Hystad Creek Project: Containing Costs to Increase Output and Profitability

The father-and-son team that built 7-MW Hystad Creek in Canada employed several strategies to contain costs while maintaining project quality and availability. Examples include buying concrete trucks instead of renting and making design adjustments that eliminated a costly surge tower. The result was solid profitability for a plant with a capacity factor of only 35 percent.

By Duke F. Peterson and Chad A. Peterson

Runoff from the Canadian Rockies powers the turbines for the 7-MW Hystad Creek run-of-river project on Hystad Creek in British Columbia. Capacity of the project, owned by Green Energy Inc., can drop to as low as 300 kW during the cold season. In fact, one challenge in developing this project was to justify the cost of a system that would meet its design flow for only two months a year, yet still operate efficiently across such a wide power range.

Because Hystad Creek is the second hydro project we have developed, we were able to apply many of the lessons learned in developing our first system (1.5-MW East Twin Creek near McBride, British Columbia). In addition, just before developing this project, Chad Peterson spent 18 months in Honduras, conducting feasibility studies for potential hydro sites and designing the 12.4-MW La Esperanza project for owner Consorcio de Inversiones S.A.

The East Twin Creek project always has been profitable, but we were convinced we could do even better with Hystad Creek. But simply cutting costs would not necessarily improve profits. Settling for lower efficiency or higher operating costs would cost us more in the long run. We also paid close attention to our construction schedule because financing costs continue to climb until the system starts generating income. The faster we could build, the sooner we could turn cash flow from negative to positive. But because of some pre-construction delays, we had to build our system during the coldest winter months.

The project has turned out well. Construction, from the first shovelful of dirt to full power production, took just nine months. It is a highly efficient system, employing identical twin turbine-generators, each fully redundant to the other. Every aspect of system monitoring and control can be accomplished from our central office via a secure Internet connection. Best of all, we have achieved solid profitability with a plant capacity factor of only 35 percent.

Who will manage the project?

Staying involved was the best way for us to save money. Rather than give control to a general manager, we took personal responsibility for each step of the process. This included design, feasibility studies, permitting, negotiating a power purchase agreement with BC Hydro, purchasing equipment, and construction. We believe this approach reduced our design/build costs by 50 percent.

This hands-on control may not work for everyone, but we had experience on our side. Our personal involvement reduced our need to rely on expensive consultants and engineers, which saved those direct costs and also gave us much more control over the underlying costs and timing of subcontractors, permitting, and sales contracts. We think this arrangement also helped us build a stronger, more motivated team.

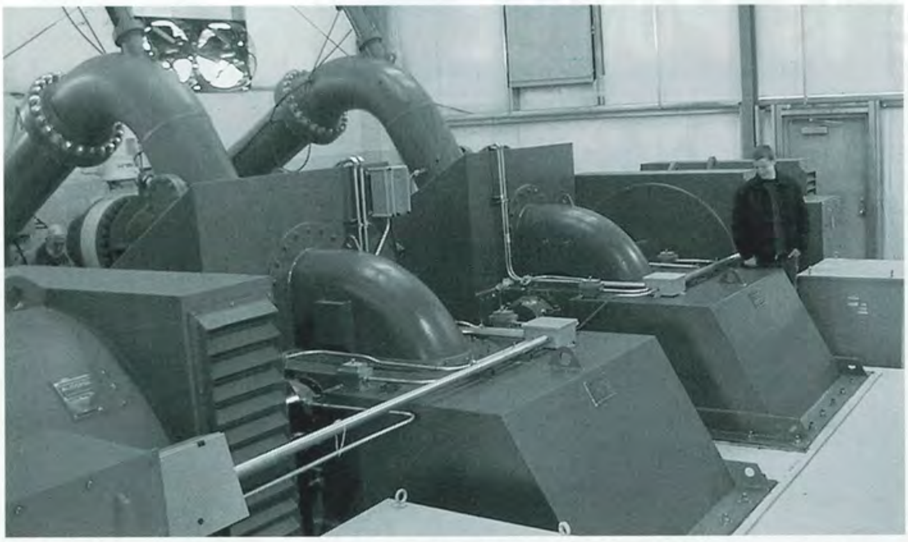
The team we assembled was phenomenal. Art Carson of Carson Electronics in Valemount, British Columbia, found the site and continues to manage our operations. Shirley Bond, our provincial minister of Legislative Assembly, provided invaluable assistance in establishing our relationship with BC Hydro. Dan New and his crew at Canyon Hydro in Deming, Wash., were very helpful with turbine design. And John Wheeler with Boundary Electric in Grand Forks, British Columbia (now with Castle Mountain Hydro in Grand Forks) was a marvel with our controls and switchgear.

