KEMANO PROJECT – 70 YEARS OF DEVELOPMENT

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ABSTRACT
The Kemano hydroelectric facility came online in 1954 to provide electricity for the world's largest hydroelectric-powered aluminum smelter in Kitimat, British Columbia. This was the largest privately funded construction project in Canadian history. The Kemano tunnel and powerhouse had three phases of construction over 70 years. In the 1950s, the Nechako reservoir was created behind the Kenney dam, and a 16 km long tunnel was blasted through the coastal mountains to carry water westward to a powerhouse built underneath Mount DuBose near sea level. In the early 1990s, construction started on a second tunnel using a tunnel boring machine. Only the downstream portion of this tunnel was completed before the project was suspended. In 2007, to ensure long-term reliable electrical power, a project to complete the second tunnel began. Relationships with the First Nation communities significantly evolved from the beginning of the project to the present.

RÉSUMÉ
Le projet hydroélectrique de Kemano a été mise en service en 1954 pour fournir de l'électricité à la plus grande fonderie d'aluminium hydroélectrique au monde à Kitimat, en Colombie-Britannique. Il était le plus grand projet de construction financée par le secteur privé de toute l'histoire du Canada. Le tunnel et la centrale électrique avaient trois phases de construction pendant 70 ans. Dans les années 50s, le réservoir Nechako a été créé derrière le barrage de Kenney et un tunnel de 16 km de long a été creusée à travers les montagnes côtières pour transporter l'eau vers l'ouest jusqu'à une centrale électrique construite sous le mont DuBose près du niveau de la mer. Au début des années 90s, la construction d'un deuxième tunnel a commencé avec un tunnelier. Seulement la partie en aval de ce tunnel a été terminé avant la suspension du projet. En 2007, pour assurer une alimentation électrique fiable à long terme, un projet de réalisation du deuxième tunnel a démarré. Les relations avec les communautés des Premières nations ont considérablement évolué du début du projet à nos jours.

1 INTRODUCTION

The Kemano hydroelectric facility is a world-class project and feat of Canadian engineering. It came online in 1954 to provide electricity for the world's largest hydroelectric-powered aluminum smelter in Kitimat, British Columbia, 90 km northwest of the facility. The site has never had road access; instead, it is reachable only by air or by boat through the coastal fjords. Kemano was the largest privately funded construction project in Canadian history at the time, costing CAD$500 million in 1950 or approximately $5 billion in today's currency. The Kemano hydroelectric facility includes the Kenney dam impounding the Nechako reservoir, two 16 km long tunnels through the Coast Mountains at an elevation between 790 and 830 metres above sea level (one completed and

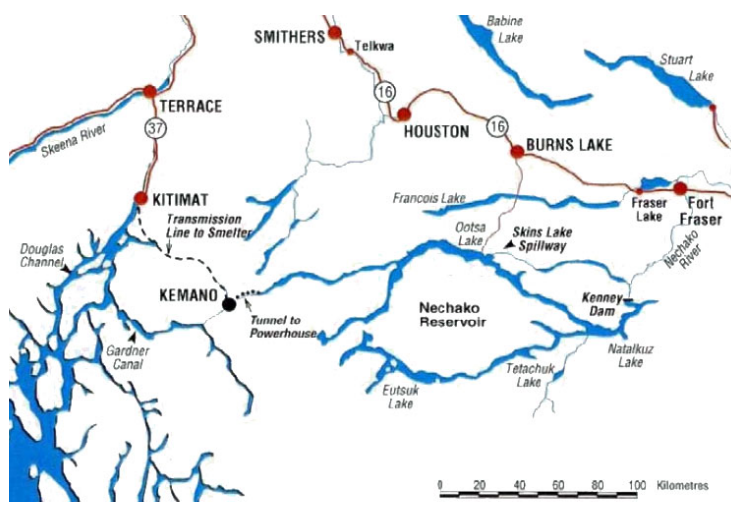

Figure 1. Kemano hydroelectric features (modified from BC Utilities Commission 2008)

one currently under construction), an underground powerhouse built underneath Mount DuBose near sea level, and a 90 km long transmission line constructed through the rugged coastal mountains to the smelter in Kitimat (Figure 1).

