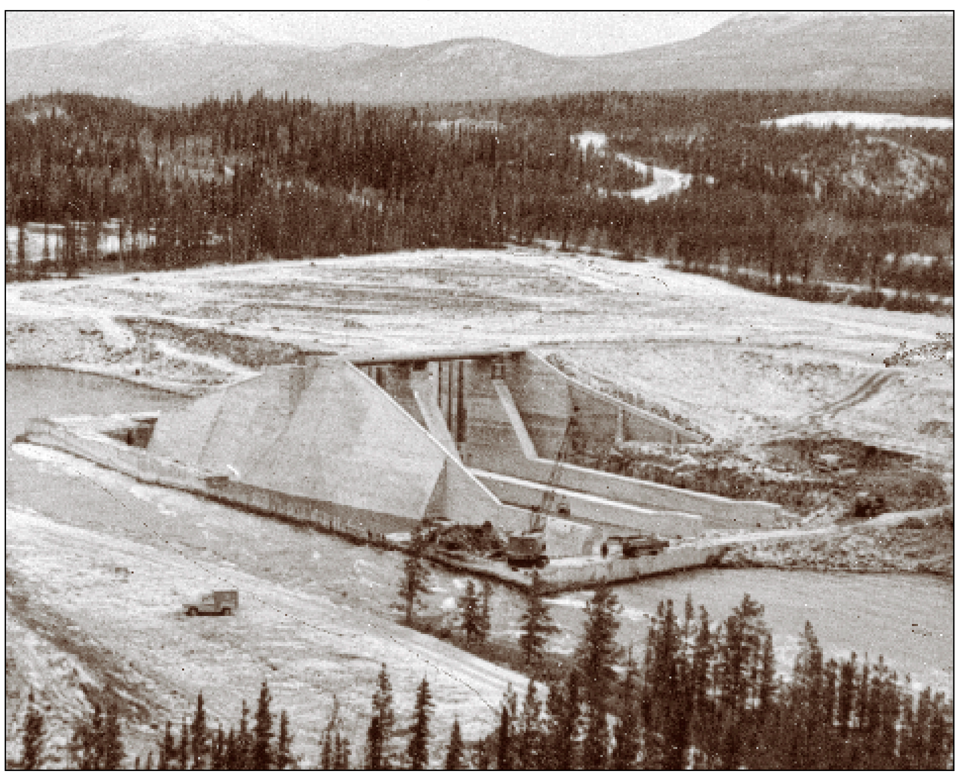
In the fall of 1958, NCPC installed two 7,500-horsepower turbines, capable of generating 11,200 kW. Through YECL, power was then supplied to DND buildings, boilers at the hospital, and the rest of the Whitehorse area. The total cost of the project was $7.2 million.

Third turbine

In 1966, studies confirmed that the installation of a third turbine was the most efficient way to supply the new Cyprus Anvil Mining Corporation lead-zinc mine in Faro. Between 1968 and 1969, NCPC installed an 8,200-kW turbine and constructed a 360-kilometre, 138,000-volt transmission line from Whitehorse to Faro to supply the town and mine.

When commissioned in 1958, the Whitehorse Rapids dam depended on the natural storage of the Yukon River and its headwaters. However, in 1969, with the third turbine in place, extra capacity was needed. The Lewes dam was rebuilt to serve as a control structure to regulate the level of Marsh Lake and provide storage for the Whitehorse Rapids power plant.

Sluiceway structure just before the cofferdam was removed, 1957. The cofferdam kept the river water out while construction proceeded.



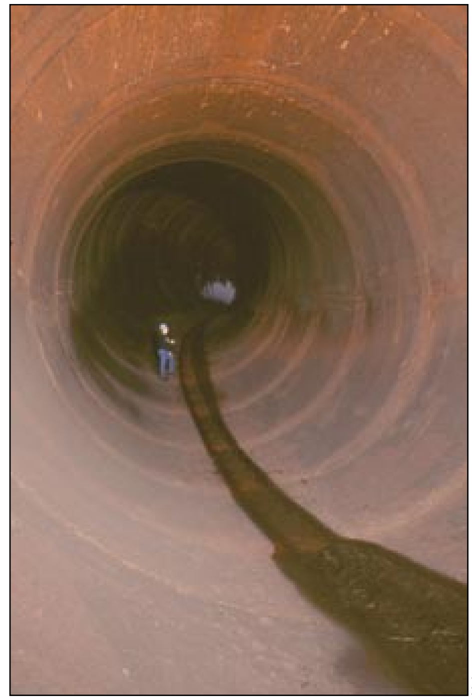
Even with the third turbine, diesel units were required at the Whitehorse Rapids plant to handle start-up and peak loads, and a standby unit was installed in Faro.

