Tyson Creek: Tapping into the Highest Head in North America

At 865 meters, the 9.3-MW Tyson Creek project is the highest head hydro system in North America. Unlike most run-of-river systems, however, the intake taps into a natural alpine lake that acts as a storage reservoir, resulting in an unusually high capacity factor.

By Peter Schober

The Tyson Creek project is the third hydro system developed by Renewable Power Corporation, a British Columbia company. On the Sunshine Coast of BC, Tyson Creek went online in December 2009 and has a rated output of 9.3 MW based on 865 meters gross head and a flow of just 1.3 cubic meters per second.

The "head pond" for the project is Tyson Lake, a pristine alpine sanctuary at 1,040 meters. Flanked by high altitude forests and snowcapped peaks, this large lake offers a couple of significant benefits. First, it acts as a storage reservoir, allowing Renewable Power to match its output with both short-term and seasonal demand fluctuations. Second, it acts as a giant settling pond to prevent dirt and debris from entering the intake. Ironically, this aspect has turned out be a surprising problem, which this article will address in more detail.

The Sunshine Coast of BC is wet, steep and rugged – perfect conditions for small hydro. Along the coastline, light development is scattered among forested wilderness, and many of the smaller communities are subject to frequent power outages. The town of Egmont, a few kilometers from our project, has historically averaged about 2 weeks per year without power. For this reason, Renewable Power felt it would be a strong advantage to design a hybrid system able to operate both grid-tied and islanded. Tyson Creek supplies power to BC Hydro. But when the grid fails, Renewable Power continues to operate as a utility to the local community. This has been especially well received, because Renewable Power is now able to keep the area's largest employer running during prolonged outages.

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The selection of Tyson Creek

Like all independent power producers, our objective at Renewable Power is to keep the turbine spinning and deliver the most power when demand is highest. This can be a challenge at northern latitudes such as BC, when high power demand in winter typically correlates with freezing temperatures and low flow. Early on, Renewable Power made a business commitment to environmental preservation.

While the company recognized that every project – hydro or otherwise – will have some impact, it actively looked for ways to minimize its footprint. This emphasis helps the company's projects gain public acceptance, but more directly, Renewable Power believes it is the right thing to do.

Renewable Power was particularly interested in finding a way to employ storage without a dam. Larger utilities like BC Hydro are challenged to meet peak load demands, but most run-of-river projects have little or no reserve to draw upon when demand spikes. For utilities, this peak demand problem is exacerbated by the growth in green power alternatives like solar and wind production, as output can be highly unpredictable and unlikely to align nicely with demand.

Renewable Power's plan was to use a pre-existing lake for reserve capacity, which could solve a problem for BC Hydro and allow Renewable Power to tailor its output to take advantage of peak rates.

Tyson Lake had great potential. At 60 meters deep, it offered plenty of reserve, assuming the company could find a way to tap in well below the surface. In addition, by bringing the penstock in below ground, Renewable Power could preserve the untarnished beauty of the area with no visible signs of our intake system.

The outlet from the lake, Tyson Creek, was so small it didn't have a name before Renewable Power got there. From Tyson Lake, it flows under boulder fields for a third of its length, then plunges down sections so steep it would be impossible for fish to navigate. Near sea level, Tyson Creek empties into the Tzoonie River, where it then travels a short distance to salt water at Narrows Inlet.

One major environmental hurdle – fish – was somewhat less of an issue for Renewable Power, since Tyson Lake and most of Tyson Creek were barren. The company still had to be very careful not to impact the Tzoonie River, however, as it is a major spawning ground for several species of salmon and trout. Water from our tailrace would return to a short, fish-bearing stretch of Tyson Creek before joining the river. It was imperative to maintain good water quality to protect downstream habitat.

The high head was particularly attractive. It would require a special turbine design to handle unusually high pressure, but would also save considerably on turbine cost. Physical turbine size relates directly to flow, not head, so higher flows require larger, more expensive turbines. In contrast, our high head system produces almost 10 MW using a single Canyon Hydro Pelton turbine with a pitch diameter of just 1.3 meters.

High head kept penstock expenses down as well, allowing us to choose a pipe size of 36 inches (narrowing to 28 inches). The steep terrain helped us limit the penstock length to 4.2 km, not bad considering almost of quarter of this represents vertical head.