Shopping for key components

So many components and services go into a hydro project, we knew it would be easy to overspend. That is why we ordered a bank of telephone lines and set aside three months for shopping. We discovered there often are substantial differences between competing bids, as well as between a supplier's first and second (or third) bid. As project owners, we probably had more influence to drive prices lower. We certainly had stronger motivation!

We refused to compromise on key components like turbines and generators, but we were not afraid to scour for bargains on less important items. For example, we bought used manually-operated chain hoists for use with our overhead crane. Our powerhouse is a standard pre-engineered building. And our penstock is built with 42-inch pipe commonly used in the oil industry, which is larger than our original specification and yields a

Duke Peterson is chairman and Chad Peterson is president of Green Energy Inc., the company that owns the 7-MW Hystad Creek project.



The twin Pelton-type turbines installed at the 7-MW Hystad Creek project each are equipped with two continuously variable needle nozzles, allowing project owner Green Energy Inc. to maintain high efficiency from about 300 kW to nearly 7 MW.

higher net head for less money.

To track project costs, we developed a custom spreadsheet. As our design and cost structure evolved, we updated the spreadsheet to doublecheck our projections for cost versus return. We also projected efficiency over time, accounting for factors like incremental penstock friction due to rust. The spreadsheet was the basis for our decision to design around a 35 percent plant capacity factor. It was interesting to see the contrast between our "owner build" spreadsheet and another program that uses formulas for more traditional project management. Had we relied on those projections, we never would have built Hystad Creek.

Buying concrete trucks

To construct the footings, diversion structure, and thrust blocks, we needed a large amount of concrete — more than 3,000 yards — delivered over primitive roads well into the mountains. Our local supplier was reluctant because of anticipated wear and tear on his trucks, and the company quoted us a higher price because of the distance from the yard to our site. The long drive time from the plant also would have limited our pouring time, thus lengthening our schedule.

Our solution saved hundreds of thousands of dollars and a lot of time. We did the concrete work ourselves. We bought two of this concrete supplier's older trucks and applied for a permit to establish a gravel pit on site. We also rented equipment for sorting gravel and had bags of cement delivered in

B-train (double tractor trailer) loads.

Pouring concrete in the dead of a Canadian winter — when temperatures occasionally dropped to minus 30 degrees Celsius — requires special provisions. We pre-heated the gravel and cement with propane burners and used hot water for mixing. We trained multiple propane torches against the drum on the concrete truck to keep the mixture warm as it turned. And we covered the poured concrete with thick layers of preheated insulation to give it time to set up and cure before freezing. Our propane bills were impressive!

Because the pre-heating required extensive setup, the team worked around the clock once a pour was underway. At one point, Duke Peterson drove to the site at 1 a.m. and found Chad Peterson, Brian Shawara (one of the owners), and the entire crew (about 12 people) pouring concrete by the light of a bonfire. Their record was 23 truckloads in one day — more than 200 cubic yards!

