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FORREST KERR
195-MW HYDROELECTRIC POWER PROJECT

HATCH

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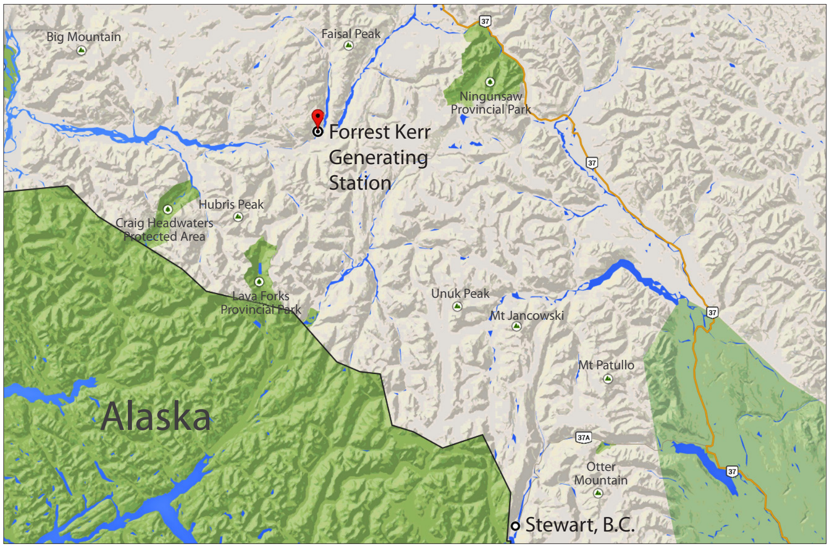
The Forrest Kerr project had very clear objectives: design and construct a 195-MW hydroelectric facility on time and on budget in a safe and environmentally responsible manner.

AltaGas recognized Hatch as an industry leader and Hatch enthusiastically accepted the challenge. Through the application of innovative design concepts at both the headworks and underground powerhouse, the success of the Forrest Kerr project represents a triumph not only in multidisciplinary engineering coordination, but also in First Nations collaboration and sustainability.



Location map for the Forrest Kerr Hydroelectric Project

Key

- A Sluiceway approach channel
- B Sluiceway box culvert
- C Forebay control structure
- D Desanding basin
- E Main power tunnel intake
- F Radial gate structure
- G Obermeyer weir
- H Fish channel
- I Iskut River
- J Main island
- K Forrest Kerr Creek

Innovation comes from a desire to push back boundaries so that dreams become reality

The Forrest Kerr project, a run-of-river hydroelectric facility with an installed capacity of 195-MW, had to deal with the Iskut River's and Forrest Kerr Creek's sediment load of an astonishing 4.4 million tonnes per year. Without the creativity and technical input provided by Hatch, the project would never have gotten off the ground. The project mandate was clear: design and construct a 195-MW underground hydroelectric facility on time and on budget in a safe and environmentally responsible manner. Once underway, the project was executed on a "fast-track" setting with feasibility level work, construction at the site and detailed design all taking place simultaneously. Through continuous collaboration with the construction team from 2011 to 2014, Hatch was able to minimize rework and lost time in the field. Impressively, the Hatch team developed an efficient and cost-effective solution to limit river sediment larger than 2 mm in size from entering the power tunnel and being passed through the turbine runners.

From a design perspective, Hatch used its cutting-edge expertise to solve engineering challenges at both the headworks and powerhouse locations. At the headworks, the Hatch design team developed an intake and sediment handling system that included optimizing the geometry of the various structures to "mix" the inflow of the two converging rivers. The headworks also included an unusual but highly effective design for the sluiceway, keeping bedload material separate from the main intake flow and continually accelerating this material, which allowed it to be flushed back into the natural river course.

This bedload flushing system is contingent on the first section of the sluiceway approach channel (A) with it's flared entrance and elevated invert (photo 04), which acts to limit the amount of material that enters the sluiceway from the river and also to continually accelerate the material that does enter the channel so that it is not able to settle out.

Sluiceway and Forebay Control Structure (Looking Upstream)

Immediately downstream of the approach channel is the second section of the sluiceway, which is split into upper and lower compartments by means of a concrete box culvert (photo 01, bottom left). The largest and heaviest material, naturally travelling at the bottom of the water course, is directed through the lower compartment of the structure.