In the early 1970s, NCPC began planning for an Aishihik power station to help meet increased power needs for the Yukon.

Fourth wheel

In 1975, NCPC also developed plans for a 20-MW fourth hydro unit, designed to displace diesel use from June to October when the plant was operating at full capacity and water was being wasted. However, initial studies showed that it would not be economical to build.

Finally, in 1979, rising fuel prices led to further studies, and a 1980 decision to proceed. As its intake, the fourth wheel used the slot created by the regulating sluice next to the big sluiceways. It required a 400-metre long tailrace between the power canal dam and the river. Fish screens were built at the end to prevent migrating salmon from entering the tailrace. It was completed in September 1985 on schedule and on budget.



Yukon government

(above) Maintenance inside the penstock. (left) Building the fish screens during the construction of the fourth wheel, May 1983. (below) Working on the turbine runner.

Yukon government

Flow control

Yukon government

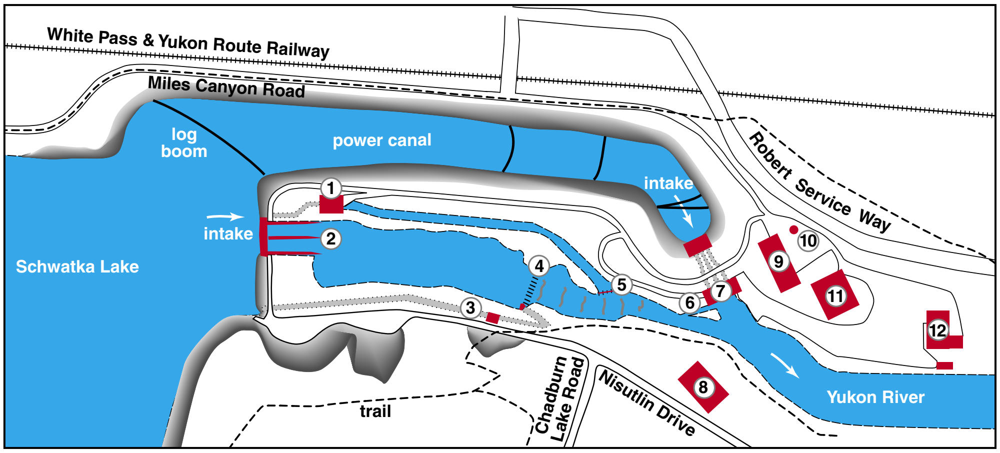
The Whitehorse Rapids plant is capable of generating maximum power from late June through to the first half of October. During this period, there is usually enough flow to operate all four turbines, for a total generating capacity of 40 MW. Water not required for generation goes through the spillway gates.

In the fall, flows decline, limiting power potential. In December, winter flow rates are set with the aim of achieving constant flow and generating capacity during the coldest months of the year. Winter flow management also manages frazil ice.

By late winter, power output is usually limited to between 19 and 22 MW. Early May marks the lowest flows and lake levels.

Each inch of water held behind the dam has a value of $52,000 — the cost of replacing its generating potential with diesel power. The fourth wheel usually runs year-round, with the other three turbines brought into play as necessary to meet loads above 20 MW.

Touring the dam



In 1987, all NCPC assets in the Yukon were turned over to Yukon Development Corporation. Its subsidiary, Yukon Energy Corporation, now operates all these electrical assets.

Yukon Energy is the primary producer and transmitter of electrical energy in the Yukon. It distributes electrical power to wholesale and industrial customers, and to retail customers in Dawson City, Faro, Mayo, Champagne and other rural Yukon areas.

Energy at the Whitehorse dam (officially known as the Whitehorse Rapids Generating Facility) is generated by four run-of-river turbines. Water for three of the turbines⑦ enters from the power canal. With the addition of the fourth turbine① in 1985, capacity was doubled to 40 MW. There is an 18-metre height difference (or head) at the dam. Excess water in the summer and fall passes through the spillway.②

There are seven diesel generators⑨ which together generate up to 25 MW. The diesel storage tank⑩ holds about one day's worth of fuel should all Whitehorse diesel units be generating.

The new administration and technical services building,⑫ constructed to replace facilities destroyed by a fire on October 30, 1997, won a national energy efficiency design award.

Power from the site is joined, via the Whitehorse Rapids substation,⑪ to the Whitehorse/Aishihik/Faro power grid at the Riverdale switching station.⑧ Also part of the system are the two wind turbines on Haeckel Hill.