Choosing the right turbine

The unique characteristics of our project created some special requirements for the turbine. 865 meters head translates to more than 1,200 pounds per square inch (psi) at the turbine. Renewable Power was concerned a conventional Pelton design would disintegrate under load. Likewise, operating in islanded mode creates an entirely new set of issues relating to load compensation and frequency control. It is no longer possible to simply rely on the grid to keep everything in sync.

Renewable Power talked with several turbine suppliers and eventually selected Canyon Hydro. The company appreciated Canyon's attention to detail on a previous project, and Canyon had extensive experience with islanded systems. But Renewable Power still needed to address concerns about turbine reliability under very high head. Only a few suppliers have had direct experience with such high pressures.

I contacted Dan New, president of Canyon, and suggested he join me on a trip to Switzerland to visit a project similar to ours, with just a couple more meters head. We learned a great deal about how water behaves at those pressures, and upon our return, Canyon Hydro designed and fabricated a heavily gusseted Pelton turbine that continues to run flawlessly.

Islanded operation requires control systems that, while common on larger hydro systems, are unusual for a 10-MW project. Instantaneous changes in load are compensated by the jet deflector shield, which immediately adjusts to

Pictured is the lower end of the tunnel during construction. In addition to the main penstock, a smaller return pipe is used to pump water back up to the source of Tyson Creek to maintain constant flow in the creek bed. The curved white pipes vent the tunnel.

deflect more or less of the water jet to the turbine runner. Canyon Hydro integrated controls from Unit Electric with their jet deflector design to maintain constant frequency under rapidly changing load conditions.

Intake & penstock challenges

Getting the water to the turbine was tricky, given the combination of steep terrain, the use of a lake as our intake system, and our objective to preserve the natural landscape.

We decided to underground the penstock on all but the steepest section of terrain. This would minimize potential damage in the years ahead, and allow nature to gradually hide any evidence of a pipeline.

On the uppermost 300 meters of the route, the surface was not disturbed. Instead, the company tunneled through contiguous bedrock, including a few small bends to ensure the penstock remained in stable rock. The penstock reaches the lake about 30 meters below the surface.

Before the final route for the tunnel was determined, Renewable Power had to decide where to tap into the lake. To help with this, we used an unmanned submarine to navigate around sunken logs and boulders to chart the bottom of the lake. Tyson Lake was once fed by a now-extinct glacier, and there was evidence of a thick layer of fine, glacial flour along the bottom surfaces. We concluded that if we tapped into the lake near any horizontal surface, the suction would pull this muddy, abrasive layer into the turbine. But luck was with us. We discovered a nearly vertical, underwater rock wall that offered an excellent point of intake. With appreciable distance to any horizontal surface, it would allow the company to draw water without disturbing glacial flour.

Or so we thought.

Building the steep section of pipe

A steep hillside is great for keeping a penstock short, but getting those pipe sections into place was a lesson in creative logistics. Unlike the lower sections of penstock, we couldn't simply clear a path, dig a trench, set a length of pipe and cover it up. Faced with a 400-meter stretch of grade angled at more than 45 degrees, we knew the use of trucks and mobile cranes would be out of the question.

The company considered winching the pipe sections up the slope, but realized it would still have no way of manipulating the pipe position when it got there. A method to precisely control the small adjustments necessary to align the sections was needed. On a mountain as steep as this, gravity is not always your friend.

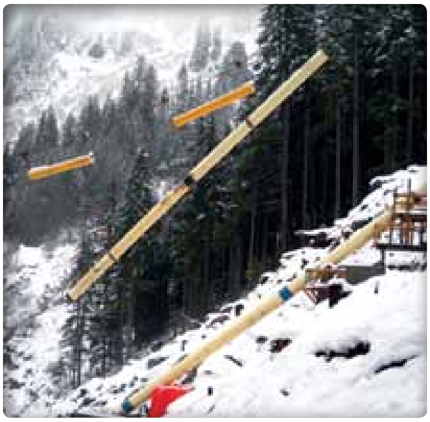
Renewable Power solved the problem with a skyline crane. Originally designed as a system for the logging industry, a skyline is a suspended cable running up the mountain, anchored at towers (or trees) on each end. A carriage with a winch travels along the length of the skyline. In logging operations, the carriage rides up the skyline cable and the winch lifts the logs off the hillside for the ride back down.

The same principles would be used, but the company demanded a lot more precision. Our skyline would require two carriage/winch units so each end of a pipe section could be raised and lowered independently. Alignment of the skyline cable was also critical.

