# **BOX CANYON** Hydroelectric project

VA103-119/7-S1

### **CANADIAN CONSULTING ENGINEERING AWARDS 2017** TECHNICAL CATEGORY E: NATURAL RESOURCES, MINING, INDUSTRY & ENERGY





ASSOCIATION OF CONSULTING ENGINEERING COMPANIES CANADA ASSOCIATION DES FIRMES D'INGÉNIEURS-CONSEILS CANADA



# **TABLE OF CONTENTS**

1111

**Project Summary Project Highlights** 2

## BOX CANYON HYDROELECTRIC PROJECT PROJECT SUMMARY

The 16 MW Box Canyon Hydroelectric Project may have the most hydraulically complex design of any run-of-river hydroelectric project in North America, if not the world. It has nine intake structures on different creeks and tributaries, all feeding into a single, high-pressure penstock that directs water to the powerhouse containing a 6-jet vertical axis Pelton turbine generating unit.

The project has three main intakes and six tributary intakes that address the unique hydrology, river morphology, and fish species distribution along McNab Creek and its tributaries. It has an 8.6-kmlong water conveyance system of interconnecting pipelines and high-pressure penstocks that handles varying intake elevations and flow contributions, requiring the addition and design of surge facilities and check valves. The project design also took into account the complex hydraulic transient pressures (water hammer), and provided unique ecological flow releases at each of the diversion weirs.

Knight Piésold Ltd. assisted Box Canyon Hydro Corp. in project development, from concept development through to operational monitoring, and the project now generates approximately 46 GWh/year of renewable energy, contributing towards BC's electricity self-sufficiency target.



### INNOVATION

The 16 MW Box Canyon Hydroelectric Project may have the most hydraulically complex design of any run-of-river hydroelectric project in North America, if not the world. The project, which is located in the McNab Creek watershed in Howe Sound, BC, has nine intake structures on different creeks and tributaries, all feeding into a single, high-pressure penstock that directs water to the powerhouse containing a 6-jet vertical axis Pelton turbine generating unit.

Knight Piésold Ltd. assisted the owner, Box Canyon Hydro Corp. (a subsidiary of Elemental Energy Inc.), with concept development, optimization studies, environmental assessment, and permitting, that continued through to detailed design and operational monitoring.

The original project concept was a 7 MW facility with a single intake on Box Canyon Creek. Knight Piésold optimized the design to the current 16 MW facility with multiple intakes, addressing complexities not typical in a single intake, run-ofriver hydroelectric project. The project has intake structures on three tributaries to McNab Creek (Box Canyon, Marty, and Cascara Creeks) as well as six minor tributary diversions, all of which address the unique hydrology, river morphology, and fish species distribution along the creeks and tributaries.

Key details for the major components of the project are summarized as follows:

#### RATED CAPACITY OF THE PLANT 16 MW

- **INTAKES** 9 (3 main intakes and 6 tributary intakes)
- **DESIGNFLOW** 3.96 m<sup>3</sup>/s
- PENSTOCK LENGTH 8.6 km (dia: 665 mm to 997 mm ID)
- GROSSHEAD 488 m
- TURBINE(S) 1 x Pelton unit, 6-jet vertical axis

SWITCHYARD 13.8 kV to 138 kV transformers

TRANSMISSION LINE 2.8 km of 138 kV transmission line



**POWERHOUSE AND SUBSTATION** Powerhouse and substation adjacent to McNab Creek.



**TIV AND GENERATOR** Inside the powerhouse, looking at the TIV and generator.

The project has an 8.6-km-long water conveyance system to connect the multiple intakes—much longer than most run-of-river hydroelectric projects. It handles varying intake elevations and flow contributions, requiring the addition and design of surge facilities and check valves.

The water conveyance system includes open channel sections, which divert water from the tributary intake to the main intakes, and a combination of low-pressure HDPE and steel highpressure penstock. Given the steep terrain, all penstock branches were installed below surface to overcome challenging construction and design conditions that were encountered at several sections of its length. All penstock branches combine into a single, high-pressure penstock that directs water to the turbine.

Each intake is at a different elevation, with elevation increasing from Box Canyon Creek intake to Marty

Creek intake, and Cascara Creek intake being the highest. Key hydraulic challenges with the penstock included:

**DESIGN FLOW** At design flow, the differences in penstock length and diameter between the Marty Creek and Box Canyon Creek penstock legs allow the penstock to flow full in all branches of the penstock, despite the differences in intake elevation. At flows less than design flow, the upper sections of the Marty and Cascara Creek penstock branches flow partially full.