Over its lifespan, Kemano has endured the Cold War, changes in the provincial political winds, evolutions in relationships with local First Nations, and the many technical and logistical challenges associated with its remote location. This paper aims to highlight the extraordinary Canadian innovation that went into making this facility a reality.

2 1950s - INITIAL CONSTRUCTION

Although the original Kemano project started in the 1950s, investigations of the hydroelectric potential in the region date back to the 1920s. The diversion of the Fraser River and blockage of the eastward flowing Nechako River were required in order to reverse the flow of a 13000 km^2 drainage area to create the 230 km long Nechako Reservoir. This massive change in the hydrogeological regime was achieved by constructing the 97 m high and 457 m long Kenney dam. At the time, this was the third-highest rockfill dam in the world (Lawton 1953) (Photo 1).

Photo 1. Kenny Dam, circa 1960 (Kitimat Museum & Archives)

Between 1951 and 1954, six thousand construction workers built Kenney Dam, Skins Lake spillway, Kemano T1 Tunnel (including the intake, two penstocks and tailrace channel), the subterranean powerhouse, and the transmission line to Kitimat (Matthias 1954). Photo 2 shows a photograph of the Kemano engineering staff in 1952. Morrison Knudsen was the contractor responsible for building the tunnels and powerhouse and subcontracted the Kenney dam construction to Mannix from Calgary. A new company, Okanagan Helicopters, was contracted to provide services for the project, especially the construction of the transmission line to Kitimat. The work propelled Okanagan Helicopters into the largest commercial helicopter operator in North America and one of the largest in the world by the end of 1952 (Verticalmag 2017).

Photo 2. Kemano engineering staff in December 1952 (Kitimat Museum & Archives)

Figure 2 shows a schematic layout of the tunnels completed to redirect water that once flowed eastward into the Fraser River through the coastal mountains to the powerhouse near sea level at the Kemano River. The excavation work for the first tunnel (T1) removed 13.3 million m^3 of rock for the tunnel and powerhouse, consisting of predominantly diorite and granodiorite (Stuart 1960). The facility was constructed from 1951 to 1954 to supply power to the aluminum smelter in Kitimat, British Columbia. Eight 112 MW generators were originally installed, resulting in the facility having a total capacity of 896 MW (Rankin & Finlay, 1992).

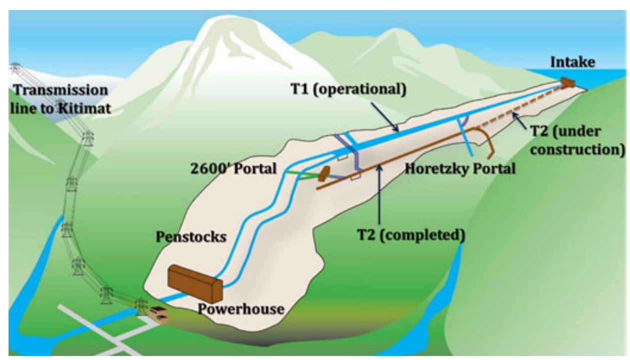

Figure 2. Kemano hydroelectric facility (Morgenroth, 2016)

The 16 km long horseshoe-shaped tunnel with an 8 m span was blasted through the coastal mountains at an elevation between 790 and 830 metres above sea level to carry water westward to a powerhouse built underneath Mount DuBose near sea level. The tunnel was excavated from two headings. Photos 3 and 4 show construction activities. At some locations in blocky porphyries and andesite, it was necessary to reinforce the walls of the tunnel with timber and steel sets. All sections requiring support were lined with concrete, and any timber sets were replaced with steel before the completion of the project. Drill and blast tunnelling advance rates averaged to approximately 3-4 m per shift, with a world record of 282 ft in a 6-day week and 61 ft in 24 hours set on February 25, 1953 (Hard Rock at Kitimat, 1952). Although the T1 Tunnel construction set world record advance rates (Photo 5), sixteen people died during its construction (Kitimat Museum & Archives).

