MIDGARD
CONSULTING INC.

Yukon Next Generation Hydro and Transmission Viability Study:

Project Cost Per Hydro Development Phase Report

Submitted By: Midgard Consulting Incorporated

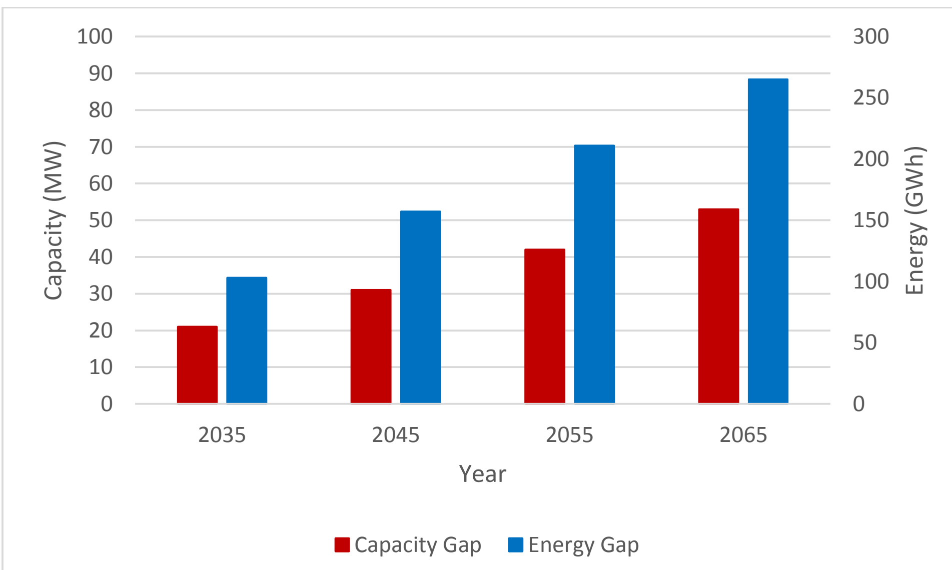
Date: October 19, 2015

Executive Summary

The Yukon Development Corporation ("**YDC**") has commissioned Midgard Consulting Incorporated ("**Midgard**") and its team of sub-consultants to complete the *Yukon Next Generation Hydro and Transmission Viability Study.* The study, delivered through a series of technical papers, is intended to help inform the decisions necessary to fill the territory's growing energy gap and to support the Yukon's continued economic growth and development.

In the *Yukon Electrical Energy and Capacity Need Forecast (2035 to 2065)* the Yukon's future electrical energy and electrical capacity needs were estimated based upon expected demand drivers such as population, per capita electrical energy consumption, and industrial (e.g. mining) activity. Consideration was also given to future scenarios that could alter electrical energy and electrical capacity demand such as the impacts of climate change, technological change, and changing electrical energy consumption patterns (e.g. fuel switching from heating oil to electricity for heating homes). The result was a Baseline scenario which forecast electrical capacity and energy gaps from 2035 to 2065 as summarized in Figure 1.

Figure 1: Forecasted Baseline Capacity and Energy Gap



Building on the results of the Yukon Electrical energy and Capacity Need Forecast (2035 to 2065), the *Scalability Assessment Report* evaluated potential projects based on their ability to meet the forecasted 2065 Baseline Energy Gap while minimizing reservoir footprints. At the end of the assessment, six projects of interest were shortlisted as shown in Table 1 and Figure 2. Four of the projects were standalone sites and two projects were two site cascades on a common river system with an upstream water storage dam and a downstream Run-of-River (ROR) facility.

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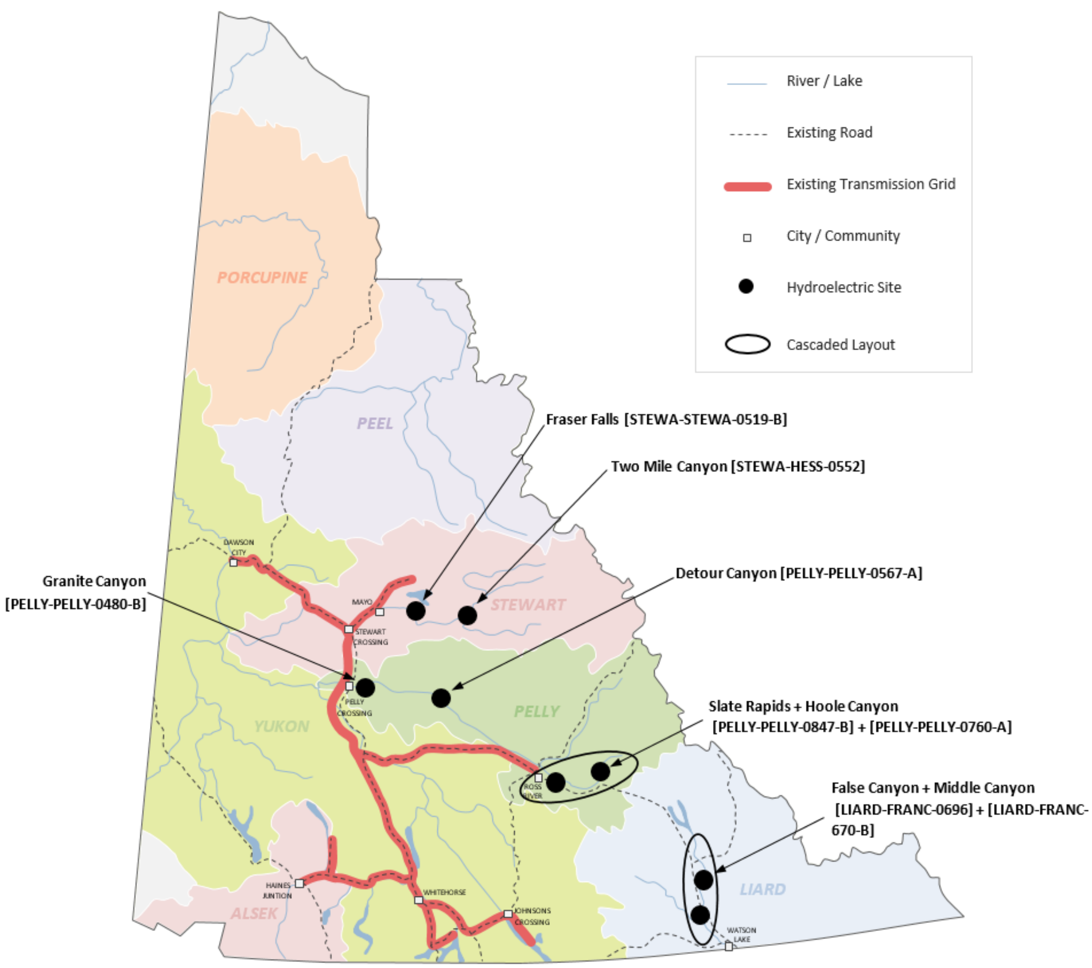
Table 1: Scalability Shortlist

Site Name	Site ID	Existing Lake Area[1]	Incremental Reservoir Footprint	Total Reservoir Footprint	Gap Closure
Detour Canyon	PELLY-PELLY-0567-B	0 km^2	130 km^2	130 km^2	100%
Fraser Falls	STEWA-STEWA-0519-B	0 km^2	311 km^2	311 km^2	100%
Granite Canyon	PELLY-PELLY-0480-B	0 km^2	173 km^2	173 km^2	100%
Two Mile Canyon	STEWA-HESS -0552	0 km^2	101 km^2	101 km^2	97%
False Canyon + Middle Canyon ROR	LIARD-FRANC-0696 + LIARD-FRANC-0670-B	109 km^2	154 km^2	263 km^2	100%
Slate Rapids + Hoole Canyon ROR	PELLY-PELLY-0847-B + PELLY-PELLY-0760-A	37 km^2	154 km^2	191 km^2	100%

Figure 2: Scalability Short List Map



[1] Existing lake areas do not include river beds.

The projects were also studied in terms of a staged build out over time so that they could be sized to better match growing electricity demand in the years leading up to 2065 (i.e. from 2035 up to 2065). Therefore, the *Scalability Assessment Report* evaluated projects on the basis of progressively increasing project energy and capacity over time. The shortlist projects scalability build out timeline is shown in Table 2.

Table 2: Scalability Build Out Timelines

Project Name and Site ID	Build Out Timeline				
Detour Canyon [PELLY-PELLY-0567-B]	2035: First 2 turbines installed	2045	2050: 3rd Turbine Added	2055	2060
Fraser Falls [STEWA-STEWA-0519-B]	2035: First 2 turbines installed	2045	2050: 3rd Turbine Added	2055	2060
Granite Canyon [PELLY-PELLY-0480-B]	2035: First 2 turbines installed	2045	2050: 3rd Turbine Added	2055	2060
Two Mile Canyon [STEWA-HESS -0552]	2035: First 2 turbines installed	2045: 3rd Turbine Added	2050	2055	2060
False Canyon + Middle Canyon ROR [LIARD-FRANC-0696 + LIARD-FRANC-0670-B]	2035: Upstream Project Operation with 2 Turbines	2045	2050: 3rd Turbine Added	2055	2060: ROR Operation
Slate Rapids + Hoole Canyon ROR [PELLY-PELLY-0847-B + PELLY-PELLY-0760-A]	2035: Upstream Project Operation with 2 Turbines	2045	2050: ROR Operation	2055	2060

This report, the *Project Cost per Hydro Development Phase Report* describes the Scalability Short List projects in terms of design features, scalability build out, cost, energy output, and Levelized Cost of Energy (LCOE). LCOE was calculated two different ways:

1) **Full Utilization LCOE:** The Full Utilization LCOE, expressed in $/MWh, is calculated assuming that a project is built at its full size and capacity (including post 2065 upgrades for standalone projects), that the projects generate at their maximum potential, and that all of the generated energy is consumed.
2) **Forecast Utilization LCOE:** The Forecast Utilization LCOE, expressed in $/MWh, is calculated on the basis that a project is built as per the Scalability Build Out Timeline shown in Table 2, and that only the energy generated up to a maximum defined by the Baseline 2035 to 2065 forecast is consumed (and contributes to the LCOE calculation).

Table 3 shows the potential energy output from each of the Scalability Shortlist projects when sized for the goal of providing at least 95% of the Forecast Baseline 2065 Gap plus the addition of two turbines for post-2065 expansion for standalone projects.

Table 3: Scalability Shortlist Projects 2065 Energy Output

Project	2065 Installed Capacity (MW)	2065 Forecast Energy Output (GWh)	2065 Must Run Energy (GWh)	Post 2065 Additional Available Energy (GWh)	Max Potential Energy Output (GWh)
Detour Canyon	60	265	22	300	587
Fraser Falls	57	265	30	268	563
Granite Canyon	57	265	51	272	588
Two Mile Canyon	54	259	14	216	489
False Canyon + Middle Canyon ROR	78	265	0	186	451
Slate Rapids + Hoole Canyon ROR	107	265	0	222	487

Table 4 shows the Capital Cost Estimates for the projects including project design, environmental studies, construction (dam, powerhouse, transmission, roads etc.), scalability upgrades, optional post 2065 upgrades, miscellaneous owner's costs (for First Nations & stakeholder engagement & specific studies, general project development), and contingency.

This report also discusses the interconnection of False Canyon + Middle Canyon ROR and Slate Rapids + Hoole Canyon RORs under two different scenarios:

1) With a Faro- Watson Lake Transmission Line: Assumes a pre-existing 138kV transmission line interconnecting Faro and Watson Lake. The projects would interconnect to the Faro to Watson Lake transmission line.
2) Without Faro-Watson Lake Transmission Line: Assumes no transmission line between Faro and Watson Lake exists. The projects would interconnect to a substation near Faro.

While their energy outputs are similar, the cost of the Shortlisted projects varies by over $2 Billion with the lowest estimated at a capital cost of $847 Million (Granite Canyon) and the highest estimated at $2.96 Billion (Slate Rapids + Hoole Canyon ROR). The capital costs are dependent on site specifics factors such as location, topography, foundation conditions, availability of construction material, distance from an interconnection point etc. In general the cascaded projects require larger capital costs than the standalone project because cascade projects require the construction of two separate facilities whereas standalone projects only require one facility. Additionally, the cascaded projects also require longer transmission lines than the standalone projects which are generally located closer to the existing 138kV Yukon transmission system.