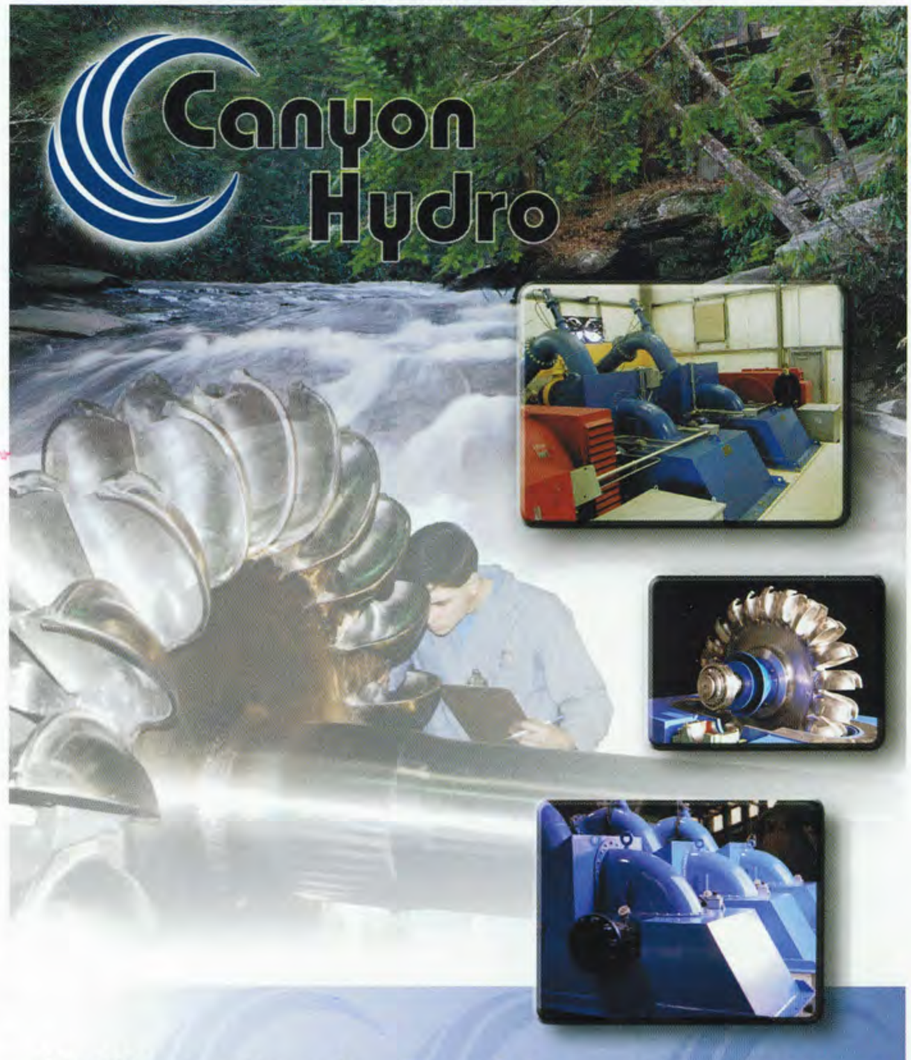
Designing to avoid the surge tower

One of our more challenging issues was dealing with potentially destructive forces like waterhammer effect, cavitation, and vacuum collapse of the penstock. Given our relatively high head (331 meters) and the topography the pipeline follows, a conventional surge tower would be extremely expensive. Located about 1,100 meters downstream from the intake, the surge tower would have been about 3 meters in diameter and 30 meters high. The cost of construction, including the substantial amount of concrete required for support, was the catalyst for some creative thinking.

We could not ignore the problem. The potential damage to our system from just one serious malfunction was sobering. But if we could design to mitigate some risks, we could either reduce the size of the surge tower or eliminate it altogether, for a savings of well over $100,000 in build cost.

We approached the waterhammer problem first. By using a Pelton-type impulse turbine, we could simply divert the jet away from the runner instead of abruptly halting flow. Canyon Hydro's failsafe jet deflector provides this function. If anything goes wrong, such as over-frequency or voltage loss, the deflector instantly drops between the nozzle and runner. We then determined we could stop the water flow without a large shock to the penstock by slowly closing down the needle nozzles. With minor adjustments, we were able to produce a fully automated, eight-minute shutdown, which adds only about 30 pounds per square inch (psi) of pressure within the penstock. As added insurance, we specified thicker wall pipe able to withstand an additional 400 psi over normal operating conditions. There are still some obscure scenarios that might cause waterhammer damage, but we are willing to absorb this small risk.

Our next challenge was cavitation. Without a surge tower, air bubbles that would inevitably be pulled into the penstock would damage our turbine runners. To prevent this, we first designed our intake system to eliminate vortexes that could suck air into the penstock. The intake begins with a 330-meter-long pond that terminates with a 7-meter head tank in which we installed a silt




Construction of the intake for 7-MW Hystad Creek was completed during the winter, when temperatures fell as low as minus 30 degrees Celsius. The head pond can store water during interruptions to the circuit, preventing lost revenue due to spill during outages.

wall and trashrack. The head tank is covered for protection, as well as for the safety of visitors.

Finally, we found a large, cone-shaped drum from a pulp mill in Prince George — complete with manhole access — to serve as the penstock intake. To help prevent penstock collapse from sudden vacuum, we installed a conventional vacuum breaker pipe above the drum.

We knew a few air bubbles would still enter the penstock, so we installed a relief valve to capture and bleed off the air. Air entering the valve displaces the water and allows a float to fall, opening a small orifice. This 10-inch valve also opens when outside air pressure is greater than pressure in the penstock, effectively eliminating the need for a surge tower. We were concerned about the valve mechanism freezing, but with proper insulation and the warm air that is discharged from the valve, this does not appear to be a problem.