Photo 3. Worker returning from the afternoon shift on June 1952 (Kitimat Museum & Archives)

Photo 4. Tram used to get to the T1 tunnel portal and penstocks, January 1954 (Kitimat Museum & Archives)

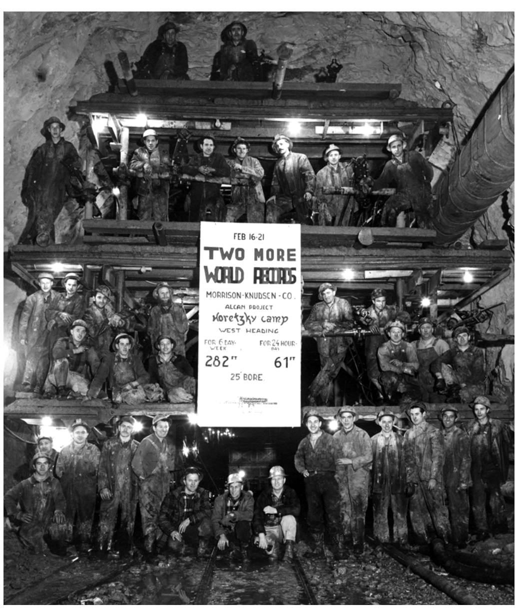

Photo 5. T1 World record tunnel advance, February 1953 (Kitimat Museum & Archives)

In this Cold War era, the strategic importance of aluminum influenced the decision to build the powerhouse (Photos 6, 7, and 8) under a mountain to protect the vital electricity needed for the aluminum smelter from aerial attack. The high water pressure in the penstocks also influenced the underground design of the facility. The powerhouse cavern is 335 m long by 25 m wide by 36 m high and lies 427 m inside Mount DuBose. The first three generators came online in the summer of 1954 (Ghate, 1991). By the end of 1955, all eight turbine generators had been installed in the powerhouse. The powerhouse was fully completed in 1955 when the tailrace channel was constructed. This was the largest power producer in BC. Even today, this is the largest high-pressure hydropower generation facility in North America.

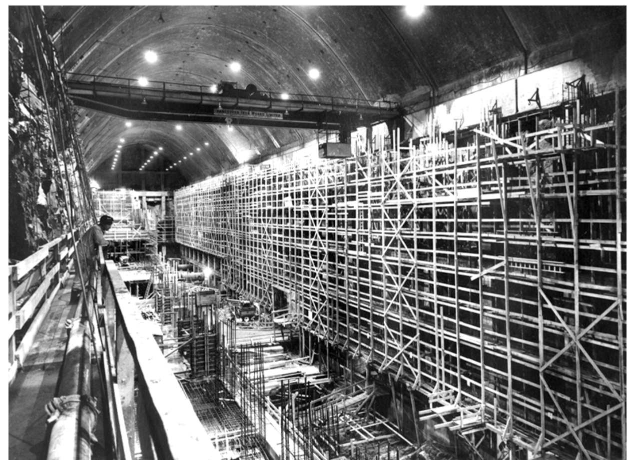

Photo 6. Powerhouse under construction, August 1953 (Kitimat Museum & Archives)