Table 4: Scalability Shortlist Projects Cost ($ Million)

Project	Initial Dam	Scalability Upgrade 1	Scalability Upgrade 2	Optional Upgrade Post 2065	Tx Line + Access Road	Capital Cost Estimate[2]
Detour Canyon	843	27	N/A	53	114	1413
Fraser Falls	753	27	N/A	54	64	1233
Granite Canyon	503	27	N/A	53	19	847
Two Mile Canyon	444	16	N/A	32	164	919
False Canyon + Middle Canyon ROR (w/ Faro-Watson Lake)	833	27	220	N/A	18	1493
False Canyon + Middle Canyon ROR (w/o Faro-Watson Lake)	833	27	220	N/A	377	1959
Slate Rapids + Hoole Canyon ROR (w/ Faro-Watson Lake)	1330	730	N/A	N/A	16	2764
Slate Rapids + Hoole Canyon ROR (w/o Faro-Watson Lake)	1330	730	N/A	N/A	169	2962

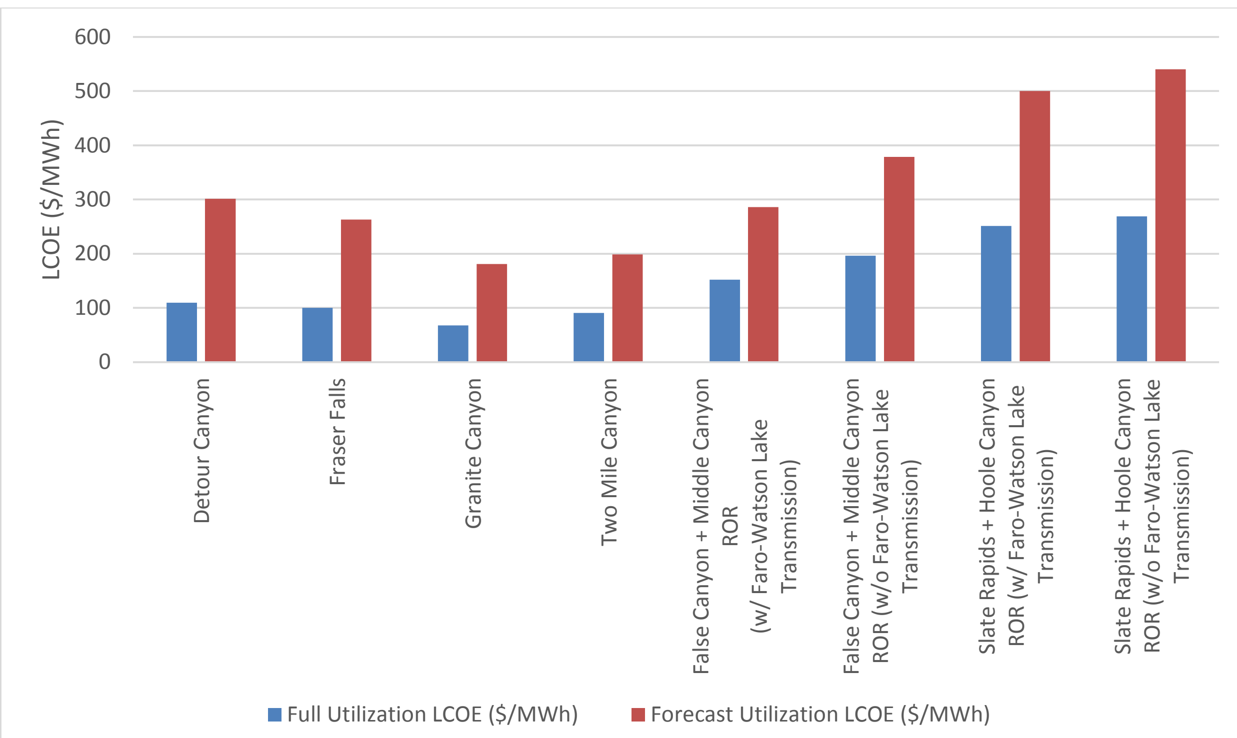
Table 5 and Figure 3 show the project LCOEs. The Full Utilization LCOEs range from $68/MWh to $110/MWh for standalone projects, and from $152/MWh to $269/MWh for cascaded projects. The Forecast Utilization LCOEs range from $181/MWh to $301/MWh for standalone projects, and from $286/MWh to $540/MWh for cascaded projects.

[2] Capital cost estimates include miscellaneous owner's cost and 30% contingency.

Table 5: Scalability Shortlist Projects Energy LCOE

Project	Full Utilization LCOE ($/MWh)	Forecast Utilization LCOE ($/MWh)
Detour Canyon	110	301
Fraser Falls	100	263
Granite Canyon	68	181
Two Mile Canyon	90	199
False Canyon + Middle Canyon ROR (w/ Faro-Watson Lake)	152	286
False Canyon + Middle Canyon ROR (w/o Faro-Watson Lake)	196	379
Slate Rapids + Hoole Canyon ROR (w/ Faro-Watson Lake)	251	500
Slate Rapids + Hoole Canyon ROR (w/o Faro-Watson Lake)	269	540

Figure 3: Projects LCOE Comparison



Given the similarity in energy outputs for each of the projects, LCOEs are driven mainly by the capital cost, and not surprisingly, the project with the lowest estimated capital cost (Granite Canyon) has the lowest LCOE ($68/MWh Full Utilization and $181/MWh Forecast Utilization). Similarly, the project with the highest estimated capital cost (Slate Rapids + Hoole Canyon ROR) has the highest LCOE ($269/MWh Full Utilization and $540/MWh Forecast Utilization).

It is important to state that this report is one of several early stage reports, and an economic comparison is only one comparator of project evaluation. Further studies, investigations and assessments are required to better understand these projects, and within the Next Generation Hydro study series, environmental and socio-economic impacts will be studied in the next technical paper titled, *Positive and Negative Socio-Economic and Environmental Effects*.

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ASL	Above Sea Level
ADL	Average Drawdown Level
CFRD	Concrete Face Rockfill Dam
FSL	Full Supply Level
LCOE	Levelized Cost of Energy
PMF	Probable Maximum Flood
RCC	Roller Compacted Concrete
ROR	Run of River
RoW	Right of Way

1 Introduction

The Yukon Development Corporation ("**YDC**") has commissioned Midgard Consulting Incorporated ("**Midgard**") and its team of sub-consultants to complete the *Yukon Next Generation Hydro and Transmission Viability Study.* The study, delivered through a series of technical papers, is intended to help inform the decisions necessary to fill the territory's growing energy gap, and to support the Yukon's continued economic growth and development.

1.1 Assessment Team

The assessment team for the *Yukon Next Generation Hydro and Transmission Viability Study* consists of the following industry experts:

1) *Midgard Consulting Incorporated ("**Midgard**")* - Midgard provides consulting services to the electrical power and utility industry. Midgard is the lead consultant for the *Yukon Next Generation Hydro and Transmission Viability Study*, with specific components of the assignment sub-contracted to other leading industry experts.

2) *SLR Consulting Global Environmental Solutions ("**SLR**")* - SLR is part of a multi-disciplinary consultancy providing worldwide environmental sciences, engineering, and socio-economic expertise and high-value advisory services.

3) *Hatfield Consultants* (***"Hatfield"***) – Hatfield's core expertise is environmental monitoring and assessment, particularly the design and deployment of environmental evaluation and monitoring programs for aquatic environments. In addition, services include environmental impact assessments, GIS applications, environmental information systems, aquatic ecology, and biodiversity assessments.

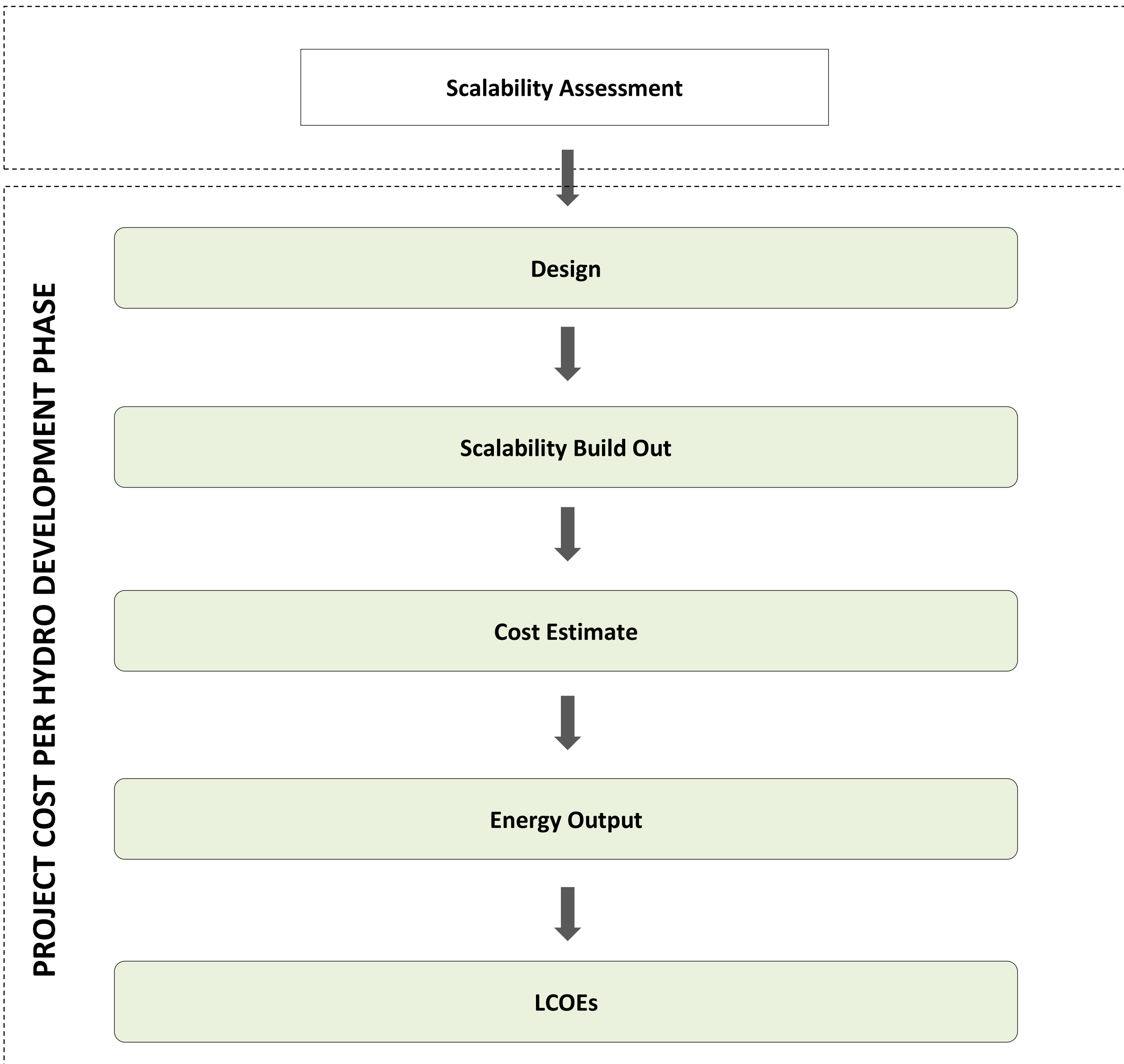
4) *J.D. Mollard and Associates (2010) Limited ("**JDMA**")* - JDMA has experience reaching back to 1956 and has carried out upwards of 5000 consulting assignments for governments, academia, and private industry, across Canada and around the world. JDMA has a long tradition of excellence in applied civil and geological engineering, geology, hydrogeology, geography, biology, remote sensing, terrain analysis, and environmental studies.

5) *Kawa Engineering Ltd ("**KAWA**")* - KAWA has expertise in the hydraulic, civil, structural, mechanical and geotechnical design of hydroelectric projects ranging from 10 kW to over 400 MW. KAWA also provides services in the quantity and construction estimation. Since its inception in 2012, Kawa has worked on over 40 projects, including recent experience with hydroelectric facilities in the Yukon and Northern Canada.

6) *Yukon Peer Review Panel (“**YPRP**”)* - The YPRP is an internal review panel that is comprised of four senior and respected Yukoners that provide oversight, feedback, and advice at all stages of the project. The four members of the YPRP ensure that a strong Yukon voice, knowledge, and experience is brought to the project from the perspective of long term residents who collectively have over 130 years of experience living in the Yukon Territory.

1.2 Overall Report Structure

The *Project Cost per Hydro Development Phase Report* describes the Scalability Short List projects in terms of design, scalability build out, cost, energy output, and Levelized Cost of Energy (LCOE).