Technical Information

Hystad Creek

General Information

Location: Near Valemount, British Columbia, Canada

Owner: Green Energy Inc.

Capacity: 7 MW

Anticipated Yearly Output: 21,000 megawatt-hours

Effective Head: 331 meters

Minimum Streamflow: 0.13 cubic meter per second (cms)

Design Flow: 2.23 cms

Project Development Team

Crane Services: Mussell Crane Manufacturing, Chilliwack, BC

Electrical Installation: Boundary Electric Ltd., Grand Forks, BC

Engineering and Project Consulting: RJS Consultants, Calgary, BC

Environmental Inspection: BC Hydro contractors

Penstock Supply: Dominion Steel, Delta, BC

Equipment

Turbines (2)
Horizontal Pelton
Dual needle nozzles
720 revolutions per minute
Manufactured by Canyon Hydro

Generators (2)
3,500 kilovolt amperes (kVa)
4,160 volts, 3 phase

Control System
Allen Bradley PLC SCADA system
Manufactured by Castle Mountain Hydro

Construction

Dam
4.6 meters high at highest point
18.3-meter-wide spillway
Concrete

Head Pond
Maximum of 80 meters wide by 300 meters long by 4.6 meters deep

Intake Structure
Concrete tank
Aluminum flow control gates
9.8 meters long by 3.7 meters wide by 7 meters deep

Penstock
Steel, buried
1.07 meter diameter
2.1 kilometers long

Powerhouse
Pre-engineered steel
12 meters long by 12 meters wide by 9.8 meters high

Tailrace
30 meters long by 4.3 meters wide; narrows to 2.4 meters

During low-flow periods, our intake design gives us the ability to store water in reserve should there be an interruption in our circuit to BC Hydro, or if we need to take the turbines off line for quick maintenance. We can store enough water in the small holding pond behind the weir to allow us to run at higher output for an hour or two after the interruption, recovering revenue we otherwise would have lost.

Choosing the right turbine-generators

The initial cost of a turbine system is important, but the cost of ongoing operation — measured in efficiency and reliability — has far more effect on the bottom line. We knew Canyon Hydro made top-quality turbines, and we were pleasantly surprised when they came in with the lowest price. Our two identical Pelton turbines have operated well since we went on line in June 2002. The generators, manufactured by Alconza Berango S.L. of Spain and supplied by Canyon Hydro as part of the package, also have been solid performers.

Our decision to use two identical units was based on three key factors. First, with our high design flow we must optimize efficiency across a wide range of flow rates. The twin turbines, each equipped with two continuously variable needle nozzles, allow us to maintain high efficiency from about 300 kW to nearly 7 MW. Second, with fully redundant systems we can shut down either turbine for maintenance during lower flow rates, with no service interruption. Third, all parts are identical, from runners to electronic monitors and controls. With just one set of tools and spares to maintain, we can keep a much larger inventory

To reduce the cost of constructing the powerhouse for the 7-MW Hystad Creek project, developers Duke and Chad Peterson chose to use a standard, pre-engineered building. This saved about $80,000 in construction costs.

and keep downtime to a minimum.

Equipping the plant for remote operation

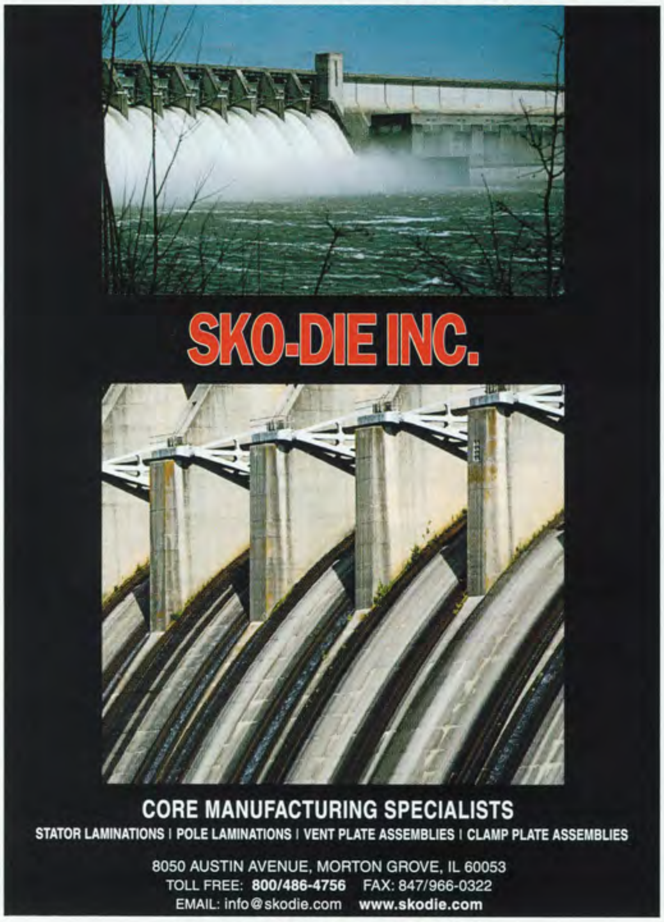
Getting to the Hystad Creek site can be a long and difficult trip, so we were concerned about the time it would take to notice outages or recover from them. An extensive set of remote monitors and controls would be critical to facilitate unattended operation.