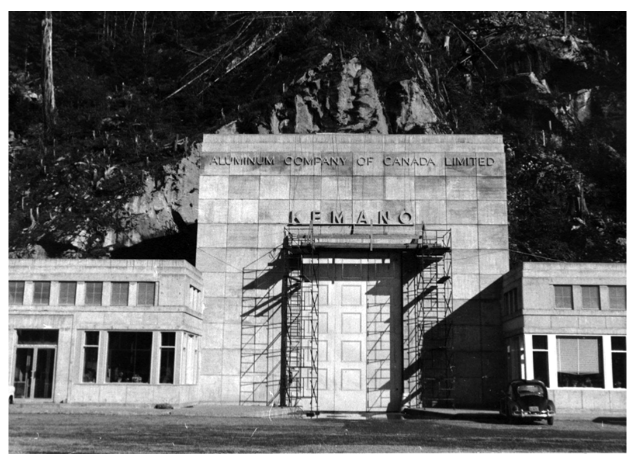

Photo 7. Powerhouse portal, October 1962 (Kitimat Museum & Archives)

Photo 8. Completed powerhouse, circa 1980 (Kitimat Museum & Archives)

It is worth noting that the official decision to build the Kemano project and the Kitimat smelter was taken in April 1951, and aluminum production commenced only three years later. To complete a project of a similar nature now would likely take much longer.

The T1 tunnel survived two large collapses over its 60+ year life, one in 1958 and the other in 1961. The collapse in 1958 resulted in a partial shutdown of water flow through the tunnel, and the 1961 collapse put the aluminum smelter in Kitimat offline (Stueck, 2012). These stability problems caused increasing concerns about the long term tunnel performance, prompting the planning for the T2 tunnel.

3 1990s - START OF T2 TUNNEL

In the late 1970s, an expansion called the Kemano Completion Project (KCP) was proposed. Some infrastructure for a potential second tunnel was constructed as part of the original project. This expansion was meant to increase the capacity of the facility by the construction of a second 16 km T2 tunnel and third penstock, as well as installing four turbine-generator units and additional transmission (Ghate, 1991). In addition, since the original infrastructure was beginning to deteriorate, this secondary tunnel was to allow for the completion of repair work and still maintain regular operation levels. Excess power production from the Kemano project was being sold to BC Hydro and exported to the US and Alberta, and the owner saw an opportunity to increase its sales.

In 1988, construction started on the T2 tunnel using a 5.73 m diameter tunnel boring machine. The work was undertaken by a joint venture consisting of Guy F. Atkinson Construction and Peter Kiewit Construction (Sorenson, 2012). This tunnel runs parallel to the first tunnel but is offset 300 m laterally to the south. Only the downstream portion of this tunnel was completed (Photos 9 and 10) before the project was suspended by the provincial government in response to objections from the First Nation communities and others that had been affected by the storage and diversion of water and concerns that even more water would be diverted away from the Nechako watershed. Reducing water levels flowing east from Nechako watershed would cause further harm to salmon stocks in the Fraser River system.

Photo 9. Partially completed T2 tunnel excavated by a tunnel boring machine (Rio Tinto)

Photo 10. Downstream portion of the T2 tunnel, excavated by a tunnel boring machine (J. Morgenroth)

On May 16, 1991, the federal court voided the 1978 Kemano Settlement Agreement, which gave Alcan the legal right to use more water from the Nechako River. Justice Walsh ruled that an Environmental Review was required, and Alcan immediately began slowing down work. By October 1991, construction was stopped, and nearly $0.5 billion had been spent without the tunnel being completed. Outstanding issues from the first phase of construction, including treaty and land claims and flooding, were other factors contributing to the termination of construction (Globe and Mail, 2006).

The village of Kemano was demobilized in 2000 with only a work camp remaining.

4 T2 TUNNEL COMPLETION

In 2007, Rio Tinto purchased Alcan, and a decision to spend CAD$3.3 billion to upgrade the smelter in Kitimat was announced. To ensure long-term reliable electrical power for the aluminum smelter, a decision was also made to complete the second tunnel to provide a backup to the original water supply tunnel. A second tunnel would also permit repairs to be made to either tunnel while still supplying water for electricity. The main purpose of the second tunnel is risk mitigation, not to increase the water intake, which is fundamentally different from the 1980s version of the tunnel (Sorenson, 2012).