The tapered design of the structure ensures that water and bedload material are continually accelerated through the culvert and discharged back into the river downstream and past the water intake. The water travelling along the top of the box culvert (B), devoid of large bedload material, is diverted into the desanding basin (D), which provides for a second level of filtration by slowing the water velocity, thus allowing particles larger than 2mm to settle out, to then be automatically flushed back into the river via a network of flushing pipes and valves (photo 5). The filtered water is finally directed into the main power tunnel intake (E) located at the extreme end of the desanding basin and through the turbines.

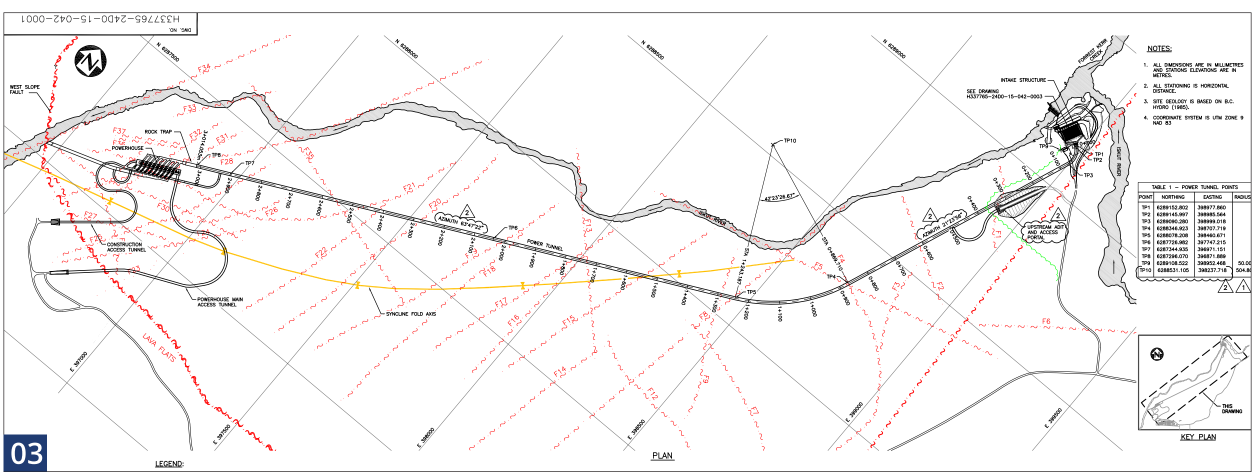
Downstream of the headworks in the powerhouse, the Hatch consulting team completely altered the configuration of the Francis turbines that were originally proposed for the project. The two large 83MW and two small 23 MW units were replaced with nine 23.5 MW units (photo 02). It was a radical approach for a project so advanced into construction but proved to be a creative and cost-effective solution, that successfully addressed concerns with river flow management, ramping, and the overall impact on sensitive fish habitat downstream of the facility.

Powerhouse Cavern

Under normal operating conditions, the energy of the water entering the powerhouse is converted into mechanical energy by the turbines then into electrical energy by the generators. Thus “drained of its energy”, this water is discharged back into the river via the tailrace channel. In the event of a transmission network failure, the electricity production from the facility must be urgently stopped. Water that is already travelling in a supply tunnel and passing through nearly a 100-meter vertical drop contains an immense amount of energy. We are talking about 252 m^3 of water per second travelling at speeds approaching 6 m/s (22 km/hr)!

To further complicate matters, "flow ramping" rates were imposed that limit water level fluctuations downstream of the facility to 2 cm/hr in order to protect and enhance important fish habitat. It was therefore not possible to simply turn the water flow off through the turbines in the event of a full plant shutdown. In order to respect these ramping rates, a solution needed to be found to allow water flow to be gradually shut off while dissipating the energy contained in the water, before returning it back to the river. This is a daunting and expensive proposition to implement in an underground powerhouse. Further underground excavation would have been required to install both additional energy dissipation equipment and the associated discharge cavern amounting to almost the same volume of material to be removed as was required to construct the main powerhouse cavern. It was not possible to implement this standard design of installing additional energy dissipation devices due to the severe impact on project budget and schedule. The only practical solution: allow the water to pass through the turbines "freewheeling" at twice their normal speed while they were disconnected from the transmission system. Such a solution is simply not feasible with large vertical generating units, however, the idea is plausible with smaller horizontal units, which can be economically designed to operate safely at much higher speeds than their larger vertical counterparts.

Through a methodical understanding of the limitations and possibilities of the available equipment, Hatch engineers were able to effectively "double-up" on the functionality of the Francis turbines. They implemented a design that used both the turbines and generators to produce electricity while connected to the transmission system at normal speed, but also utilized this same equipment to dissipate the energy contained in the water while operating disconnected from the transmission system at more than twice normal speed. This solution also had the benefit of allowing the facility to generate additional energy by capturing more of the available water resource thanks to the added flexibility from the application of nine units versus four.