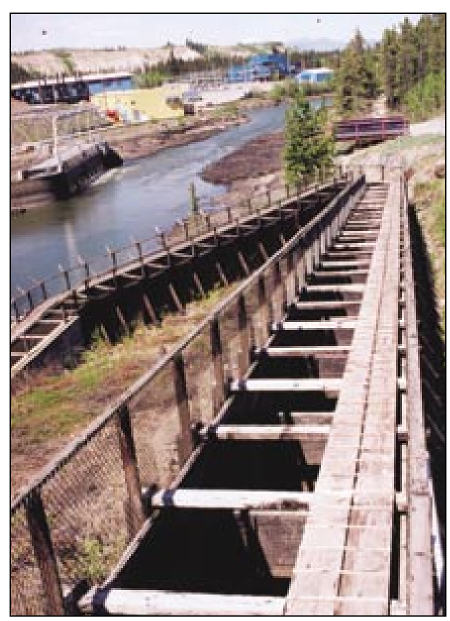
A number of features are incorporated into the plant to aid fish passage. The most visible, the fishway,③ was built at the same time as the dam to help migrating salmon bypass the dam to reach their spawning grounds. The fishway has underwater viewing windows where the fish can be seen. Eggs are taken from the fish to use in the fish hatchery. Some years, as many as 1,000 salmon pass through here.

Other aids for the fish are screens on the fourth wheel's tailrace⑤ and a diversion canal⑥ to stop fish ascending to the turbines, a fish weir④ to divert fish to the ladder, and a turbine design to help downstream passage.

In addition to salmon, you may see other fish in the fishway, including Arctic grayling, a beautiful fish with a tall dorsal fin. Grayling range in colour from dark gray through gold, green and aquamarine blue. You may also see longnose suckers, inconnu, pike, rainbow trout, lake trout and broad whitefish.

(left to right) Fish diversion canal at the tailrace on powerhouse units 1, 2 and 3; Yukon Energy technical services and administration building; fish ladder with fish screens to the left.

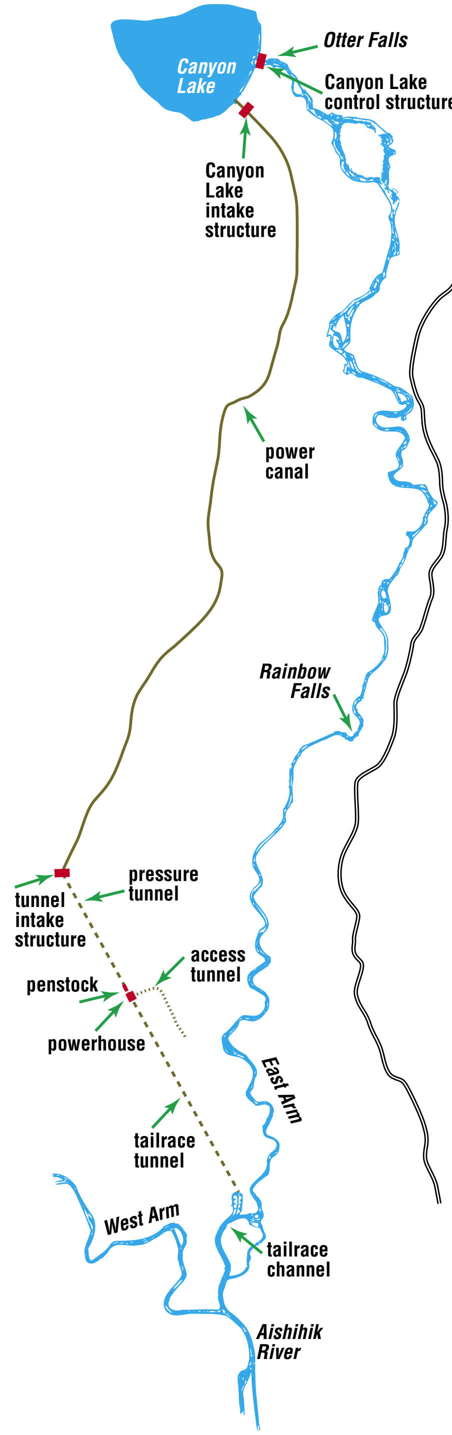
Three photos courtesy of Peter Long



AISHIHIK DAM – NEW GROUND RULES FOR HYDRO DEVELOPMENT

All photos and sketches of Aishihik dam, courtesy of Yukon Energy

At almost 6 kilometres long, the power canal at Aishihik dam is a distinctive feature, May 1975.



Adapted from April 1972 general arrangement plan

In the early 1970s, NCPC was struggling to keep up with rising Yukon power demands. When the Faro mine went into production in 1969, it took almost half of the Whitehorse Rapids hydro capacity, 9.3 MW of the 20 MW available after installation of the third turbine. By 1971, NCPC needed to install an additional 10 MW of diesel capacity at Whitehorse in order to cope with daily peak loads that had outstripped hydro capacity.