2 Introduction

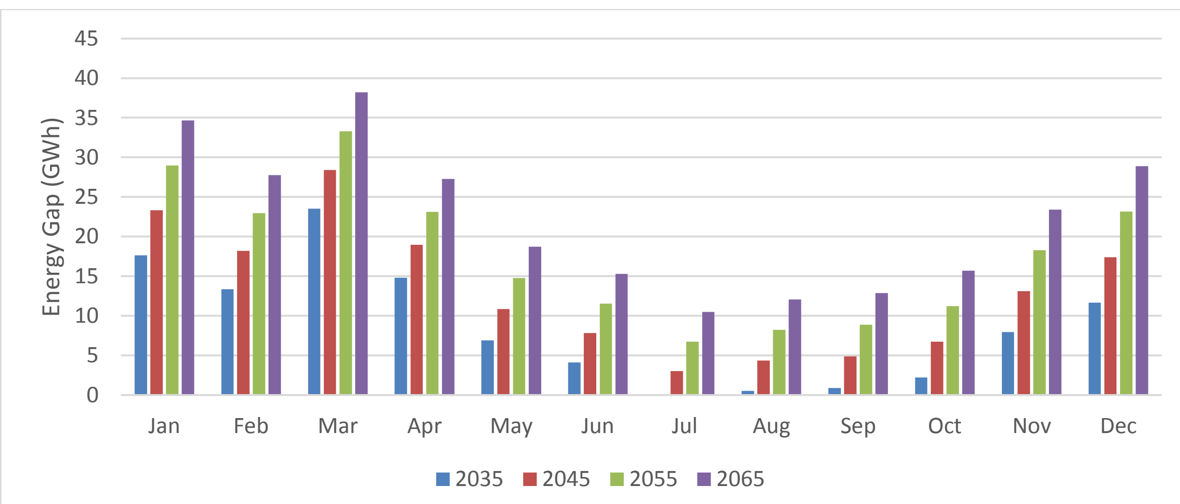
2.1 Recap - Energy Demand Forecast

In the *Yukon Electrical Energy and Capacity Need Forecast (2035 to 2065)* the Yukon's future electrical energy and electrical capacity needs were estimated based upon expected demand drivers such as population, per capita electrical energy consumption, and industrial (e.g. mining) activity. Consideration was also given to future scenarios that could alter electrical energy and electrical capacity demand such as the impacts of climate change, technological change, and changing electrical energy consumption patterns (e.g. fuel switching from heating oil to electricity for heating homes). The Yukon need for electrical energy and capacity is growing and is expected to continue growing through to the end of 2065 and beyond. As a result, Yukon must meet the monthly electrical energy gaps and capacity gaps for 2035 to 2065 as shown in Table 6.

Table 6: Yukon Energy and Capacity Gaps Forecast (2035 – 2065)

		2035	2045	2055	2065
Low Case Scenario	Capacity	11 MW	17 MW	24 MW	31 MW
	Energy	54 GWh	85 GWh	118 GWh	154 GWh
Baseline Case Scenario	Capacity	21 MW	31 MW	42 MW	53 MW
	Energy	103 GWh	157 GWh	211 GWh	265 GWh
High Case Scenario	Capacity	36 MW	62 MW	95 MW	136 MW
	Energy	180 GWh	311 GWh	476 GWh	682 GWh

Figure 4: Yukon Monthly 2065 Baseline Energy Gap



In this report, the projects are discussed based on their ability to meet the energy requirements of the Forecasted Baseline Energy Gap from 2035 to 2065.

2.2 Recap - Scalability Shortlist

The *Scalability Assessment Report* evaluated potential projects based on their ability to meet the Yukon Forecasted 2065 Baseline Energy Gap while minimizing their reservoir footprints. At the end of the assessment, six sites of interest were shortlisted as summarized in Figure 5 and Table 7.

Figure 5: Scalability Shortlist

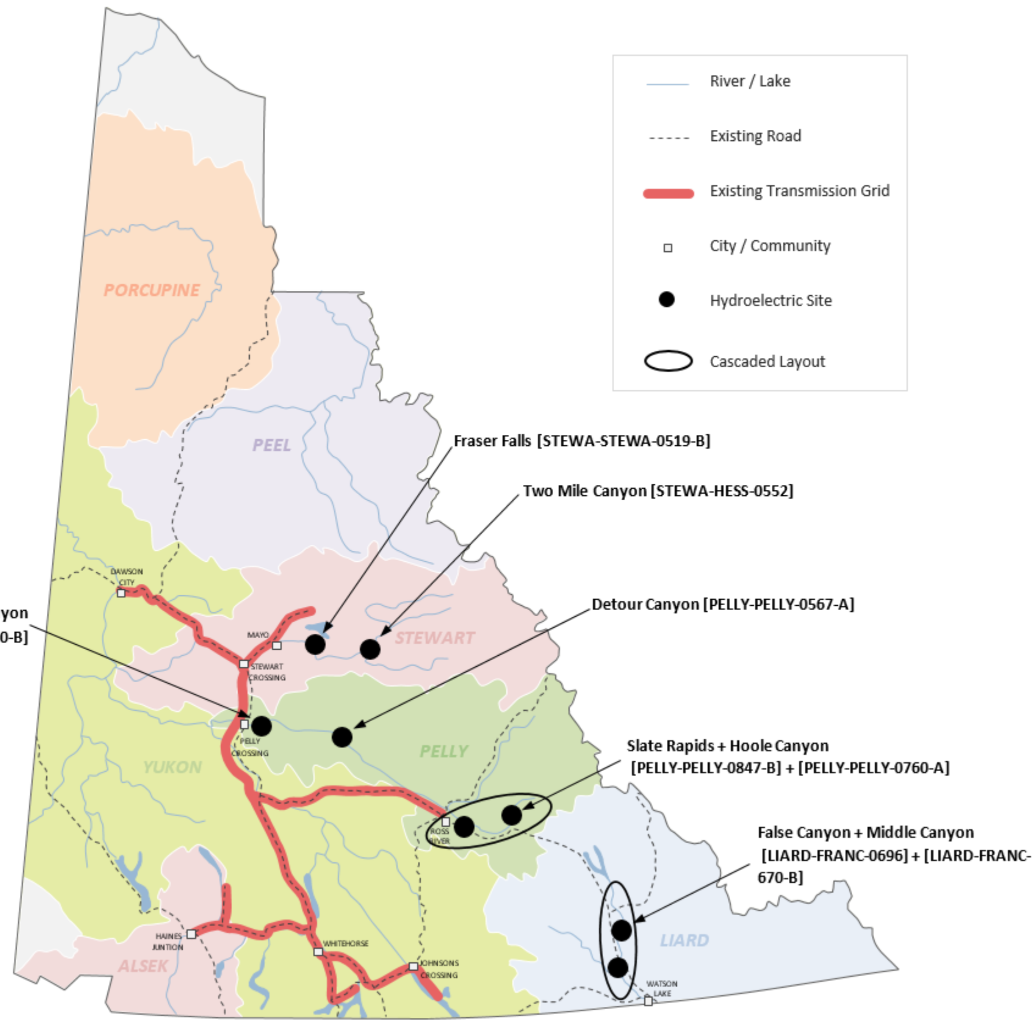


Table 7: Scalability Shortlist

Site Name	Site ID	Existing Lake Area[3]	Incremental Reservoir Footprint	Total Reservoir Footprint	Gap Closure
Detour Canyon	PELLY-PELLY-0567-B	0 km^2	130 km^2	130 km^2	100%
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The projects were also studied in terms of a staged build out over time so that they could be sized to better match growing electricity demand in the years leading up to 2065 (i.e. from 2035 up to 2065). Therefore, the Scalability Assessment Report evaluated projects on the basis of progressively increasing project energy and capacity over time. The shortlist projects scalability build out timeline is shown in Table 8.

Table 8: Scalability Build Out Timelines

Project Name and Site ID	Build Out Timeline				
Detour Canyon [PELLY-PELLY-0567-B]	2035: First 2 turbines installed	2045	2050: 3rd Turbine Added	2055	2060
Fraser Falls [STEWA-STEWA-0519-B]	2035: First 2 turbines installed	2045	2050: 3rd Turbine Added	2055	2060
Granite Canyon [PELLY-PELLY-0480-B]	2035: First 2 turbines installed	2045	2050: 3rd Turbine Added	2055	2060
Two Mile Canyon [STEWA-HESS -0552]	2035: First 2 turbines installed	2045: 3rd Turbine Added	2050	2055	2060
False Canyon + Middle Canyon ROR [LIARD-FRANC-0696 + LIARD-FRANC-0670-B]	2035: Upstream Project Operation with 2 Turbines	2045	2050: 3rd Turbine Added	2055	2060: ROR Operation
Slate Rapids + Hoole Canyon ROR [PELLY-PELLY-0847-B + PELLY-PELLY-0760-A]	2035: Upstream Project Operation	2045	2050: ROR Operation	2055	2060

[3] Existing lake areas do not include river beds.

2.3 Levelized Cost of Energy - LCOE

Calculating a unit cost of energy, or a "Levelized Cost of Energy" (LCOE), provides a consistent means of economically comparing hydroelectric and other generation projects. The LCOE calculation accounts for both the energy generated, and the total capital and operating costs for a generation facility over its expected lifetime. Levelized Cost of Energy models base the valuation on net present value calculations of the time value of capital costs, operating costs, and energy outputs.

The Yukon Energy Corporation ("YEC") also makes use of LCOE calculations. In the 2011-2030 Resource Plan YEC defined the LCOE as:

> "LCOE indicates on a consistent and comparable basis each option's overall costs per kWh. It includes capital and operating costs and, where specified, any related transmission, storage or capacity costs. This cost is subject to ongoing annual inflation for each subsequent year of operation in order to assess costs over the option's economic life."[4]

Several inputs are required to calculate Levelized Cost of Energy, including annual energy production, costs (in the form of project costs, interest during construction, and operating costs), and economic assumptions (discount rate and project lifetime). These inputs are applied in the following LCOE equation:

$$LCOE = \frac{Total\ Present\ Value\ of\ Costs}{Total\ Present\ Value\ of\ Energy\ Output}$$

[4] Source Details: Yukon Energy Corporation, "20-Year Resource Plan: 2011-2030", December 2011, p. 67

2.3.1 Energy Types

From the *Scalability Assessment Report* the energy output from a hydroelectric generation project is classified into different categories as described in Table 9.

Table 9: Energy Types

Component	Description
Energy Output	Generated energy that is fully utilized to meet the Yukon demand.
Must Run Energy	Generated energy that is surplus to the Yukon demand. Must Run Energy must be produced due to operational constraints such as minimum turbine flow requirements or minimum environmental water flow releases (IFR). Must Run Energy would require other Yukon facilities (e.g. Whitehorse) to restrict generation to balance Yukon electrical load and demand.
Additional Available Energy	Available energy that is surplus to the Yukon demand that can be generated as needed by either operating all turbines at an assumed 95% capacity factor or by ROR operation. The available energy may be utilized for energy gaps larger than the forecast 2065 Baseline gap.
Spilled Energy	Water that is spilled due to the limited size and operating restrictions of a project (e.g. water flows are so high during the summer freshet that the generation facility spills excess water).
Generation Shortfall	Generation shortfall represents an energy deficit between the Yukon demand for energy and the ability of the project to meet that gap. In practice this energy shortfall will need to be produced from another source (e.g. diesel, natural gas fired generation, wind or other hydro) to meet the Yukon demand.

As a result of how the different types of energy a project generates are accounted for, there are two different ways to calculate a project's LCOE.

1. Full Utilization LCOE
2. Forecast Utilization LCOE

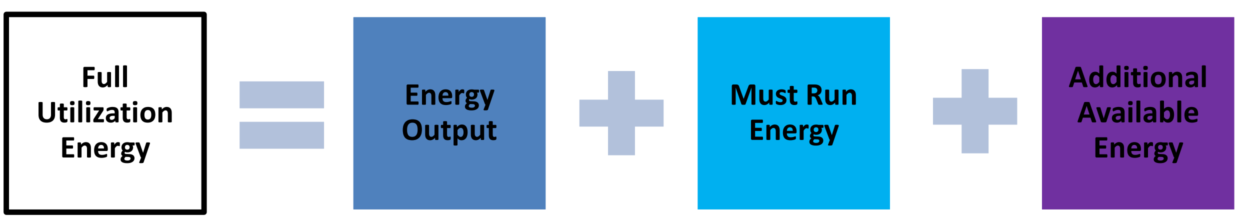
2.3.2 Full Utilization LCOE

The Full Utilization LCOE, expressed in $/MWh, is calculated assuming that a project is built at its full size and capacity, that the project generates at its maximum potential, and that all of the generated energy is consumed[5].

The total present value of costs is calculated based on the capital and operating costs assuming that the project is built to its maximum size from the start (i.e. includes all turbines and expansions).

The total present value of energy outputs is calculated based on the Full Utilization Energy Output which is the sum of the following energy output types from Table 9.

Figure 6: Full Utilization Energy



The Full Utilization LCOE is therefore calculated as follows:

$$Full\ Utilization\ LCOE = \frac{Total\ Present\ Value\ of\ Costs}{Total\ Present\ Value\ of\ \mathbf{Full\ Utilization\ Energy}}$$

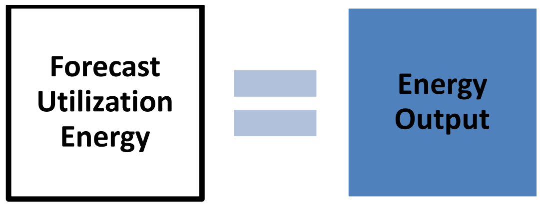
2.3.3 Forecast Utilization LCOE

Although similar, the Forecast Utilization LCOE has two primary differences from the Full Utilization LCOE. Specifically, the Forecast Utilization does not assume that the project is built to full size immediately, and it also does not assume that the entire energy output is fully consumed.

[5] Calculation details for LCOE are shown in Appendix A: LCOE Calculation.

As a result, the Forecast Utilization LCOE, expressed in $/MWh, is calculated on the basis that a project is built as per the Scalability Build Out Timeline shown in Table 8 and that only the energy generated up to a maximum defined by the Baseline 2035 to 2065 forecast is consumed (and contributes to the LCOE calculation).