03

Power Tunnel Alignment (3 km)

4.4 million tons of sediment to divert each year

It was more than 85 years ago when a project of this nature saw light in Canada; it was a 222 MW run-of-river facility located in the Province of Quebec. However, the Forrest Kerr hydroelectric project in British Columbia is unique in that it includes an underground powerhouse and headworks structures that had to be constructed on unstable volcanic rock, requiring complex engineering solutions.

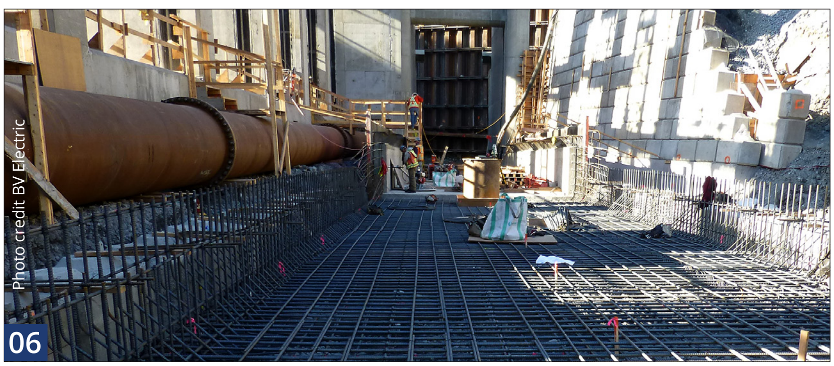


Photo 04 - Sluiceway Entrance; Photo 05 - “V”-shaped sediment collection chambers with perforated pipes; Photo 06 - Sluiceway Looking Downstream at Radial Gate

To effectively deal with the 4.4 million tons of sediment carried by the river each year was indeed a major obstacle to the successful development of the project. To realize it, the engineering team was tasked with designing facilities capable of flushing the equivalent of 1,205 dump trucks of material per day, which is no small feat!

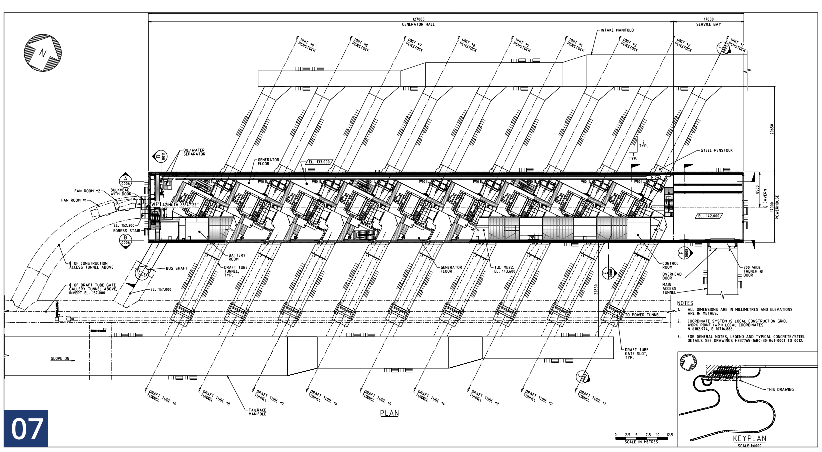
In addition to the design features of the sluiceway, which prevents large bedload material from entering the facility, a desander structure was designed that utilizes a total of 8 “V”-shaped sediment collection chambers (photo 05) with perforated pipes installed at the invert of each of these chambers to collect small suspended sediment. The collected sediment then settles to the bottom of the chamber and is flushed back to the river via the perforated pipe using the natural head pressure created by this configuration. The automatic flushing system operates two chambers at once and is able to completely flush the entire desander every 10 hours without impacting plant operations. Moreover, the convergence of the Iskut River and Forrest Kerr Creek just upstream of the intake area produces highly complex flow conditions involving significant variations in both water levels and river flows, ranging from as little as 10 m^3/s to over 5000 m^3/s (to the point of totally immersing the headworks structures during extreme flood events). The detailed analysis of these unique hydraulic characteristics utilizing numerical flow modelling as well as the construction of a comprehensive physical model (photo 08) helped to achieve an ideal configuration for the various headworks structures.