Even with the skyline, managing 39-meter sections of 36-inch steel pipe is tricky. Unlike a steel-beam crane, a skyline cable swings and bounces. Every small positional adjustment triggers new motion that requires time to settle. With practice, however, we found we manipulate the carriage and both winches to set the pipe sections on their supports, align the ends, and hold back the forces of gravity while we welded them into place.

Powerhouse construction, turbine installation and the transmission system all went according to plan, with great coordination between our many contractors and suppliers. The quality and support we received from Canyon Hydro was second to none. On several occasions, senior managers and engineers from

At 865 meters above the turbine, Tyson Lake acts as a storage reservoir. The lake is 60 meters deep and offers plenty of reserve.



A suspended cable "skyline" moves a 26-meter penstock section into position on a grade too steep for conventional machinery.

Canyon were on site, often providing expert advice on non-turbine issues such as control programming and tailrace design.

The use of Tyson Lake as a storage reservoir allows the project tremendous flexibility as to how much power it generates and when. Storage capacity is significant, enough to run at full output 70 to 80 percent of the time. The freezing winter temperatures at lake altitude halt water flow into the lake, but a full lake gives us sufficient reserves.

In spring and summer, runoff from snowmelt will be adequate to run the hydro system at full capacity and refill the lake for use the following winter. Because full time production began in December, Renewable Power was able to test the storage aspect immediately.

Good water gone bad

The news is not all good, however. As mentioned earlier, the bottom of Tyson Lake has a layer of fine, glacial flour, deposited long ago by an old glacier. We were fortunate to find the nearly vertical, underwater cliff for our intake, but we were not expecting the problem that came winging in from left field.

As the lake level was drawn down, a previously submerged delta of glacial slur became unstable and slid into the lake. The delta had once been the base of the glacier, and as it dislodged it caused a significant release of mud and glacial flour into the lake water.

This immediately triggered two very serious problems. First, glacial flour is extremely abrasive. The combination of abrasive particles and exceptionally high water pressure quickly caused severe surface degradation around the turbine jet, particularly on the highly polished stainless needle nozzles. Just a few weeks into production, we were already facing wear issues that should have taken years.

Worse, a milky trail of turbid water stretched from our tail race down Tyson Creek, along the Tzoonie River, and out into Narrows Inlet. Understandably, this created alarm within the local community and within hours, the Ministry of Environment was asking tough questions. They agreed with Renewable Power's

proposal to drastically reduce output, but to retain enough flow to prevent the entire system from freezing up. During this time, Renewable Power worked closely with Ministry officials to test the water for environmental impacts, and installed a turbidity monitoring system that would automatically shut down the plant if a similar situation occurred again.

The heavier particles from the slide settled to the lake bottom fairly quickly, but the extremely fine glacial flour can remain suspended for months. Once the mud cleared, the Ministry concluded that these microscopic particles were not an environmental threat and allowed us to return to limited production.

Renewable Power is taking steps to prevent a similar incident. In the meantime, the company continues to deal with elevated levels of glacial flour passing through the turbine while waiting for the lake to clear.

A plan for environmental restoration

Despite our unforeseen problem with turbid water, Renewable Power remains committed to preserving both habitat and scenery, and we are well into the four-year plan to restore the area as closely as possible to its original state. There will always be some visible evidence of the hydro project such as the powerhouse and one steep section of penstock.

Over the next few months, Renewable Power will remove the minor traces of its work at Tyson Lake. When the lake is full, it will be difficult to detect that a hydro system is in operation. Most of our penstock is hidden underground and, while it was necessary to clear a path to install portions of it, Renewable Power is working on a reforestation program. And since the level of Tyson Lake will periodically fall below the threshold to feed Tyson Creek, the company pumps water back up to the original creek source to maintain minimum flow on all sections of the creek.

The Tyson Creek project has its detractors. To help mitigate potential problems, Renewable Power proactively communicates. During construction, the company invited a local environmental group to the site to show them what was really happening and to answer their questions and concerns.

Not surprisingly they found a few things that didn't pass muster (such as water runoff during heavy rain), and the company followed their recommendations to resolve those issues. When the release of muddy water occurred, Renewable Power issued a press release outlining exactly what happened and what it was doing about it.

The company also maintains a website for all of our projects, focused on helping the general public understand what we do and why clean hydropower is good for all of us. ■