Figure 7: Forecast Utilization Energy



It is worth noting that although Must Run Energy is generated by a project, it does not contribute to the Forecast Utilization Energy because the Must Run Energy is offset by a reduction in energy production elsewhere in the Yukon system. For example, the Whitehorse facility would reduce its generation output to balance the amount of Must Run Energy produced by the project, thus resulting in a net zero increase in overall generation output for the entire Yukon system.

The Forecast Utilization LCOE is calculated as shown below[6]:

$$Forecast\ Utilization\ LCOE = \frac{Total\ Present\ Value\ of\ Costs}{Total\ Present\ Value\ of\ \mathbf{Forecast\ Utilization\ Energy}}$$

[6] Calculation details for LCOE are shown in Appendix A: LCOE Calculation.

3 Scalability Shortlist Project Description

This section of the report discusses the Scalability Short List projects in terms of:

1. **Project Description and Design:** Physical description of the project along with specific major construction details (if appropriate). As a convention, locations and sides of the rivers are described looking downstream towards the project.
2. **Scalability Build Out:** Description of the forecast build out timeline for the project.
3. **Cost:** Capital and operating costs. The dams capital cost estimates where provided by Kawa. Midgard estimated the transmission line and access road costs. On top of these costs, Midgard included an allowance for other miscellaneous owner's cost (permitting, environmental assessment) and contingency.
4. **Energy Output:** The energy output with different energy types described as in Table 9.
5. **LCOE:** LCOE calculated two ways:
    a. Full Utilization Cost of Energy,
    b. Forecast Utilization Cost of Energy.

3.1 Detour Canyon [PELLY-PELLY-0567-B]

Detour Canyon is a potential hydroelectric project on the Pelly River, located in the Pelly River Basin, approximately 85 km downstream (northwest) of Faro. The total drainage area is estimated to be 28,500 km^2.

The major components of the preliminary project layout are listed in Table 10. The project components are shown in Figure 8 and described in more detail as per sections listed in Table 10.

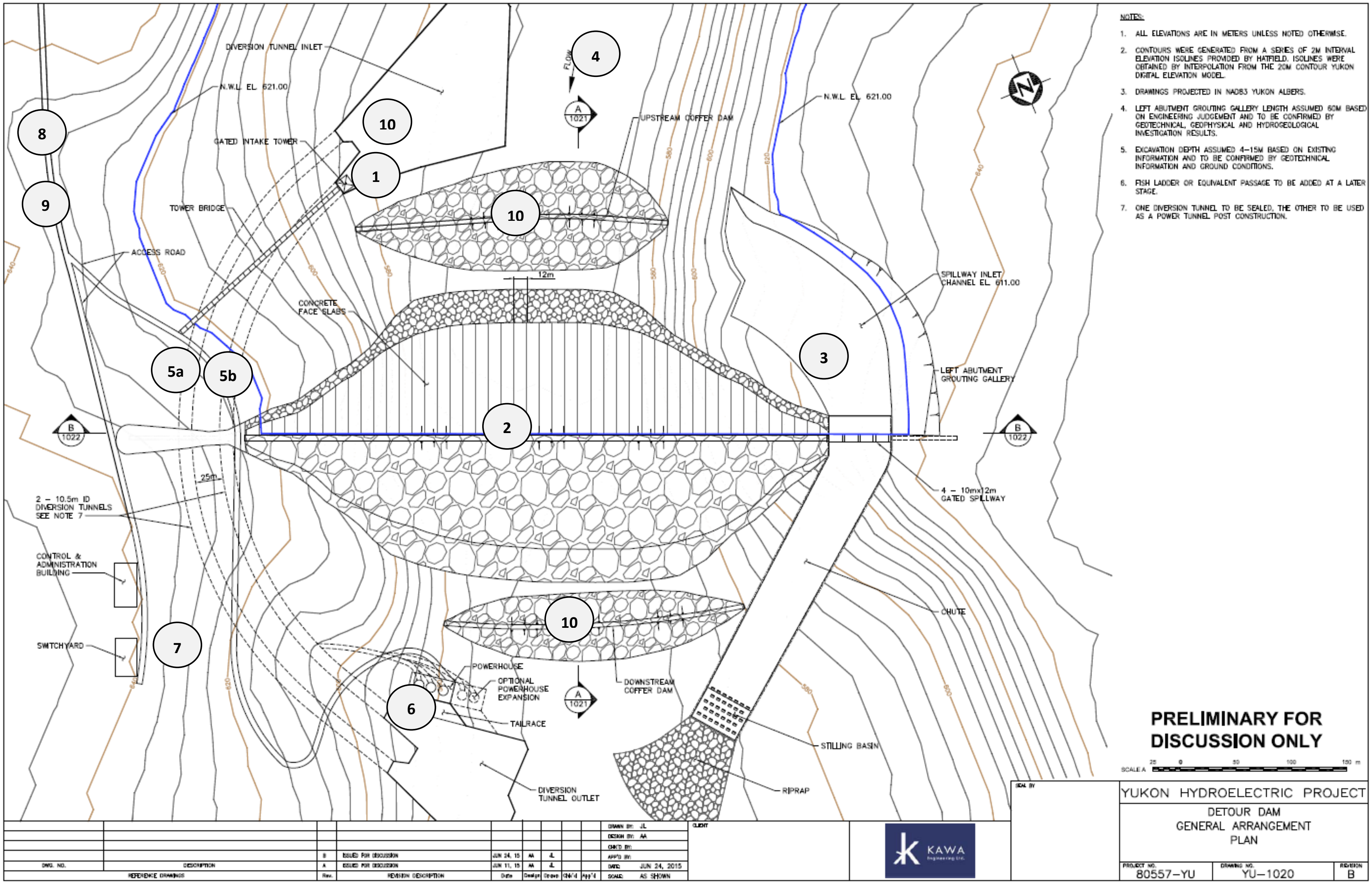
Table 10: Detour Canyon Major Project Components

Component	Drawing Item	Description Section
Intake Structure	①	3.1.1
Dam	②	3.1.2
Spillway	③	3.1.3
Reservoir	④	3.1.4
Power Tunnel and Penstock	⑤	3.1.5
Powerhouse	⑥	3.1.6
Fish Conveyance[7]	See Note 7	See Note 7
Switchyard	⑦	3.1.7
Transmission Line	⑧[8]	3.1.8
Access Infrastructure (Roads & Bridge)	⑨	3.1.9
Temporary Construction Works	⑩	3.1.10

[7] At this stage of study, upstream fish passage is expected to be facilitated via fish ladder. During subsequent phases of development, different alternatives may be considered including, but not limited to, mechanical lifts or trap-load-haul operations. Downstream fish passage is expected to be facilitated through fish friendly turbines (e.g. Kaplan Turbine).

[8] The transmission line is not shown on the drawing but is expected to approximately follow the access road from the switchyard to the interconnection point.

Figure 8: Detour Canyon Layout



3.1.1 Intake

The water intake is a concrete tower structure located on the river-right (east) bank and is based on rock foundation which requires between 4 to 15 m of excavation. The intake structure will be accessed via a 200 m long bridge connected to the project access road, and is also connected to the west diversion tunnel (Drawing item 5b) that will convey water for electric generation during operation up to the full plant design flow of approximately 130 m^3/s.

The main components of the intake include:

1) Trash Racks - To prevent driftwood and other floating debris such as ice and leaves from being entrained by the water conveyance structures.

2) Trash Rack Cleaning Equipment - To allow for clearing of entrained debris.

3) Head Gate Structure - To provide the ability to stop water flow into the water conveyance structures as part of regular maintenance or for emergency purposes.

4) Intake to Penstock Transition - To convey water from the intake box to the penstock while providing enough submergence to avoid vortex formation and ice.

3.1.2 Dam

The project is designed with a 72 m high Concrete Faced Rockfill Dam (CFRD). The dam structure is primarily composed of a rock core with filter layers of fine materials finished with an upstream concrete face to provide water impermeability to the structure. The dam is classified in the "High" hazard category and is designed for a 2475-year seismic event. The design includes 3 m of freeboard for flood retention and to prevent overtopping, and a spillway to pass high flow events such as floods and summer peak flows. The dam crest is assumed to be 6 m wide to allow for operations and maintenance access along the top of the dam. The dam structure also includes a 60 m long grouting gallery on the river-left (west) side to consolidate the foundation during and after construction. The dam structure is founded on rock which will require between 4 to 15 m of excavation to fully uncover the bedrock. The dam structure is attached to the bedrock foundation by means of rock anchors that will typically be 4 to 6 m long.

3.1.3 Spillway

The dam includes a gated concrete spillway structure on the river-left (west) bank that controls water flow releases during high flow periods. The spillway is designed to release flows up to Probable Maximum Flood (PMF) flow. The spillway structure includes a concrete inlet channel with four 10 m x 12 m gates and concrete chutes which return the water to the river. The foot of the spillway and area immediately downstream includes a stilling basin designed to withstand the erosive effects of the spillway water flows and to dissipate the energy contained in the flowing water.

3.1.4 Reservoir

The proposed dam creates a reservoir upstream of the dam site. The estimated full supply level (FSL) of the water reservoir is 621 m above sea level (ASL) and floods a total area of approximately 130 km^2. The average drawdown level (ADL) of the water reservoir is 614 m ASL, with a corresponding typical average reservoir water level drawdown of 7 m. A project reservoir map at FSL and ADL is shown in Appendix B: Reservoir Map.

3.1.5 Power Tunnel and Penstock

The west diversion tunnel (Drawing item 5b) will connect the water intake tower to the powerhouse via a 150 m long steel penstock. The right diversion tunnel (Drawing item 5a) will be sealed before operations commence. The 10.5 m diameter power tunnel is approximately 600 m long and will be grouted post excavation for erosion protection.

3.1.6 Powerhouse

The surface powerhouse is located downstream of the dam on the river-right (east) bank. The powerhouse is designed to house three equally-sized Kaplan turbines and has an optional two-unit expansion for post 2065 upgrades. Each Kaplan turbine has a design flow capacity of approximately 45 m^3/s fed via the intake and power tunnel arrangement described above. As currently designed, the three-unit powerhouse has an installed capacity of 60 MW (100MW including the optional two-unit upgrade) and is expected to generate 265 GWh per year based on the Baseline 2065 Forecast. However, the three base units combined with the two optional units are able to generate 587 GWh per year in an average water year.

The powerhouse contains all required operational, maintenance, and protection and control equipment required to operate the facility. Loading bays and an overhead crane will allow for maintenance access during operations. A tailrace channel directs water from the submergence pool back to the river.

3.1.7 Switchyard

The switchyard is a fenced area which contains transformers and electrical protection equipment (such as circuit breakers and disconnect switches). The electricity produced via the turbine-generators inside the powerhouse is conveyed at an intermediate voltage to the switchyard located adjacent to the powerhouse. In the switchyard, the intermediate voltage is transformed up to a 138 kV transmission voltage and transported to the Yukon electrical grid via a 138kV transmission line.

3.1.8 Transmission Line

Approximately 83 km of new 138 kV transmission line is required to interconnect the project. The 138 kV transmission line connects the powerhouse (via the switchyard) to the Yukon electrical grid. The point of interconnection is expected to be at the substation near Faro. The transmission line Right of Way (RoW) will be approximately 50 m wide and impact about 5 km^2 of land.[9]

3.1.9 Access Infrastructure

Approximately 82 km of new gravel road is required to access the project. The proposed access infrastructure is required for both construction activities (e.g. moving of heavy equipment and materials) and operations activities (e.g. operator access). The road alignment will approximately follow the transmission line corridor and is expected to cross three valleys and one river which will require a bridge at each crossing.

3.1.10 Temporary Construction Works

As with the construction of any hydroelectric project, various temporary construction works are required during construction. The largest temporary construction works is a diversion scheme on the river-right (east) bank which allows the river to flow naturally during construction while maintaining a dry area for construction. The diversion scheme includes:

1) Two 10.5 m diameter diversion tunnels,
2) An upstream cofferdam which may be removed before operations commence or be left in place, and
3) A downstream cofferdam which will be removed before operations commence.

Additionally, a number of temporary construction phase facilities are anticipated during the construction period, including:

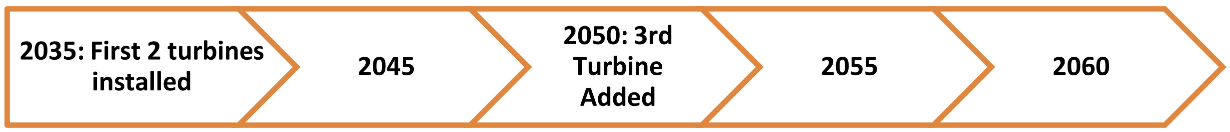
1) Site Office and Construction Camp
2) Workshops, labs, and testing facilities
3) Fabrication shops
4) First aid / safety / safety stations
5) Staging / lay down areas
6) Waste water treatment plant
7) Concrete batch plants
8) Truck washing stations
9) Explosives storage
10) Fuel storage and refuelling

[9] Land impacts include First Nations settlement lands, settled lands and lands set aside for First Nations.