As usual, there were hurdles to overcome, the foremost being cost. We could buy commercially available solutions, but most were designed for much larger systems — and all were too expensive to justify for our project. There also was the problem of communicating to our remote location. Telephone lines and cellular service were non-existent.

With the help of John Wheeler, we built a sophisticated control and switchgear system using equipment supplied by Boundary Electric. The plant is fully automatic, starting and stopping turbines as required due to available water, and adjusting nozzle openings for efficient operation at any given flow. Both the control system and the digital protection relays detect utility abnormalities and shut the plant down as appropriate. When permitted, the system automatically re-synchronizes to the utility and goes on line after an outage.

From our office in McBride (or anywhere in the world), we can remotely monitor more than 100 parameters such as phase voltages, frequency, needle nozzle position, pond level, and various temperatures of components such as bearings, generator windings, and ambient air. The system alerts us by telephone and e-mail when it detects a warning or fault, such as a utility disconnect or a bearing over-temperature.

The heart of the system is a modular programmable logic controller (PLC), which acts as the central control point for all monitors and controls, except video. A personal computer connected to the PLC with category 5 (CAT-5) Ethernet cables handles data logging, operator control, and programming. Additional computers act as video servers, using software from GeoVision Inc. in Irvine, Calif., to capture and time-stamp video segments that can be synchronized with data logs for reporting. A system of Ethernet routers pro-



vides secure Internet access to each component on the network.

We pre-programmed a number of commonly used reports that show a time-stamped history of parameters like power output, ambient temperature at the water intake, utility voltages, and water levels. The data log software also lets us create a report of virtually any combination of events. For example, a report could compare kilowatt output to needle nozzle position (flow) and compute efficiency; a sudden efficiency change usually indicates an obstruction in the nozzle. Time-stamped video segments can be included, allowing us to see external problems.

To avoid the hazards of voltage spikes during faults, all communication with the outside world is wireless. By using high-gain antennas and a repeater at the top of the mountain, we were able to use an inexpensive, point-to-point, low-power WiFi system for data, along with a UHF radio link for voice communications.

A bank of backup batteries supplies power to an uninterruptible power system (UPS), which ensures we can maintain both communication and control if the utility power is out. The plant has full black start capability, and under strictly controlled conditions can even operate in islanded mode to supply the local area. During a utility outage, one turbine-generator continues to run to maintain power in the building. If the hydro generators are not on and the batteries run low, a small generator automatically kicks in to recharge them.

Lessons learned

Over the course of developing Hystad Creek, we learned several valuable lessons we can apply to future projects.

First, buying equipment versus renting can save money. We kept costs low, but we could have done better. We probably should have bought more equipment because we wasted valuable time finding rental equipment and getting it to and from our site. But the excavator we bought has paid for itself three times over. Our overhead crane lets us move powerhouse components whenever we want. Acquiring concrete trucks was smart, but we should have bought a pumper truck. Next time, we will include equipment as part of our construction financing.

Second, taking time to shop saves money. For our next project, we also will allocate more time for shopping. We think we could have saved a good deal more with a little extra time. Some of these savings come from simple comparison shopping, but in many cases we discovered alternative approaches that produced a better result.

Third, assembling the right team of people is vital. It would have been tough to improve on our team. Key contributors like Shirley Bond, John Wheeler, and our contacts at Canyon Hydro took a personal interest in our success, along with hundreds of other individuals who were committed to excellence. We were incredibly fortunate to assemble such a powerful group of people.

Finally, we are convinced that our hands-on approach netted huge savings in build cost, and we strongly recommend staying close with your project. No one else shares your motivation. ■

Messrs. Peterson may be reached at chadpeterson@telus.net.