In June of that year, NCPC conducted field surveys of potential hydro sites on the Aishihik, Little Salmon, Teslin and Long Lake systems. Aishihik proved to possess much higher potential than previously thought. Senior officials of NCPC believed there was the potential for up to 630 feet of head from the project, 300 more than originally identified.

As a result, on August 31, 1971, NCPC applied for a water licence for the Aishihik project under the *Dominion Water Power Act* (DWPA). Water licence applications under the act had generally been granted with whatever conditions NCPC sought.

Now, however, the new *Northern Inland Waters Act* (NIWA) was pending, and the Department of Indian and Northern Affairs advised NCPC that no new water licences would be issued until the new act came into effect.

This meant that environmental impact assessments would be required, and that the licence application and assessment reports would have to be approved by a new water board established by NIWA.

NCPC had trouble adjusting to the new regulatory regime and was slow to respond. In November 1971, the board wrote NCPC to suggest that an environmental impact study and report would be necessary. In February 1972, it advised that the study should consider impacts on fish, wildlife and aesthetics, and on human interests, such as archeological sites on the shores of the lake.

Finally, in March 1972, NCPC commissioned a study. Just seven weeks later, at the end of April, it filed "A Preliminary Environmental Impact Statement" which it expected to satisfy board requirements. It hoped for its licence by the end of May.

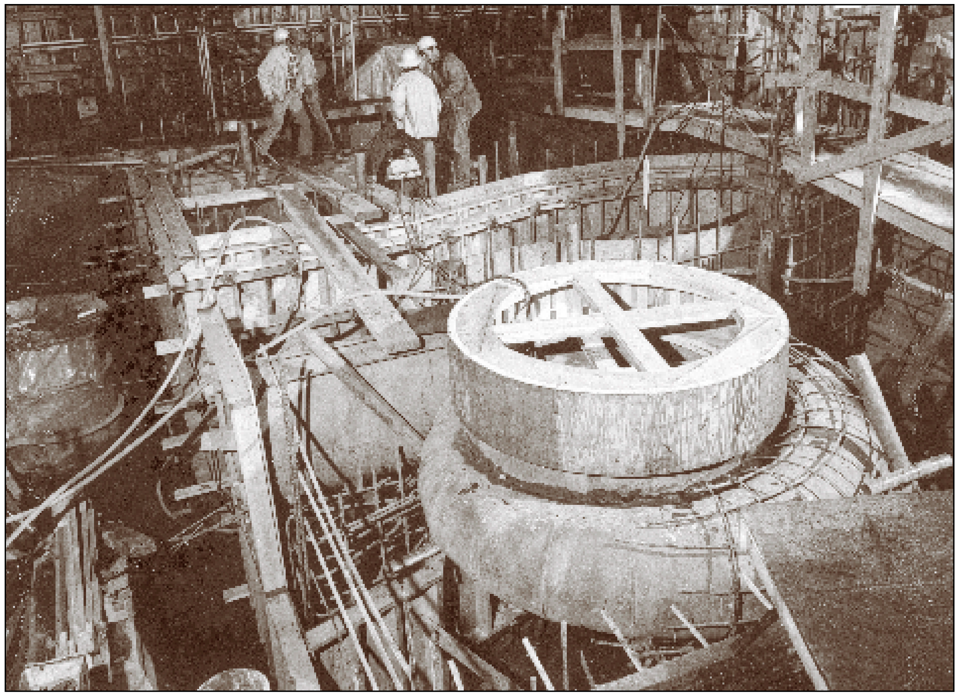
Engineering for the project was also on a fast track. At the same time the impact statement was being filed, Crippen Engineering, with the participation of David Duguid of

Montreal Engineering, completed an engineering report. It noted that although feasibility had been established, there were "still many unknowns which should be investigated prior to, or in the early stages of, construction."

On May 24, the water board convened a hearing. For the first time, there was a formal forum where interested parties, other than government and the project's proponents, could make their views known.

The Yukon Conservation Society, the Yukon Historical Society, the Canadian Society of Wildlife and Fisheries Biologists, the Department of Environment – Fisheries Service, the Canadian Environmental Law Research Fund, and the Canadian Nature Federation all called for further studies to be completed before a licence was issued.

Ray Jackson, on behalf of the Champagne and Aishihik people, Chief Elijah Smith for the Yukon Native Brotherhood and Ted Geddes of the Yukon Association of Non-Status Indians opposed the project, arguing that the government had an obligation to deal with land claims and that compensation would be due if it proceeded.