The project to complete the T2 tunnel consists of two phases. The first phase was completed in 2013 (Photo 11). It entailed the construction of the interconnections between the new tunnel and the existing penstocks and a second surge shaft adjacent to the T2 tunnel. The new penstock was blasted and excavated next to the existing, operational power plant. Several adjustments were made to ensure that the blast vibrations had no impact.

Photo 11. Access portal for T2 tunnel construction (D. Brox)

The final construction phase involves refurbishing the existing 8.4 km of the tunnel and completing 7.6 km of new tunnel involving the excavation of 250,000 m^3 of rock. Hatch was selected by Rio Tinto to provide the engineering, project, and construction management services for the project while Frontier-Kemper Aecon JV did the tunnelling. In October 2018, Rio Tinto, together with the Haisla First Nation and the Cheslatta Carrier Nation, and project contractors, unveiled the fully assembled 1,300 t tunnel boring machine, named tl'ughus (Photos 12 and 13), which was a key milestone towards completing the Kemano T2 project. Twenty-five years after the failed attempt to construct the second tunnel, partnerships with First Nations are a critical component to the project's success.

Photo 12. Tunnel boring machine commissioned to complete the T2 tunnel named by the Cheslatta Carrier nation after the legend of a giant monster snake that bored through mountains. It is decorated with artwork by a Haisla Nation student (Hatch)

Photo 13. Tunnel boring machine ready to complete the T2 tunnel (Northern Sentinel, 2019)

Geological reports for the tunnel alignment indicate that the geology throughout the upstream half of T2 is more complicated than the downstream half, as there are multiple shear zones, faults and intersecting veining. In addition, the predicted stresses vary widely around the tunnel, which may result in difficult rock support design. The tunnel is now scheduled to be completed in 2021.

5 FIRST NATIONS ENGAGEMENT

This project has been associated with an evolution of relationships and interactions with the First Nation communities as well as consideration of environmental impacts from the beginning to the present. The current tunnelling is being conducted in partnership with Haisla First Nation and the Cheslatta Carrier Nation, in stark contrast to how these affected communities were treated in the past. The earlier stages of the Kemano project are used as a case history for how not to conduct mega projects (Baba and Raufflet 2014).

For a few decades before the Kemano project started, the BC Water Rights Branch was looking at the hydroelectric power potential in the general area. On December 30, 1950, a power agreement between the BC

Government and Alcan was signed. Alcan was given a 50-year lease of the region's land and water, and permission to flood up to 750 km^2 to create a 920 km^2 reservoir. The people living in the area were not adequately consulted or compensated for the loss of their lands. The Cheslatta Carrier First Nation accepted $7.4 million in 1993 from the Government of Canada as a settlement for inadequate compensation in 1952. Assessment of the environment and social impacts of the project were not performed. Instead, the prevailing approach at the time was the promotion of the project and the exploitation of natural resources.

Lack of consultation and environmental assessment occurred again when the Kemano Completion Project was proposed, and as Alcan began to divert more water to increase power production and electricity sales. The water diversion affected salmon runs in the Nechako watershed. The Kemano Completion Project failed due to these considerations and a disregard for environmental flow needs in the Nechako watershed (Gomez-Amaral and Day 1987).

The more recent work to complete the second tunnel was conducted with proper consideration of environmental concerns and by fully partnering with the local First Nations communities. The Kemano project illustrates how far engineering projects have evolved in terms of their approach to the environment and affected communities.

6 CONCLUSION

The Kemano project is a feat of Canadian engineering and construction in a challenging location. Construction of the second tunnel will ensure the long-term reliability of the power supply to the Kitimat smelter from the Kemano powerhouse by creating a backup to the original tunnel. It is a project that deserves wider recognition in terms of its role in advancing new engineering designs and construction practices. It also illustrates the evolution of engagement with First Nations and conducting comprehensive environmental impact assessments.

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