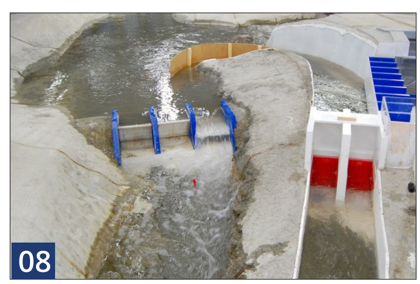
With these tools, in conjunction with Hatch's engineering expertise, the design and alignment of the headworks structures were adjusted using an iterative process to obtain optimum performance under all river flow conditions.

Finally, the change in the configuration of the plant to make room for nine turbines instead of four had a major impact on the dimensions of the underground powerhouse whose length now had to be increased to 144 m (photo 02). How could such a fundamental change take place while the excavation work was already underway? This is a feat in itself, which Hatch was able to accomplish with the help of 3D design (photo 09) and modelling techniques.

In addition to the necessary space for the equipment, Hatch engineers had to ensure that access for safe operations and maintenance of the facility was maintained. The end result is a world-class facility with an optimum equipment layout for facility operations. The intake manifold (photo 07, top; photo 11) that directs water flow from a single power tunnel to nine separate turbines was designed for optimum performance and efficiency. The "equalization" of the water flow to all the turbines was achieved by narrowing the diameter of the manifold as it runs the length of the powerhouse. Specially-designed flared ends were also added to each of the nine penstock pipes to smooth water flow and minimize disturbances.

Hatch was challenged throughout the project to finalize the detailed design for various critical elements while construction work progressed simultaneously. Hatch was able to keep ahead of construction while at the same time consistently providing quality engineering deliverables. The packaging of construction contracts into a number of smaller time- and materials-based contracts proved to be very cost effective, while affording the ability to effectively manage construction risk and allowing the contractors on site to efficiently address the project's changing requirements and priorities through all phases of construction. Throughout the design and construction process, Hatch worked closely with the various contractors to focus on assessing the impact that design details had on the budget, resulting in cost-effective construction works while maintaining the quality of the finished product.





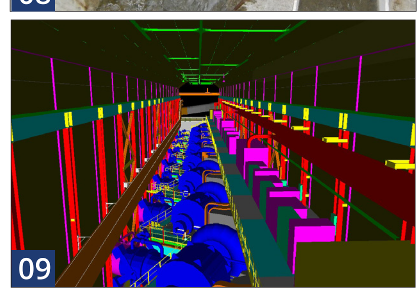


Photo 07 - Powerhouse Plan View
Photo 08 - Headworks Physical Model
Photo 09 - Powerhouse 3D Model

Photos

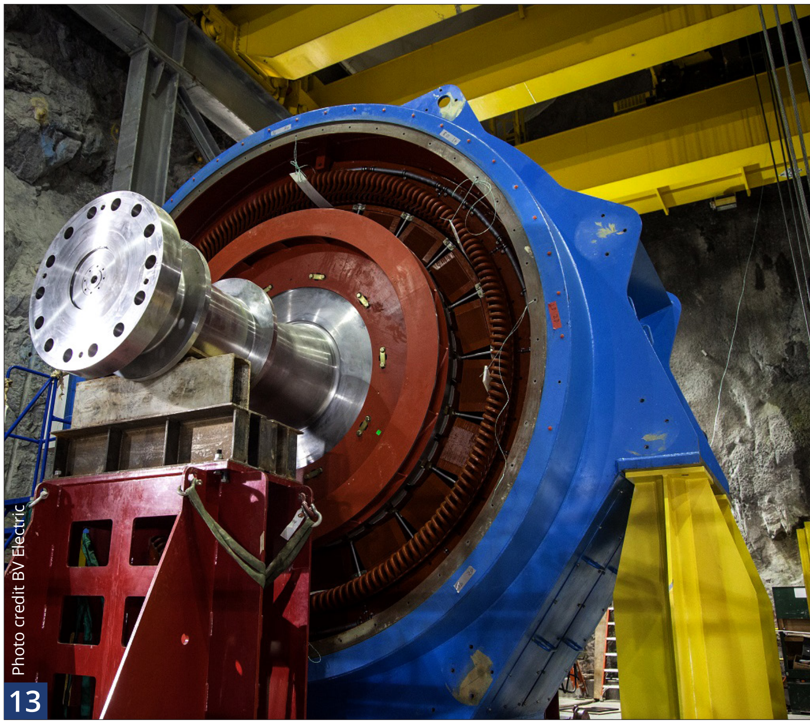


Photo 10 – Sluiceway Approach Channel

Photo 11 – Intake Manifold and Penstock Pipes

Photo 12 – Desanding Basin

Photo 13 – Generator Assembly

Photo 14 – Underground Penstock Tunnel Excavation

The dream of First Nations people is to live in harmony with nature

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Construction at the Headworks