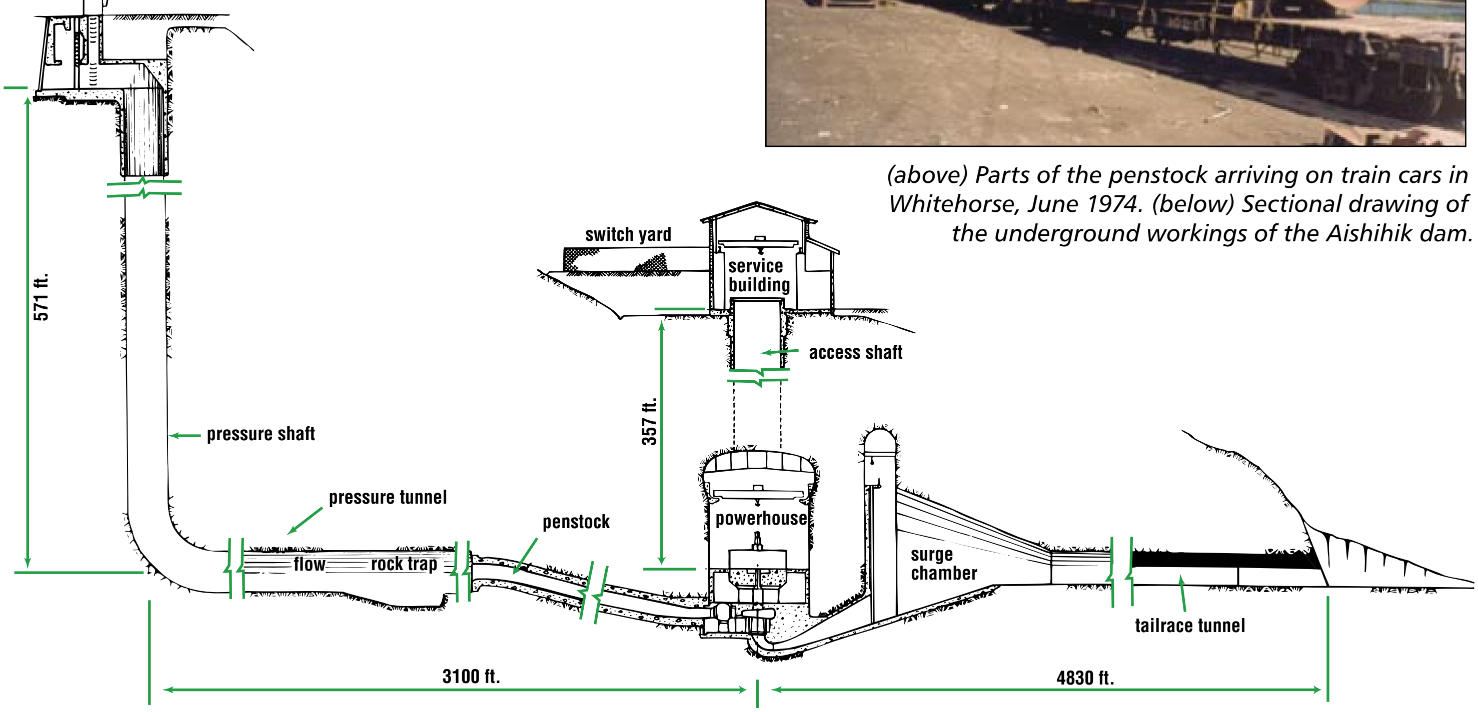


Interior of powerhouse with scroll case of number 2 unit in foreground, June 1974.

Calling for the immediate issuance of the licence were the Yukon Mine Operators Association, the Engineering Institute of Canada, the Yukon Chamber of Mines and the Whitehorse Chamber of Commerce.

The board accepted that a new source of electrical power was needed and that the Aishihik proposal had merit. But it detailed a list of environmental and systems studies necessary before a licence could be issued. Jean Chrétien, the Minister of Indian and Northern Affairs, also responsible for NCPC, accepted the board's recommendations.

(above) Parts of the penstock arriving on train cars in Whitehorse, June 1974. (below) Sectional drawing of the underground workings of the Aishihik dam.



In January 1973, another water board hearing was held. At it, NCPC sought an additional storage range on Aishihik Lake, while interveners continued to express concerns about the quality of NCPC impact studies and about land claims. At this second hearing, the Yukon Electrical Public Utilities Board and The Yukon Electrical Company Limited were concerned about NCPC cost estimates and the project's likely impacts on electrical rates.

However, the board recommended approval of the licence, while attaching a number of conditions, including a more restricted storage range. NCPC found it difficult to accept a limitation to a six-foot range because this called all of the economics into question. For three months, it held back on further engineering studies and agonized over what to do. Finally, on April 24, 1973, it accepted the water board's terms, a restricted licence was issued and construction began.