3.1.11 Build Out Timeline

The scalability build out timeline of the projects is shown in Figure 9 with the project built at full size in 2035 with two (2) turbine generators, and the 3rd turbine generator (and supporting infrastructure) added in approximately 2050.

Figure 9: Detour Canyon Build Out Timeline



3.1.12 Cost Estimate

The estimated capital costs for Detour Canyon are shown in Table 11. A detailed cost estimate is included in Appendix C: Cost Estimates.

Table 11: Detour Canyon Cost Estimate

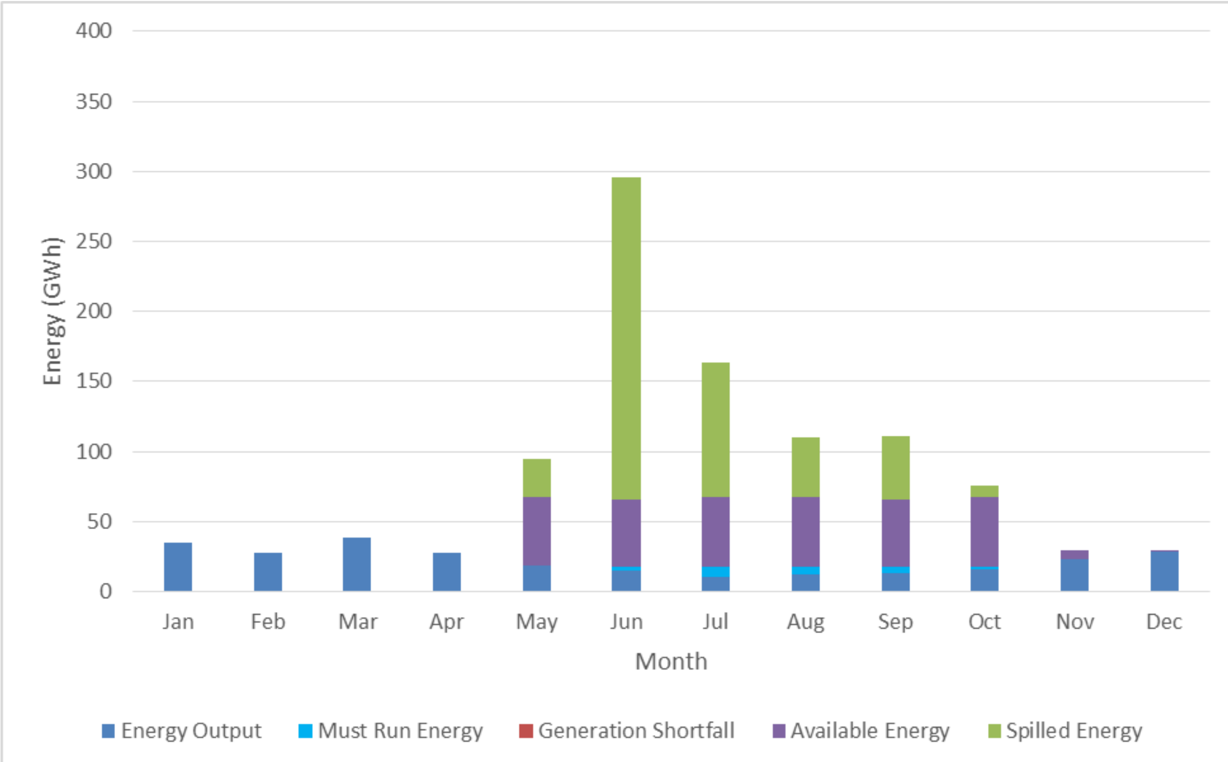
Project Component	Cost Estimate ($2015 Million)
2035 - Initial Dam	843
2050 - Scalability Upgrade	27
Post 2065 - Optional Upgrade	53
Transmission Line and Access Road	114
Miscellaneous Owners Cost	50
Contingency (30%)	326
Total	**1413**

In addition to capital costs, the estimated operating and maintenance costs of the dam facility, transmission line and road are estimated at $9.5 Million/year ($2015).

3.1.13 2065 Energy Summary

The Detour Canyon energy summary in Figure 10 shows that Detour Canyon is able to provide 100% of the forecasted 2065 Baseline 265 GWh gap, generates 22 GWh of must run energy, and is able to provide an additional 300 GWh of available energy beyond the 2065 Baseline Energy Gap.

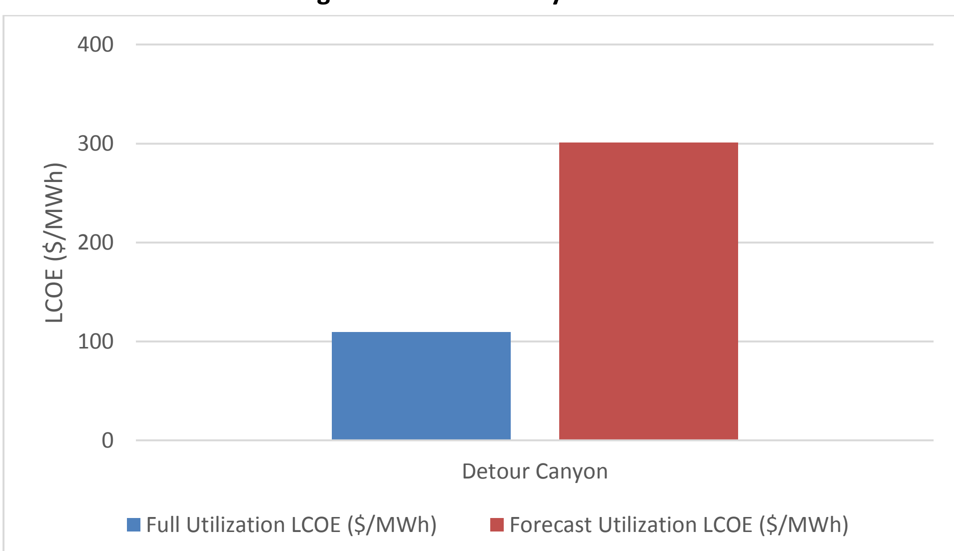
Figure 10: Detour Canyon 2065 Energy Summary



3.1.14 LCOE

The project Full Utilization LCOE is $110/MWh and the Forecast Utilization LCOE is $301/MWh as shown in Figure 11.

Figure 11: Detour Canyon LCOEs



3.2 Fraser Falls [STEWA-STEWA-0519-B]

Fraser Falls is a potential hydroelectric project on the Stewart River, located in the Stewart River Basin, approximately 40 km upstream of Mayo. The total drainage area is estimated to be 30,700 km^2.

The major components of the preliminary project layout are listed in Table 12. The project components are shown in Figure 12 and described in more detail as per sections listed in Table 12.

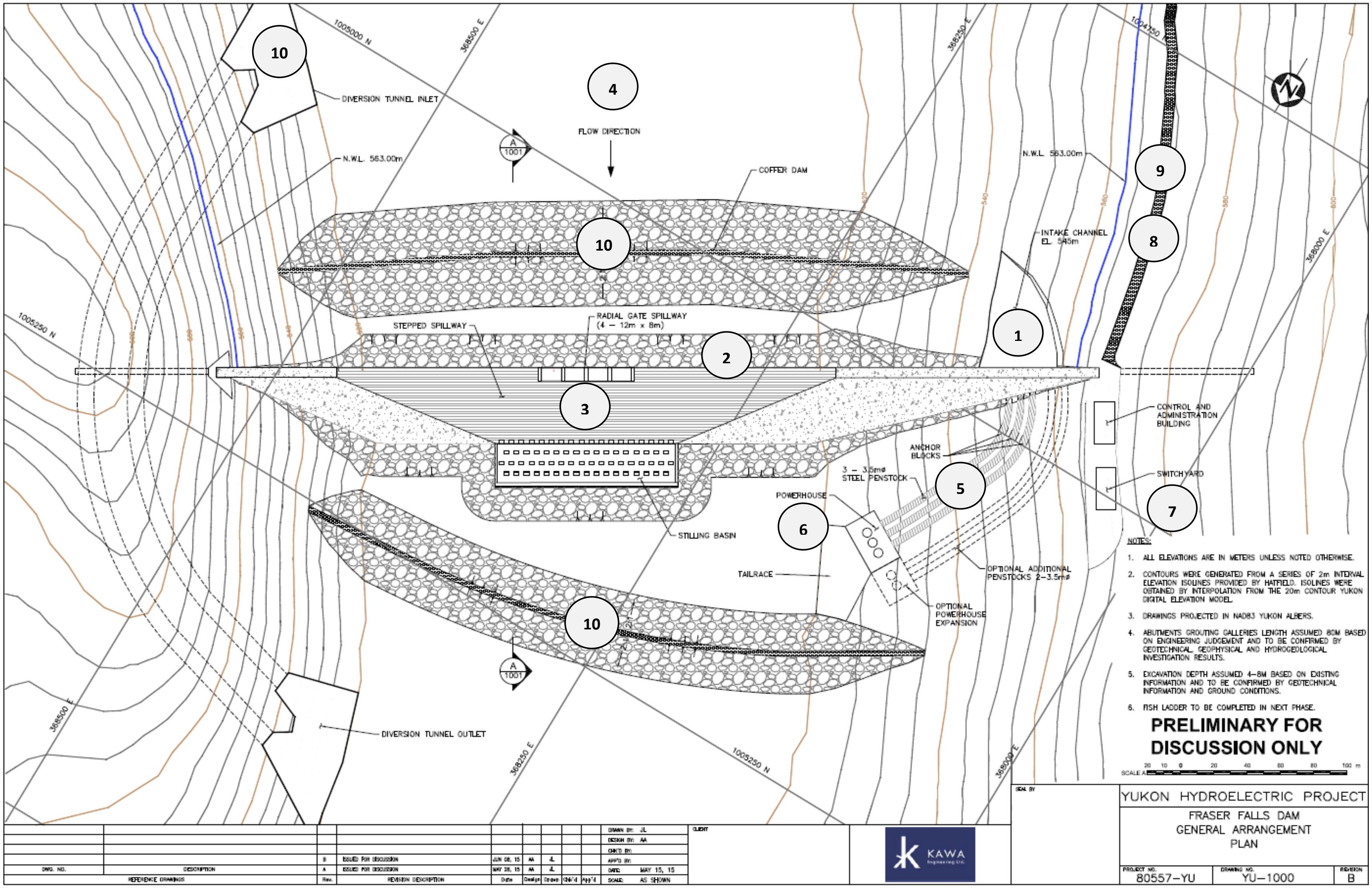
Table 12: Fraser Falls Major Project Components

Component	Drawing Item	Description Section
Intake Structure	①	3.2.1
Dam	②	3.2.2
Spillway	③	3.2.3
Reservoir	④	3.2.4
Penstock	⑤	3.2.5
Powerhouse	⑥	3.2.6
Fish Conveyance[10]	See Note 10	See Note 10
Switchyard	⑦	3.2.7
Transmission Line	⑧[11]	3.2.8
Access Infrastructure (Roads & Bridge)	⑨	3.2.9
Temporary Construction Works	⑩	3.2.10

[10] At this stage of study, upstream fish passage is expected to be facilitated via fish ladder. During subsequent phases of development, different alternatives may be considered including, but not limited to, mechanical lifts or trap-load-haul operations. Downstream fish passage is expected to be facilitated through fish friendly turbines (e.g. Kaplan Turbine).

[11] The transmission line is not shown on the drawing but is expected to follow approximately the access road from the switchyard to the interconnection point.

Figure 12: Fraser Falls Layout



3.2.1 Intake

The water intake is a concrete structure located on the river-left (west) bank and is based on a rock foundation which requires between 4 to 8 m of excavation. The intake structure is connected to five penstocks that convey water for electric generation during operation up to the full plant design flow of approximately 150 m^3/s.

The main components of the intake include:

1) Trash Racks - To prevent driftwood and other floating debris such as ice from being entrained by the water conveyance structures.

2) Trash Rack Cleaning Equipment - To allow for clearing of entrained debris.

3) Head Gate Structure - To provide the ability to stop water flow into the water conveyance structures for regular maintenance or emergency purposes.

4) Intake to Penstock Transition - To convey water from the intake box into the penstock while providing enough submergence to avoid vortex formation and ice.

3.2.2 Dam

The project is designed with a 56 m high Roller Compacted Concrete (RCC) dam. RCC is a concrete placement method that is widely used in gravity dams because of its higher installation rate (i.e. greater construction quantities in a shorter period of time), and lower curing / forming costs compared to conventional concrete placement. The dam is classified in the “High” hazard category and is designed for a 2475-year seismic event. The design includes 3 m of freeboard for flood retention, and a stepped spillway to pass high flow events such as floods and summer peak flows. The dam crest is assumed to be 6 m wide to allow for operations and maintenance access along the top of the dam. The dam structure also includes two 80 m long grouting galleries on each side of the river to consolidate the foundation during and after construction. The dam structure is founded on rock which will require between 4 to 8 m of excavation to fully uncover the bedrock. The dam structure is attached to the bedrock foundation by means of rock anchors that are typically 3 to 6 m long.