**FLOW CONDITIONS** Under certain flow conditions, primarily during plant start-up, net head is higher in the Marty Creek penstock than the Box Canyon Creek penstock. A backflow valve prevents water diverted from Marty Creek and Cascara Creek from flowing into Box Canyon Creek.



**PENSTOCK INSTALLATION** Installation of buried penstock on a steep leg of the Box Canyon penstock.



**PENSTOCK** Penstock, HDPE with sweeping bend and soil restraint.

### COMPLEXITY

The project design accounted for complex hydraulic transient pressures and provided unique ecological flow releases at each diversion weir. The project, under its Water License, must maintain minimum instream flow requirements (IFR), maximum allowable diversion rates, and maximum flow ramping rates that vary for each intake, due to differences in hydrology, river morphology, and fish species distribution.

**IFR** The IFR at each intake is controlled by the intake design to ensure that IFR is released as priority before water can be diverted for power generation.

**DIVERSION RATE** In single intake projects, the maximum diversion rate is often plant controlled (i.e., throttled by turbine nozzles). Due to the multiple intake design, the maximum amount of water that can enter the penstock must be limited



#### **MARTY CREEK MAIN INTAKE**

Marty Creek main intake, showing Coanda screen and maximum diversion control weirs.

at each intake. The Marty Creek and Cascara Creek intakes have a weir system to passively limit the maximum diversion rate.

**RAMPING RATE** When the project starts-up, creek flows downstream of the intakes are reduced and flows downstream of the tailrace are increased. The opposite response occurs during a shutdown. Because the intakes are connected to a single, high-pressure penstock and are at different elevations, the start-up procedure is governed by the ramping rates at each intake depending on the conditions in the penstock.

The project is operated from level control at the "master" Box Canyon Creek intake. This intake can be locked-out, if required, making the project operable from level control at the Marty Creek intake, with water being diverted from any combination of Marty Creek and Cascara Creek.



**CASCARA CREEK MAIN INTAKE** Aerial view of Cascara Creek main intake.



#### BOX CANYON CREEK TRIBUTARY INTAKE#1

Box Canyon Creek tributary intake #1 looking downstream.

The facility monitors water level at Box Canyon Creek and Marty Creek intakes to manage ramping rates in each creek. The three main intakes were designed to provide the following functions:

**DIVERSION RATE** Divert a portion of the natural stream flow to the water conveyance system. Each of the two passive intakes at Marty Creek and Cascara Creek has a weir system to passively limit the maximum diversion rate. Maximum diversion rate can be modified by installing or removing stoplogs.

**COANDA SCREEN** The Coanda screen prevents debris and course sediment entrainment into the turbine flow. The screen is hydraulically designed to operate efficiently up to 1:2-year peak instantaneous flood event and the screen length includes a safety factor to account for possible blockage during the fall and winter months by ice formation and leaves/needles, and for wear on the leading edge of the wedge wire screen.



**BOX CANYON CREEK TRIBUTARY INTAKE#1** Box Canyon Creek tributary intake #1 looking upstream.

**OVERFLOW WEIR WALL** The overflow weir wall is designed to accommodate the 1:200-year peak instantaneous return period flood without structural damage to the intake structure and/or the penstock.

A key component of the penstock civil design included:

**OPTIMIZATION DESIGN** The penstock optimization design required a balance between head loss and the pipe installation costs associated with different sizes of pipe, the resultant net head available for power generation, and the value of that energy. The steel sections of the alignment comprised of seven different pipe sizes in total, while the HDPE sections of the alignment comprised of four different pipe sizes, utilizing six different HDPE DR ratings.

### **SOCIAL AND/OR ECONOMIC BENEFITS**

The project was awarded an electricity purchase agreement (EPA) under BC Hydro's Clean Power Call, providing 100% of its power generation to BC Hydro under a 40-year agreement. It illustrates the private sector working in a complementary manner with the public sector, exemplifying the private sector taking on project completion and operational risks. Many benefited from investment and employment, including First Nations, suppliers, contractors, consultants, local communities, and the region-at-large.