Initial plans called for a 20-month crash construction project at a cost of approximately $17 million for 30 MW of power. The delayed project start pushed construction into the 1973-1974 time frame, a time period when interest rates and material costs skyrocketed. In the end, it took 26 months to complete the 30-MW facility at a cost of $39.29 million.

Part of the underground tunnel system under construction at Aishihik Lake.

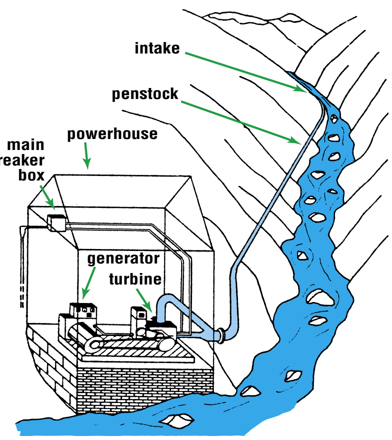
The finished dam

The Aishihik dam includes storage control structures at Aishihik and Canyon lakes and a 5.8-kilometre canal from Canyon Lake to the intake structure. The water then flows more than a kilometre through an underground shaft and tunnel to the first underground powerhouse north of the 60th parallel. There, water powers two turbines driving a pair of 15-MW generators before exiting through a 1.5-kilometre underground tailrace into the Aishihik River. As hydro projects go, Aishihik has a very low visual impact.

The Aishihik Lake system offers long-term power capacity to off-set the low winter water supply at the Whitehorse Rapids dam. It can accumulate water over several years to compensate for dry climate cycles.

MICRO-HYDRO – SMALL SCALE GENERATION

Not all hydro projects require major water diversions and dam construction. If water can be drawn from a higher location and piped to a lower hydro turbine, the resulting head — the power of the falling water — can be used to generate power. On a small scale, this kind of system is often referred to as micro-hydro.



Adapted from Micro hydro in Yukon, March 1985

Residential micro-hydro

For over 20 years, Doug and Cindy Gilday have lived on the Carcross Road, where they have raised three children and not paid a cent to an electrical company. They run electric lights, small appliances and their home and business computers from power they generate in their own backyard.

Doug Gilday says it happened fairly naturally. When they decided they wanted power at their home, they were told it would cost $20,000 to bring a line in from the highway and that they would have to carve a big right-of-way for it. Neither aspect appealed to them. They liked the privacy of their site and their closeness to the natural world. This set them to wondering if the creek that ran behind their home could be harnessed.

Gilday investigated micro-hydro possibilities and concluded that he could develop a micro-hydro system for about $15,000 — cheaper than the cost of the hookup to the utility.

The Energy Branch of Economic Development thought that what Gilday wanted to do would make an excellent demonstration project. They helped him to access the Renewable Resources component of the Canada-Yukon Economic Development Agreement.

Initially, Gilday, with the help of Peter Percival, a friend and mining engineer, considered the possibility of a larger installation so he could sell excess power. At the time, however, the utility was only willing to pay three and a half cents per kWh, which corresponded to its blended cost of power from all its generating plants. At that price, a commercial unit was not viable.

Penstock to powerhouse under construction. Note cross-flow turbine and generator on the pallet, awaiting installation.

Meanwhile, the Gildays applied for a water licence and a lease for a powerhouse. In 1981, once everything came together, they began to build. A small reservoir was dug on a glacial outflow plain uphill from the house. From a screened inflow box on that,

(left to right) Doug Gilday in front of the head pond; construction of the intake to the penstock; burying the penstock.

All photos of Gilday micro-hydro site, courtesy of Doug Gilday

400 feet of buried eight-inch PVC pipe brought water to the powerhouse, a 28-foot drop.

There, it flows through an enclosed cross-flow turbine. Gilday says that it is a simple, reliable design that the Canadian International Development Agency has used in third world projects.

The turbine powers a generator that charges a bank of deep-cycle storage batteries. An inverter is needed to turn DC power from the batteries into AC power for the household.

The system reliably produces about 1,200 kWh of power per month, roughly $100 worth at utility prices.

Since the storage system can't handle big loads, the Gildays use a propane stove and dryer, and solid fuel or oil for heating.

Twenty years later, the Gildays are upgrading to deep-cycle gel batteries and installing a new inverter that could also supply power to the electrical grid if there were ever a market for excess power.

Their original turbine and generator are still running.

Commercial micro-hydro

During the final phase and success of the micro-hydro installation, Doug Gilday teamed up with mining engineer Randy Clarkson to set up NEW ERA Hydro Corporation. They went looking for possible sites and customers. By 1985, they felt that a small lake above Fraser, B.C., on the south Klondike Highway had good potential and that the Yukon government's highway maintenance facility could be a customer. If they could draw water from the lake, they could generate power to supply both the Fraser highway camp and Canada Customs.