3.2.3 Spillway

The dam includes a stepped concrete spillway structure at the center of the dam to control water flow releases during high flow periods. The spillway is designed to release flows up to PMF flow. The spillway structure includes four 12 m x 8 m radial gates and concrete chutes which return the water to the river. The foot of the spillway and area immediately downstream includes a stilling basin designed to withstand the erosive effects of the spillway water flows and to dissipate the energy contained in the flowing water.

3.2.4 Reservoir

The proposed dam creates a reservoir upstream of the dam site. The FSL of the water reservoir is 563 m ASL, flooding a total area of approximately 311 km^2. The ADL of the water reservoir is 560 m ASL, resulting in an average water level fluctuation of 3 m over an average water year. A project reservoir map at FSL and ADL is shown in Appendix B: Reservoir Map.

3.2.5 Penstock

On the river-left (west) bank, five 3.5 m diameter steel penstocks convey water from the intake to the powerhouse. Three penstocks are part of the base scalability design and two optional penstocks are part of the post 2065 optional expansion. Each penstock is approximately 150 m long and will be restrained with concrete anchor blocks at the major bend.

3.2.6 Powerhouse

The surface powerhouse is located downstream of the dam on the river-left (west) bank. The powerhouse is designed to house three equally-sized Kaplan turbines and has an optional two-unit expansion for post 2065 upgrades. Each Kaplan turbine has a design flow capacity of approximately 50 m^3/s fed via the intake and penstock arrangement described above. As currently designed, the three-unit powerhouse has an installed capacity of 57 MW (95 MW including the optional two-unit upgrade) and is expected to generate 265 GWh per year based on the Baseline 2065 Forecast. However, the three base units combined with the two optional units are able to generate 563 GWh per year in an average water year.

The powerhouse contains all required operational, maintenance, and protection and control equipment required to operate the facility. Loading bays and an overhead crane will allow for maintenance access during operations. A tailrace channel directs water from the submergence pool back to the river.

3.2.7 Switchyard

The switchyard is a fenced area which contains transformers and electrical protection equipment (such as circuit breakers and disconnect switches). The electricity produced via the turbine-generators inside the powerhouse is conveyed at an intermediate voltage to the switchyard located adjacent to the powerhouse. In the switchyard, the intermediate voltage is transformed up to a 138 kV transmission voltage and transported to the Yukon electrical grid via a 138kV transmission line.

3.2.8 Transmission Line

Approximately 48 km of new 138 kV transmission line is required to interconnect the project.[12] The 138 kV transmission line connects the powerhouse (via the switchyard) to the Yukon electrical grid. The point of interconnection is expected to be at the Mayo substation. The transmission line corridor RoW is estimated to be approximately 50 m wide and impact about 3 km^2 of land.[13]

3.2.9 Access Infrastructure

Approximately 46 km of new gravel road is required to access the project. The proposed access infrastructure is required for both construction activities (e.g. moving of heavy equipment and materials) and operations activities (e.g. operator access). The road alignment will approximately follow the transmission line corridor and is expected to cross three valleys and one river which will each require a bridge at each crossing.

3.2.10 Temporary Construction Works

As with the construction of any hydroelectric project, various temporary construction works are required during construction. The largest temporary construction works is a diversion scheme on the river-right (east) bank which allows the river to flow naturally during construction while maintaining a dry area for construction. The diversion scheme includes:

1) Two 14 m diameter diversion tunnels,
2) An upstream cofferdam which may be removed before operations commence or be left in place, and
3) A downstream cofferdam which will be removed before operations commence.

Additionally, a number of temporary construction phase facilities are anticipated during the construction period, including:

1) Site Office and Construction Camp
2) Workshops, labs, and testing facilities
3) Fabrication shops
4) First aid / safety / safety stations
5) Staging / lay down areas
6) Waste water treatment plant
7) Concrete batch plants

[12] It is assumed that the existing 69 kV transmission line connecting Stewart and Keno will be upgraded to 138 kV by 2035. If no upgrade occurs by 2035, the current will be stepped down to 69 kV at Mayo.

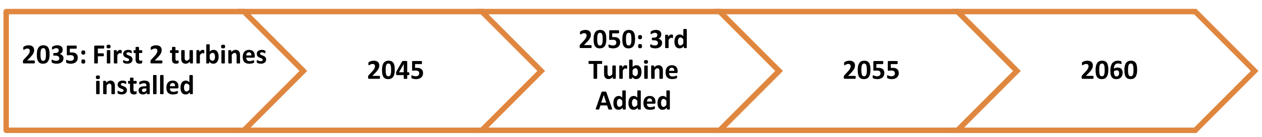
[13] Land impacts include First Nations settlement lands, settled lands and lands set aside for First Nations.

8) Truck washing stations
9) Explosives storage
10) Fuel storage and refuelling

3.2.11 Build Out Timeline

The Scalability build out timeline of the project is shown in Figure 13 with the project built at full size in 2035 with two turbine generators, and the 3rd turbine generator (and supporting infrastructure) added in approximately 2050.

Figure 13: Fraser Falls Build Out Timeline



3.2.12 Cost Estimate

The estimated capital costs for Fraser Falls are shown in Table 13. A detailed cost estimate is included in Appendix C: Cost Estimates.

Table 13: Fraser Falls Cost Estimate

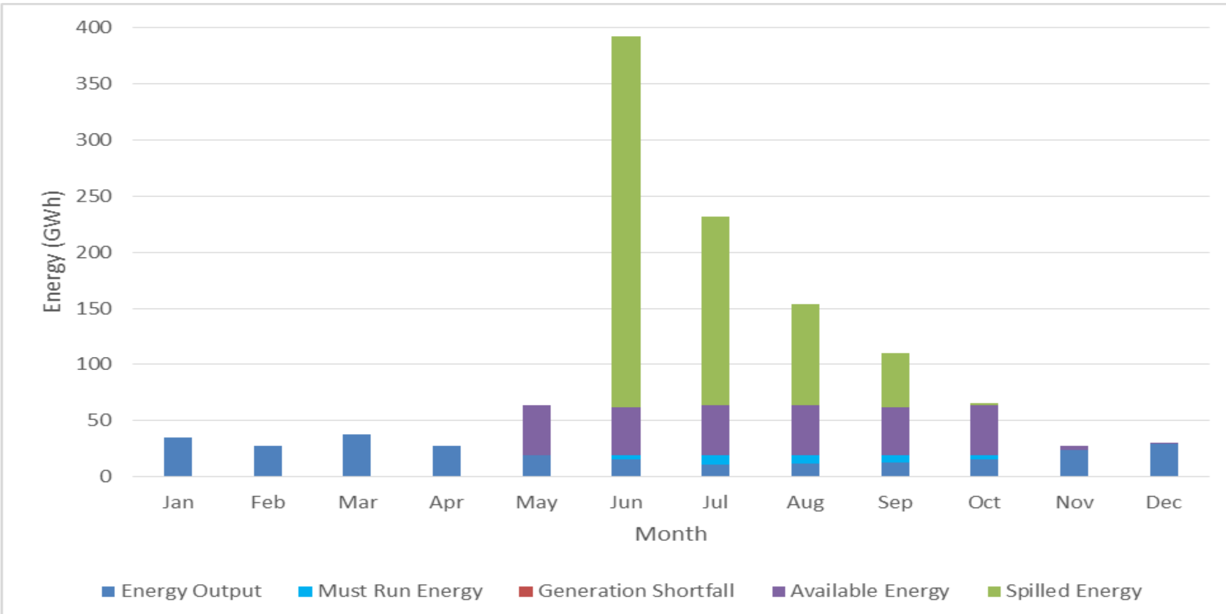
Project Component	Cost Estimate ($ Million)
2035 - Initial Dam	753
2050 - Scalability Upgrade	27
Post 2065 - Optional Upgrade	54
Transmission Line and Access Road	64
Miscellaneous Owners Cost	50
Contingency (30%)	285
Total	**1233**

In addition to capital costs, the operating and maintenance costs of the dam facility, transmission line and road are estimated at $8.7 Million/year ($2015).

3.2.13 2065 Energy Output

The Fraser Falls energy summary in Figure 14 shows that Fraser Falls is able to provide 100% of the forecasted 2065 Baseline 265 GWh gap, generates 30 GWh of must run energy, and is able to provide an additional 268 GWh of available energy beyond the 2065 Baseline Energy Gap.

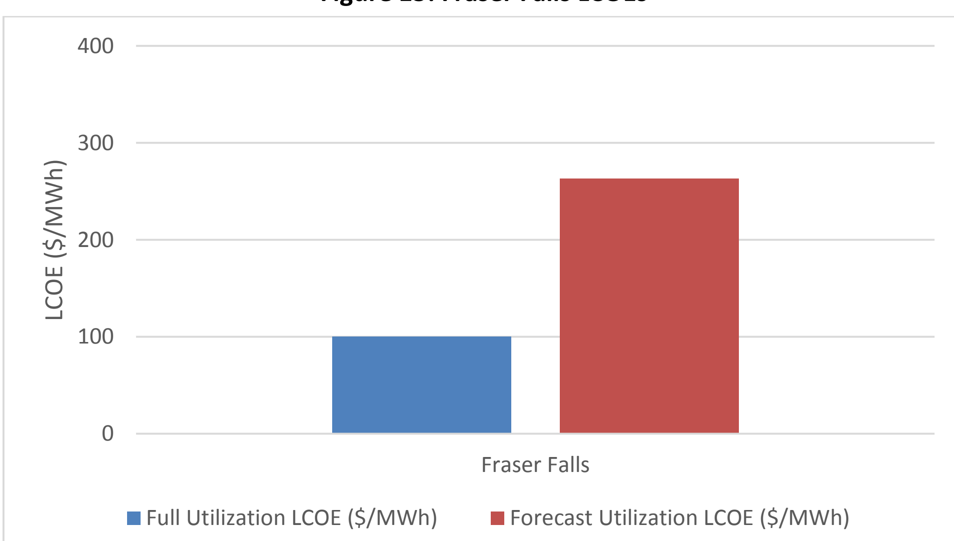
Figure 14: Fraser Falls 2065 Energy Summary



3.2.14 LCOEs

The project Full Utilization LCOE is $100MWh and the Forecast Utilization LCOE is $263/MWh as shown in Figure 15.

Figure 15: Fraser Falls LCOEs



3.3 Granite Canyon [PELLY-PELLY-0480-B]

Granite Canyon is a potential hydroelectric project on the Pelly River, located in the Pelly River Basin, approximately 20 km east of Pelly Crossing. The total drainage area is estimated to be 45,900 km^2.

The major components of the preliminary project layout are listed in Table 14. The project components are shown in Figure 16 and described in more detail as per sections listed in Table 14.

Table 14: Granite Canyon Major Project Components

Component	Drawing Item	Description Section
Intake Structure	①	3.3.1
Dam	②	3.3.2
Spillway	③	3.3.3
Reservoir	④	3.3.4
Penstock	⑤	3.3.5
Powerhouse	⑥	3.3.6
Fish Conveyance[14]	See Note 14	See Note 14
Switchyard	⑦	3.3.7
Transmission Line	⑧[15]	3.3.8
Access Infrastructure (Roads & Bridge)	⑨	3.3.9
Temporary Construction Works	⑩	3.3.10

[14] At this stage of study, upstream fish passage is expected to be facilitated via fish ladder. During subsequent phases of development, different alternatives may be considered including, but not limited to, mechanical lifts or trap-load-haul operations. Downstream fish passage is expected to be facilitated through fish friendly turbines (e.g. Kaplan Turbine).

[15] The transmission line is not shown on the drawing but is expected to follow approximately the access road from the switchyard to the interconnection point.