The Tahltan First Nation is no exception. The Iskut River is the largest tributary of the Stikine, one of the three rivers that originate in the Sacred Headwaters of this community. Managing to contain the “noise” of the river, one could say that Hatch released the music, amplifying its intrinsic strength while “equalizing” its volume to avoid disturbing the environment. The local First Nations community has been directly invoved in the success of the Forrest Kerr project, providing a third of the construction workforce that contributed to making the project a reality. Moreover, First Nations staff holds a number of permanent key positions in the AltaGas Operations and Environmental Monitoring groups.

To develop a project in Northern Canada is a challenge. As a leading reporter of Canadian news once said, the southern attitude for these regions is paradoxical: generally, they seek to extract the most of their resources without providing anything substantial in return. However, this $725 million project not only has the distinction of producing clean energy with minimum impact to First Nations ancestral lands, but is also a testament to an exemplary collaboration with the First Nations community. Furthermore, this facility will serve as a major catalyst for future development in this remote area of Northern B.C.; the mining industry can surely build on the success of Forrest Kerr. Ultimately, the locals hope for a more harmonious relationship between nature and economic activity, between physical security and dignity.

The Forrest Kerr project will generate enough energy to supply more than 70,000 homes. It strengthens the power transmission system in Northern B.C. and contributes to the Province of British Columbia’s goal of achieving energy self-sufficiency by 2016.

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287 kV Switchyard

Accepting Mother Nature as a partner

To successfully develop a renewable energy source is to welcome and accept Mother Nature as a partner. The detailed design of the Forrest Kerr facility by Hatch had to provide a minimum river flow at all times to avoid harmful water level variations that would impact fish populations and habitat. With its innovative approach, the engineering team at Hatch was able to regulate the flow of water downstream of the facility; the design of the headworks includes a return channel (H) to allow any fish caught in the sluiceway to easily return to the natural river. What's more, the choice of the site itself was ideal for use as a hydroelectric development site since the canyon that separates the water intake from the powerhouse acts as a natural barrier for fish preventing them from entering the diversion reach.


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Headworks Aerial View

To further minimize the project's environmental footprint, Hatch's design team kept records of the different types of construction materials available locally and utilized them for the project construction whenever possible. The waste rock from the excavation and blasting of the various underground tunnels was recovered to serve as a structural base for the foundation of the electrical switchyard. In addition, 20,000 m^3 of loam was also recovered from the excavation of the headworks and used as conductive backfill to improve the ground resistivity (i.e. electrical safety) of the 287 kV switchyard (photo 16).

As we know, Canada's commitment to reduce its production of greenhouse gases by 17% by 2020 compared to 2005 levels is an ambitious challenge. Nevertheless, projects like Forrest Kerr will contribute to the potential achievement of such objectives, since the 980 GWh of clean energy produced by this hydroelectric plant means that, annually, the equivalent of more than half a million metric tons of CO_2 will not be released into the atmosphere when compared to gas-fired generation (this reduction increases to 999,600 tonnes when compared with emissions from traditional coal-fired plants).

Hatch Recognized as a leader and innovator in the industry

Headworks Aerial View (during construction)

AltaGas has spearheaded numerous major projects and its expertise in the energy sector is well recognized. Some eight months into the construction program for Forrest Kerr, AltaGas turned to Hatch to solve some serious design issues that threatened the viability of the project. AltaGas recognized Hatch as industry leaders and innovators and Hatch enthusiastically accepted the challenge and mobilized a highly experienced design team that immediately undertook a comprehensive review of the project, including issues associated with the construction of the underground works already under way. When a project is located in a remote area (1000 km north of Vancouver, 100 km north of Stewart), it adds precarious elements to the many logistical challenges (communication, procurement, access). The speed with which Hatch was able to put in place a highly skilled and dedicated team, both at its Vancouver office and at the work site, allowed them to reestablish an effective line of communication that fostered the development of innovative concepts and provided an aura of leadership that reassured the teams.

AltaGas is extremely satisfied of the work done by Hatch, as evidenced by their statement: "This complex project is the most important IPP (Independent Power Producer) project to date in British Columbia." The Hatch team's ingenuity has opened up a new world of possibilities for undertaking this type of renewable energy project that, due to its particular hydraulic conditions, was once an unattainable dream.

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