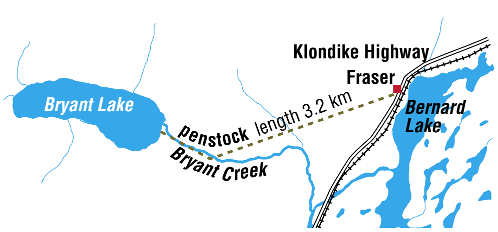
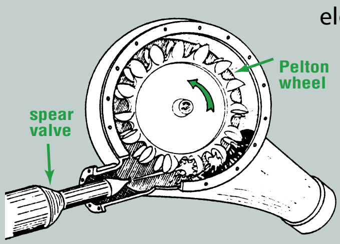


Photo and map of Fraser micro-hydro site, courtesy of Randy Clarkson

(top) Construction trench for penstock bringing water to the powerhouse at Fraser.
(bottom) Randy Clarkson doing monthly maintenance at the Fraser powerhouse.

Keeping control

A key component at the Fraser plant is a large, multi-element electric heater in the hot water heating system which acts as a governor to keep the Pelton wheel from overspeeding. If a load lightens, elements in the heater turn on to supply extra electrical load until the computer-controlled spear valve can be closed to lower the water flow hitting the Pelton wheel. The system works the other way around as well. If someone turns on a large load, controls automatically shut off elements in the governor to lighten the electrical load on the system until the spear valve can adjust to allow increased flow.



Drawing of a Pelton impulse wheel. Computer-controlled spear valve nozzle varies flow to the twin cup Pelton wheel turbine.

For a year, they took monthly flow measurements and surveyed the area to sort out ground conditions and routing options. They also applied to the B.C. government for a water licence. In 1986, they approached the Yukon government with a feasibility study and proposal to supply the highway camp with electrical power.

The government was sceptical at first, but finally, in 1988, commissioned Crippen Consultants to look at micro-hydro feasibility at Fraser and other highway camps. Their report concluded that Fraser could work.

In the fall of 1989, the government tendered a request-for-proposals to design and build a micro-hydro plant at Fraser. NEW ERA protested. When the government realized that it may have acted in bad faith and that NEW ERA had water rights pending, it withdrew its request-for-proposals and began negotiations with the company. A contract was signed the next spring. Construction started in early June, the day after their water licence was issued.

It was a straightforward construction job. At Bryant Lake, which sits at an elevation 200 metres higher than Fraser, a submerged water intake was placed in the lake. It was connected to a 300-millimetre buried steel pipe, or penstock, that brings water 3.2 kilometres to the powerhouse. Today, aside from the access road, the only visible disruption at the site is a small A-frame shelter to protect a valve between the intake and penstock.

At Fraser, a small green metal building houses a Pelton wheel turbine and a 250-kW generator. Construction of the facility cost about $550,000, not including sweat equity. The project was self-financed with assistance from the Yukon Energy Alternatives Program.

A simple oil drum raft serves as the mounting base for the submersible system.

Yukon government

The plant was commissioned on September 14, 1990. The system has been largely trouble-free, running 99.9 percent of the time for the last 11 years.

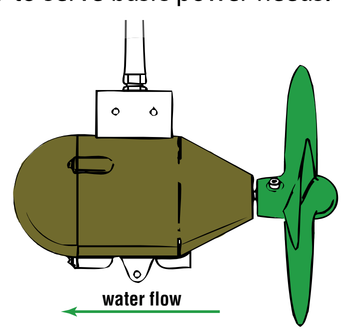
A variety of remote sensors are installed on the equipment to alert Clarkson and Gilday by telephone if anything goes wrong. They're happy to say they haven't had many calls.

Mini micro-hydro

Recently, the Heritage Branch of the Yukon government has been trying a new micro-hydro set-up at the historic site of Fort Selkirk, on the Yukon River near the mouth of the Pelly River. It is a submersible generator that requires no head of water, no turbines, no dams and no pipes.

The generator looks like the leg of an outboard motor and is designed to be suspended in a fast moving current. In a nine mile per hour current, it can produce a steady nine amps, 24 hours a day — enough to supply about a quarter of the needs of an average suburban home.

At Fork Selkirk, the generator charges a battery bank that runs through an inverter to serve basic power needs.



Submersible generator.