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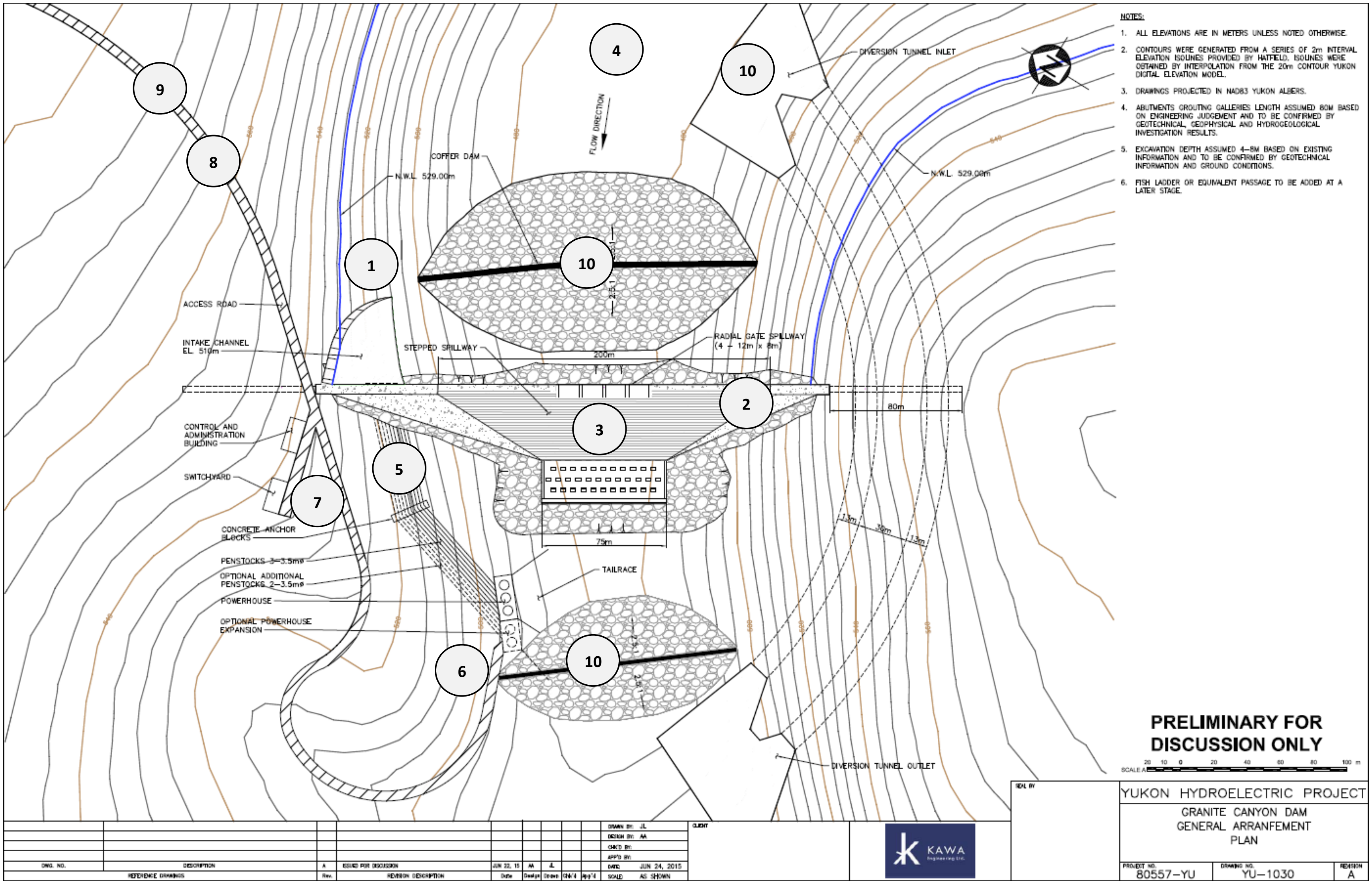
Figure 16: Granite Canyon Layout



3.3.1 Intake

The water intake is a concrete structure located on the river-right (west) bank and is based on a rock foundation which will require between 4 to 8 m of excavation. The intake structure is connected to the penstocks that will convey water for electric generation during operation up to the full plant design flow of approximately 140 m^3/s.

The main components of the intake include:

1) Trash Racks - To prevent driftwood and other floating debris such as ice from being entrained by the water conveyance structures.

2) Trash Rack Cleaning Equipment - To allow for clearing of entrained debris.

3) Head Gate Structure - To provide the ability to stop water flow into the water conveyance structures for regular maintenance or emergency purposes.

4) Intake to Penstock Transition - To convey water from the intake box into the penstock while providing enough submergence to avoid vortex formation and ice.

3.3.2 Dam

The project is designed with a 60 m high Roller Compacted Concrete (RCC) dam. RCC is a concrete placement method that is widely used in gravity dams because of its higher installation rate (i.e. greater construction quantities in a shorter period of time), and lower curing / forming costs compared to conventional concrete placement. The dam is classified in the “High” hazard category and is designed for a 2475-year seismic event. The design includes 3 m of freeboard for flood retention, and a stepped spillway to pass high flow events such as floods and summer peak flows. The dam crest is assumed to be 6 m wide to allow for operations and maintenance access along the top of the dam. The dam structure also includes two 80 m long grouting galleries on each sides of the river to consolidate the foundation during and after construction. The dam structure is founded on rock which will require between 4 to 8 m of excavation to fully uncover the bedrock. The dam structure is attached to the bedrock foundation by means of rock anchors which are typically 3 to 6 m long.

3.3.3 Spillway

The dam center includes a stepped concrete spillway structure that controls water flow releases during high flow periods. The spillway is designed to release flows up to PMF flow. The spillway structure includes four 12 m x 8 m radial gates and concrete chutes which return the water to the river. The foot of the spillway and area immediately downstream includes a stilling basin designed to withstand the erosive effects of the spillway water flows and to dissipate the energy contained in the flowing water

3.3.4 Reservoir

The proposed dam creates a reservoir upstream of the dam site. The estimated FSL of the water reservoir is 529 m ASL, and flooding a total area of approximately 173 km^2. The ADL of the water reservoir is 526 m ASL, resulting in reservoir water level fluctuations of 3 m over an average year. A project reservoir map at FSL and ADL is shown in Appendix B: Reservoir Map.

3.3.5 Penstock

On the river-right (west) bank, five 3.5m diameter steel penstocks convey water from the intake to the powerhouse. Three penstocks are part of the base scalability design and two optional penstocks are part of the post 2065 optional expansion. Each penstock is approximately 150 m long and will be restrained with concrete anchor blocks at the major bend.

3.3.6 Powerhouse

The surface powerhouse is located downstream of the dam on the river-right (west) bank. The powerhouse is designed to house three equally-sized Kaplan turbines and has an optional two-unit expansion for post 2065 upgrades. Each Kaplan turbine has a design flow capacity of approximately 47 m^3/s fed via the intake and penstock arrangement described above. As currently designed, the three-unit powerhouse has an installed capacity of 57 MW (95 MW including the optional two-unit upgrade) and is expected to generate 265 GWh per year based on the Baseline 2065 Forecast. However, the three base units combined with the two optional units are able to generate 588 GWh per year in an average water year.

The powerhouse contains all required operational, maintenance, and protection and control equipment required to operate the facility. Loading bays and an overhead crane will allow for maintenance access during operations. A tailrace channel directs water from the submergence pool back to the river.

3.3.7 Switchyard

The switchyard is a fenced area which contains transformers and electrical protection equipment (such as circuit breakers and disconnect switches). The electricity produced via the turbine-generators inside the powerhouse is conveyed at an intermediate voltage to the switchyard located adjacent to the powerhouse. In the switchyard, the intermediate voltage is transformed up to a 138 kV transmission voltage and transported to the Yukon electrical grid via a 138kV transmission line.

3.3.8 Transmission Line

Approximately 15 km of new 138 kV transmission line is required to interconnect the project. The 138 kV transmission line connects the powerhouse (via the switchyard) to the Yukon electrical grid. The point of interconnection is expected to be a tap onto the existing 138 kV line near Pelly Crossing. The transmission line corridor RoW is estimated to be approximately 50 m wide and impact about less than 1 km^2 of land.[16]

3.3.9 Access Infrastructure

Approximately 15 km of new gravel road is required to access the project. The proposed access infrastructure is required for both construction activities (e.g. moving of heavy equipment and materials) and operations activities (e.g. operator access). The road alignment will approximately follow the transmission line corridor and is not expected to cross terrain that will require a bridge crossing.

3.3.10 Temporary Construction Works

As with the construction of any hydroelectric project, various temporary construction works are required during construction. The largest temporary construction works is a diversion scheme on the river-left (east) bank which allows the river to flow naturally during construction while maintaining a dry area for construction. The diversion scheme includes:

1) Two 13 m diameter diversion tunnels,
2) An upstream cofferdam which may be removed before operations commence or remain in place, and
3) A downstream cofferdam which will be removed before operations commence.

Additionally, a number of temporary construction phase facilities are anticipated during the construction period, including:

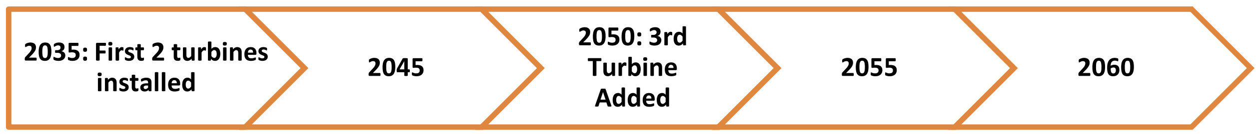
1) Site Office and Construction Camp
2) Workshops, labs, and testing facilities
3) Fabrication shops
4) First aid / safety / safety stations
5) Staging / lay down areas
6) Waste water treatment plant
7) Concrete batch plants
8) Truck washing stations
9) Explosives storage
10) Fuel storage and refuelling

[16] Land impacts include First Nations settlement lands, settled lands and lands set aside for First Nations.

3.3.11 Build Out Timeline

The scalability build out timeline of the projects is shown in Figure 17 with the project built at full size in 2035 with two turbine generators, and the 3rd turbine generator (and supporting infrastructure) added in approximately 2050.

Figure 17: Granite Canyon Build Out Timeline



3.3.12 Cost Estimate

The estimated capital costs for Granite Canyon are shown in Table 15. A detailed cost estimate is included in Appendix C: Cost Estimates.

Table 15: Granite Cost Estimate

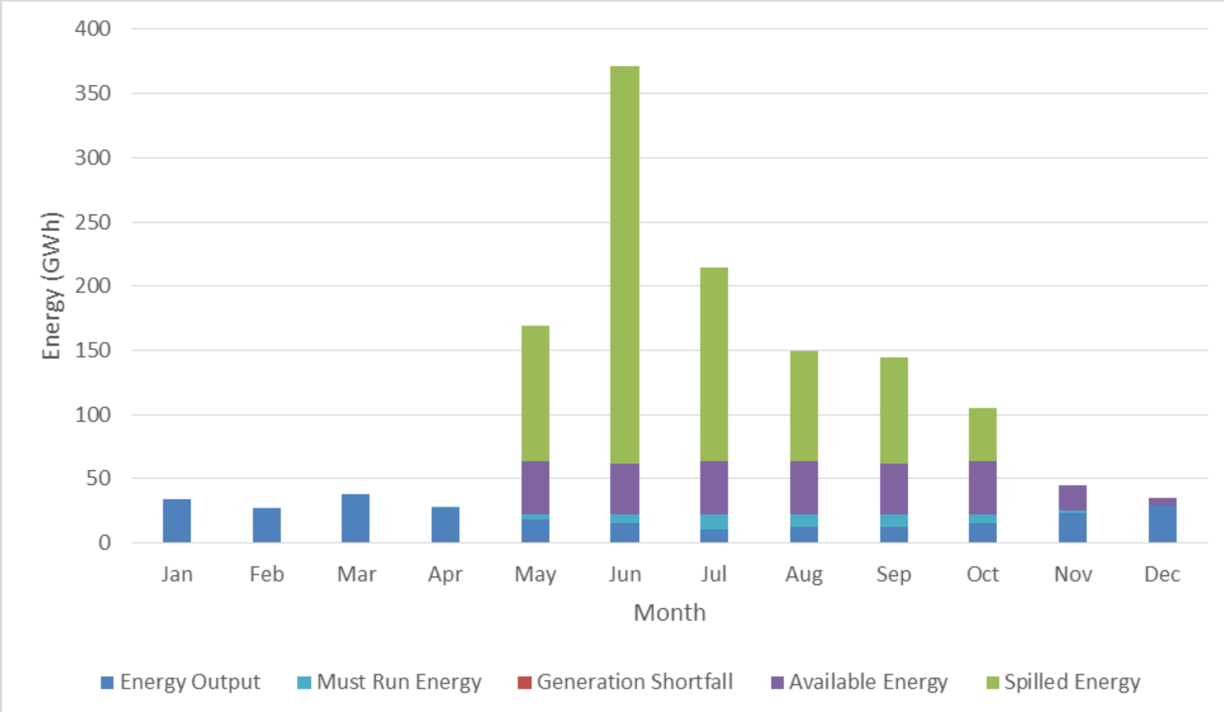
Project Component	Cost Estimate ($ Million)
2035 - Initial Dam	503
2050 - Scalability Upgrade	27
Post 2065 - Optional Upgrade	53
Transmission Line and Access Road	19
Miscellaneous Owners Cost	50
Contingency (30%)	196
Total	**847**

In addition to capital costs, the operating and maintenance costs of the dam facility, transmission line and road are estimated at $7.2 Million (2015)/year.

3.3.13 2065 Energy Output

The Granite Canyon energy in Figure 18 shows that Granite Canyon is able to provide 100% of the forecasted 2065 Baseline 265 GWh gap, generate 51 GWh of must run energy, and is able to provide an additional 272 GWh of available energy beyond the 2065 Baseline Energy Gap.