An alliance contracting model was adopted for the project in which the owner, contractor, project manager, and engineer worked together as one integrated team to manage construction costs, avoid overruns, and remove barriers for construction delivery. The model proved successful, with all parties in the team sharing the risks and rewards of completing the project on time and on budget. The project is located within the traditional territory of the Squamish Nation. The Squamish Nation was integral through all phases of the project, including development, working to identify and address traditional land-use and environmental issues. It was also involved in the construction phase through an Implementation Committee that was established to maximize employment, contracting, and training opportunities. Now that the project is operational, the Squamish Nation receives revenuesharing benefits that will provide funds for member services, such as education, social programs, and infrastructure.

The project provides reliable, renewable energy for the BC electrical grid. In particular, it is an important local electrical generation centre that will serve the Sunshine Coast and Lower Mainland for the next 60 to 75 years.



#### PARTNERSHIP WITH SQUAMISH NATION

The project is a partnership between Box Canyon Hydro Corp. (Elemental Energy Inc.) and Squamish Nation.



#### **CEREMONIAL OPENING**

Squamish Nation elders ceremonially cleansed the project and blessed it for a long and prosperous operation.

### **ENVIRONMENTAL BENEFITS**

The project has taken into consideration the differences in hydrology, river morphology, and fish species distribution along McNab Creek and its tributaries. Design considerations included:

**AQUATIC ECOLOGY** To maintain natural aquatic ecology, the IFR and maximum flow diversion are controlled independently at each of the main intakes; flow ramping is controlled independently at each of the main intakes and powerhouse.

IFRs are released via a bypass pipe and secondary IFR release options provide redundancy. The maximum diversion rate is controlled through a system of weirs that limit and reject excess water from entering the penstock. Flow ramping is controlled by operating plant start-up and shutdown to meet stage-change rates at instream level sensors.

**TAILRACE** The tailrace exit was elevated approximately 2 m above normal water level to

limit access of anadromous salmon and trout. Additionally, an enclosed corrugated steel pipe tailrace design was used to make the tailrace water appear dark further discouraging fish access and was graded to avoid stranding of any fish that enter.

**PENSTOCK** The penstock was buried to minimize footprint and visual disturbance to the natural environment and the Squamish Nation's traditional territory. Wherever possible, soil restraint was used to mitigate the requirement for either thrust blocks or anchor blocks.

The project generates approximately 46 GWh/year of renewable energy, enough to power approximately 4,500 homes. As a clean energy source, the project contributes to the BC Government's Energy Plan objectives.



#### **AQUATIC ECOLOGY**

The project preserves the natural aquatic ecology in McNab Creek and the surrounding area.



**TAILRACE** The tailrace is designed to exclude fish.

### **MEETING CLIENT'S NEEDS**

From early to operational, Elemental Energy has projects at various developmental stages. Commissioned in early 2016, the project is Elemental Energy's first operational hydroelectric project, strengthening its vision of building a strong portfolio of renewable energy projects.

Elemental Energy is "committed to projects that generate long term financial returns, environmental benefits for the planet, and positive social impacts for the communities in which we work." The project successfully embodies each commitment.

Through the alliance contracting model, the project team worked in partnership with Squamish Nation, innovating away from the standard, single intake design.

**FINANCIAL RETURNS** The project provides longterm financial returns for Elemental Energy, as 100% of the power generated is being sold to BC Hydro, under a 40-year EPA. The project is also expected to be operational for approximately 60 to 75 years. **ENVIRONMENTAL BENEFITS** The project preserves the natural aquatic ecology of the Howe Sound area. Its multiple intake design, with unique IFR, diversion rates, and ramping rates per watercourse, address the distinctive hydrology, river morphology, and fish species distribution along McNab Creek and its tributaries.

**SOCIAL IMPACTS** The single, high-pressure penstock directs water to the powerhouse to produce economically viable, productive energy that is financially beneficial for Elemental Energy, Squamish Nation, and local communities.

The project is among the hydroelectric schemes that have successfully been completed under BC Hydro's Clean Power Call. It contributes to BC's robust renewable energy sector, bringing the province closer to its *Clean Energy Act* commitment of being electricity self-sufficient.



#### **ALLIANCE CONTRACTING MODEL**

The owner, project manager, contractor, and engineer worked together as one integrated team to remove barriers for construction delivery, sharing the risks and rewards for completing the project on time and on budget.