THE FUTURE OF HYDRO

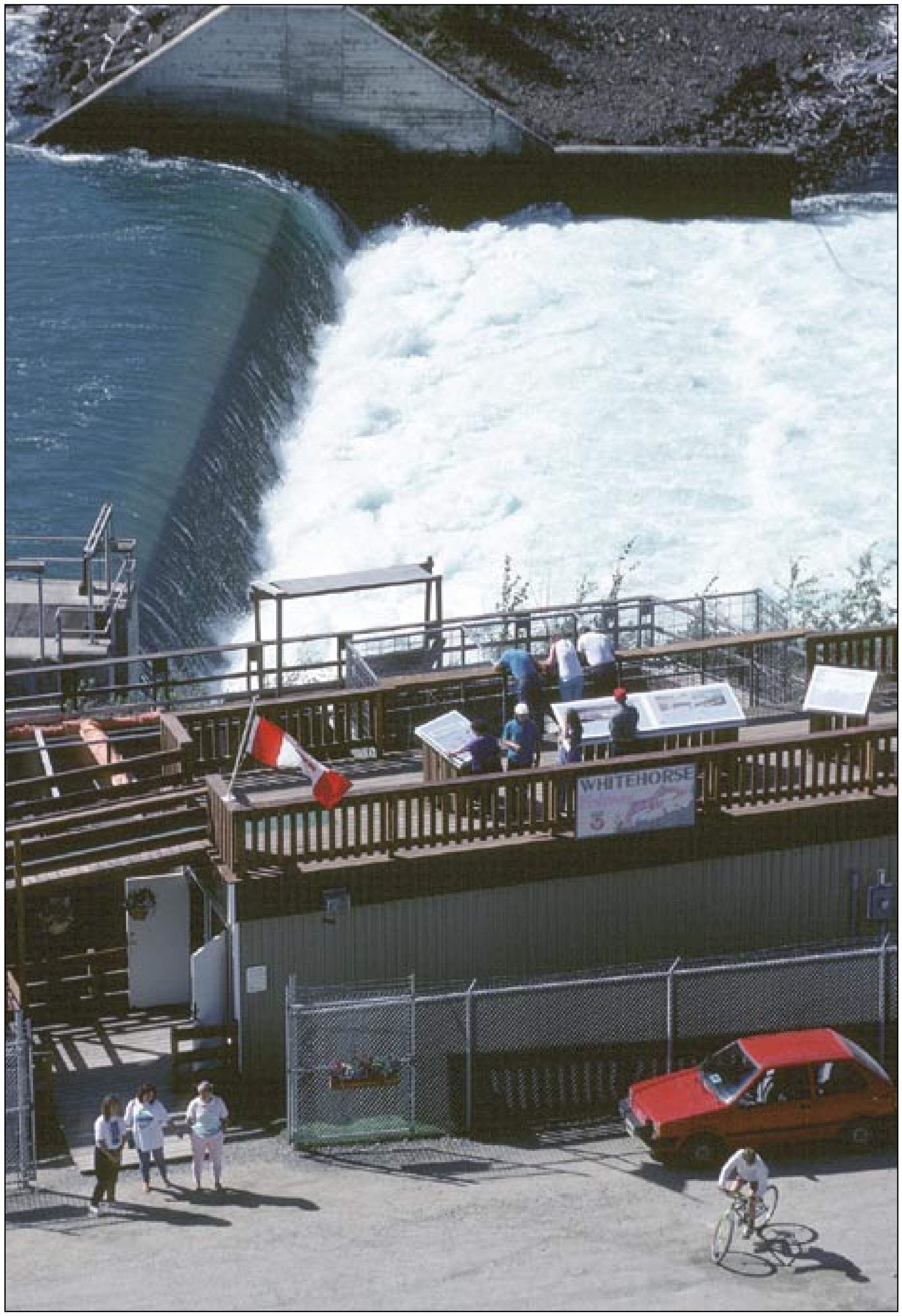
Construction of large hydro facilities in the Yukon has almost always been driven by new mining developments which promised significant power sales over a long period of time, sometimes bringing improved services for other electrical consumers.

The permanent shutdown of the Faro mine, the single largest power consumer for many years, means that the Yukon now has an excess of power, and no immediate prospect of selling any of it.

In this context, Yukon Energy is moving towards better use of existing developed hydro resources and displacement of diesel-generated electricity. The transmission line from Mayo to Dawson City is an example of this. A further connection between Stewart Crossing and Carmacks would put all but a handful of communities on an integrated, renewable power system.

Future growth capacity will likely come from smaller, renewable developments. These could include potential hydro sites near communities and energy transmission corridors in various parts of the territory.

In the meantime, the Yukon is continuing to generate most of its power from clean, reliable hydro and wind resources; diesel is used when and where there are no viable alternatives.



Yukon government

Ongoing improvements to the Whitehorse Fishway, at the Whitehorse dam, not only benefit the fish population, but provide a strong community focus on the environment. The water in the background is falling over the fish weir which directs the salmon towards the start of the fish ladder.

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