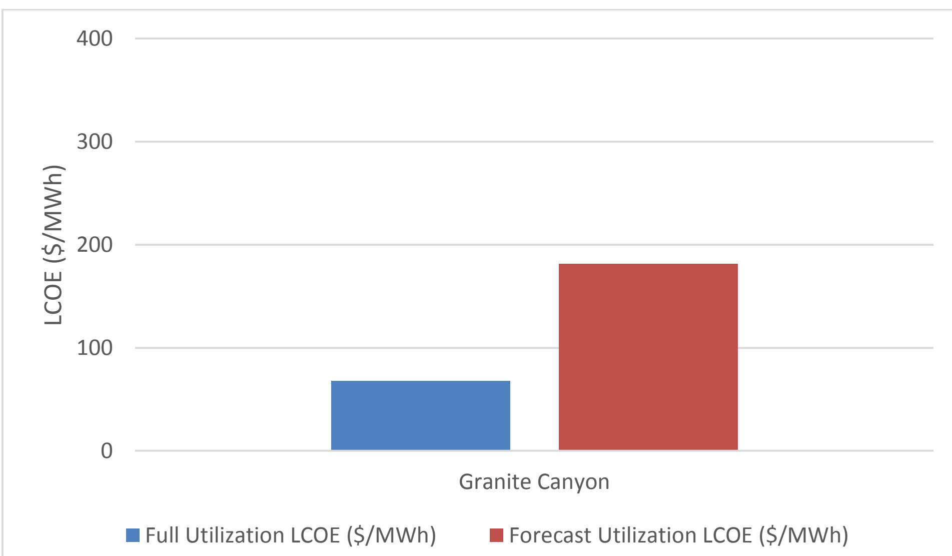
Figure 18: Granite Canyon 2065 Energy Summary



3.3.14 LCOEs

The project Full Utilization LCOE is $68/MWh and its Forecast Utilization LCOE is $181/MWh as shown in Figure 19.

Figure 19: Granite Canyon LCOEs



3.4 Two Mile Canyon [STEWA-HESS -0552]

Two Mile Canyon is a potential hydroelectric project on the Hess River, located in the Stewart River Basin, approximately 100 km east of Mayo. The total drainage area is estimated to be 14,200 km^2.

The major components of the preliminary project layout are listed in Table 16. The project components are shown in Figure 20 and described in more detail as per sections listed in Table 16.

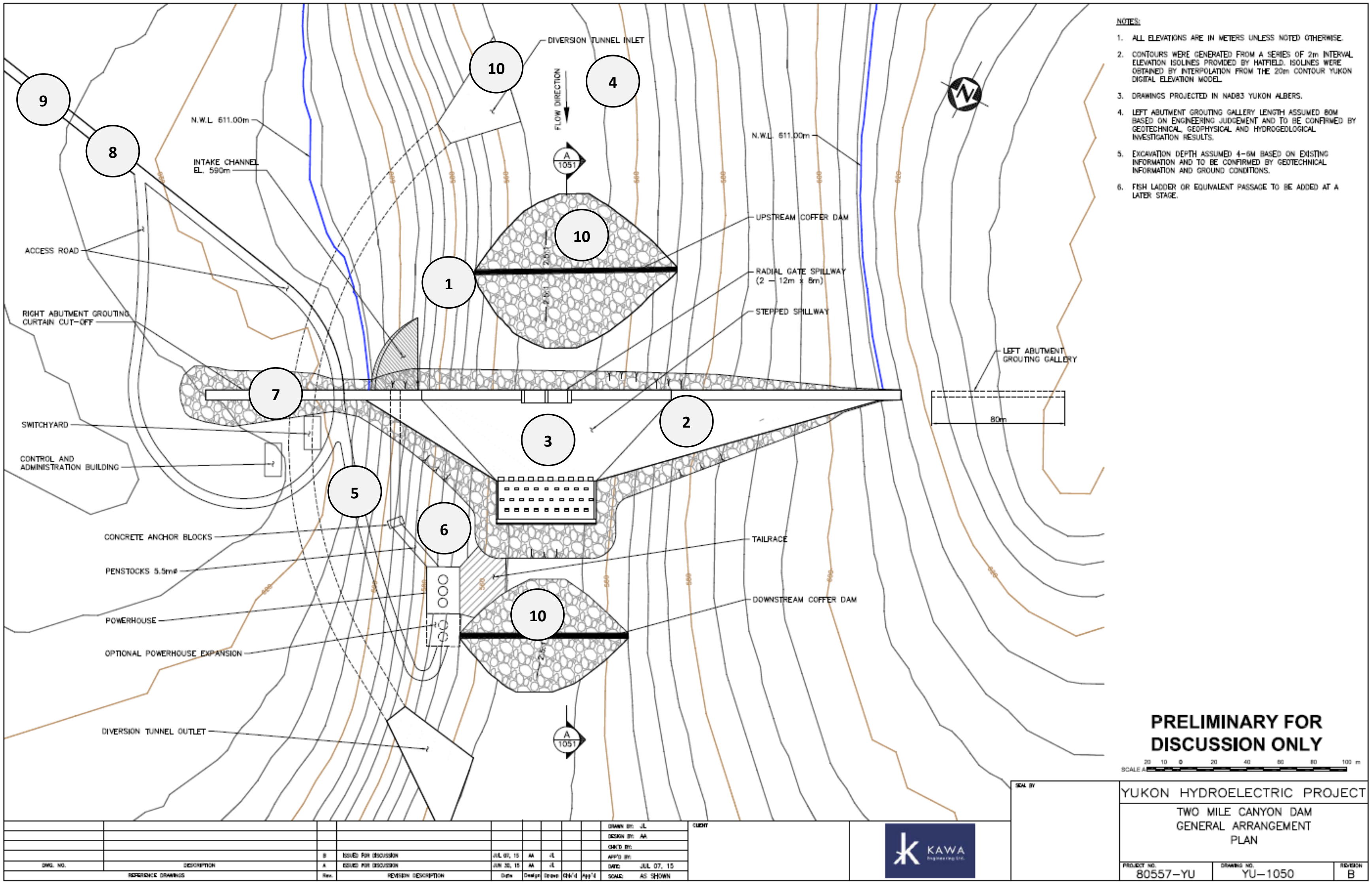
Table 16: Two Mile Canyon Major Project Components

Component	Drawing Item	Description Section
Intake Structure	①	3.4.1
Dam	②	3.4.2
Spillway	③	3.4.3
Reservoir	④	3.4.4
Penstock	⑤	3.4.5
Powerhouse	⑥	3.4.6
Fish Conveyance[17]	See Note 17	See Note 17
Switchyard	⑦	3.4.7
Transmission Line	⑧[18]	3.4.8
Access Infrastructure (Roads & Bridge)	⑨	3.4.9
Temporary Construction Works	⑩	3.4.10

[17] At this stage of study, upstream fish passage is expected to be facilitated via fish ladder. During subsequent phases of development, different alternatives may be considered including, but not limited to, mechanical lifts or trap-load-haul operations. Downstream fish passage is expected to be facilitated through fish friendly turbines (e.g. Kaplan Turbine).

[18] The transmission line is not shown on the drawing but is expected to follow approximately the access road from the switchyard to the interconnection point.

Figure 20: Two Mile Canyon Layout



3.4.1 Intake

The water intake is a concrete structure located on the river-right (east) bank and is based on a rock foundation which requires between 4 to 6 m of excavation. The intake structure is connected to penstocks that convey water for electric generation during operation up to the full plant design flow of approximately 90 m^3/s.

The main components of the intake include:

1) Trash Racks - To prevent driftwood and other floating debris such as ice from being entrained by the water conveyance structures.

2) Trash Rack Cleaning Equipment - To allow for clearing of entrained debris.

3) Head Gate Structure - To provide the ability to stop water flow into the water conveyance structures for regular maintenance or emergency purposes.

4) Intake to Penstock Transition - To convey water from the intake box into the penstock while providing enough submergence to avoid vortex formation and ice.

3.4.2 Dam

The project is designed with a 68 m high Roller Compacted Concrete (RCC) dam. RCC is a concrete placement method that is widely used in gravity dams because of its higher installation rate (i.e. greater construction quantities in a shorter period of time), and lower curing / forming costs compared to conventional concrete placement. The dam is classified in the “High” hazard category and is designed for a 2475-year seismic event. The design includes 3 m of freeboard for flood retention, and a stepped spillway to pass high flow events such as floods and summer peak flows. The dam crest is assumed to be 6 m wide to allow for operations and maintenance access along the top of the dam. The dam structure also includes two 80 m long grouting galleries on each side of the river to consolidate the dam foundation during and after construction. The dam structure is founded on rock which requires between 4 to 8 m of excavation to fully uncover the bedrock. The dam structure is attached to the bedrock foundation by means of rock anchors that are typically 3 to 6 m long.

3.4.3 Spillway

The dam includes a stepped concrete spillway structure at the center of the dam to control water flow releases during high flow periods. The spillway is designed to release flows up to PMF flow. The spillway structure includes two 12 m x 8 m radial gates and concrete chutes which return the water to the river. The foot of the spillway and area immediately downstream includes a stilling basin designed to withstand the erosive effects of the spillway water flows and to dissipate the energy contained in the flowing water.

3.4.4 Reservoir

The estimated FSL of the water reservoir is 611m ASL, flooding a total area of approximately 101 km^2. The ADL of the water reservoir is 602m ASL, resulting is reservoir water level fluctuations of 9m over an average year. A project reservoir map at FSL and ADL is shown in Appendix B: Reservoir Map.

3.4.5 Penstock

On the river-right (east) bank, one 5.5 m diameter steel penstock conveys water from the intake to the powerhouse. The penstock will split three (base scalability design) or five ways (with optional upgrade). The penstock is approximately 125 m long and will be restrained with a concrete anchor block at the major bend.

3.4.6 Powerhouse

The surface powerhouse is located downstream of the dam on the river-right (east) bank. The powerhouse is designed to house three equally-sized Kaplan turbines and has an optional two-unit expansion for post 2065 upgrades. Each Kaplan turbine has a design flow capacity of approximately 30 m^3/s fed via the intake and penstock arrangement described above. The three-unit powerhouse has an installed capacity of 54 MW (90 MW including the optional two-unit upgrade) and is expected to generate 265 GWh per year based on the Baseline 2065 Forecast. However, the three base units combined with the two optional units are able to generate 488 GWh per year in an average water year.

The powerhouse contains all required operational, maintenance, and protection and control equipment required to operate the facility. Loading bays and an overhead crane will allow for maintenance access during operations. A tailrace channel directs water from the submergence pool back to the river.

3.4.7 Switchyard

The switchyard is a fenced area which contains transformers and electrical protection equipment (such as circuit breakers and disconnect switches). The electricity produced via the turbine-generators inside the powerhouse is conveyed at an intermediate voltage to the switchyard located adjacent to the powerhouse. In the switchyard, the intermediate voltage is transformed up to a 138 kV transmission voltage and transported to the Yukon electrical grid via a 138kV transmission line.

3.4.8 Transmission Line

Approximately 113 km of new 138 kV transmission line is required to interconnect the project.[19] The 138 kV transmission line connects the powerhouse (via the switchyard) to the Yukon electrical grid. The point of

[19] It is assumed that the existing 69 kV transmission line connecting Stewart and Keno will be upgraded to 138 kV by 2035. If no upgrade occurs by 2035, the current will be stepped down to 69 kV at Mayo.

interconnection is expected to be at the Mayo substation. The transmission line corridor RoW is estimated to be approximately 50 m wide and impact about 6 km^2 of land.[20]

3.4.9 Access Infrastructure

Approximately 111 km of new gravel road is required to access the project. The proposed access infrastructure is required for both construction activities (e.g. moving of heavy equipment and materials) and operations activities (e.g. operator access). The road alignment will approximately follow the transmission line corridor and is expected to cross six valleys and one river (two times) which will require a bridge at each crossings.

3.4.10 Temporary Construction Works

As with the construction of any hydroelectric project, various temporary construction works are required during construction. The largest temporary construction works is a diversion scheme on the river-right (east) bank which allows the river to flow naturally during construction while maintaining a dry area for construction. The diversion scheme includes:

1) One 14 m diameter diversion tunnel,
2) An upstream cofferdam which may remain or be removed before operation, and
3) A downstream cofferdam which will be removed before operation commences.

Additionally, a number of temporary construction phase facilities are anticipated during the construction period, including:

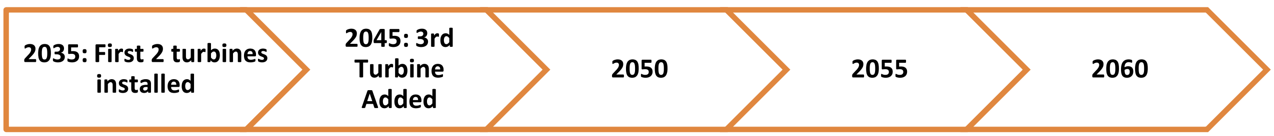
1) Site Office and Construction Camp
2) Workshops, labs, and testing facilities
3) Fabrication shops
4) First aid / safety / safety stations
5) Staging / lay down areas
6) Waste water treatment plant
7) Concrete batch plants
8) Truck washing stations
9) Explosives storage
10) Fuel storage and refuelling

[20] Land impacts include First Nations settlement lands, settled lands and lands set aside for First Nations.

3.4.11 *Build Out Timeline*

The scalability timeline for Two Mile Canyon is shown in Figure 21 with the project built at full size in 2035 with two turbine generators, and the 3rd turbine generator (and supporting infrastructure) added in approximately 2045.

Figure 21: Two Mile Canyon Build Out Timeline



3.4.12 *Cost Estimate*

The estimated capital costs for Detour Canyon are shown in Table 17. A detailed cost estimate is included in Appendix C: Cost Estimates.

Table 17: Two Mile Canyon Cost Estimate

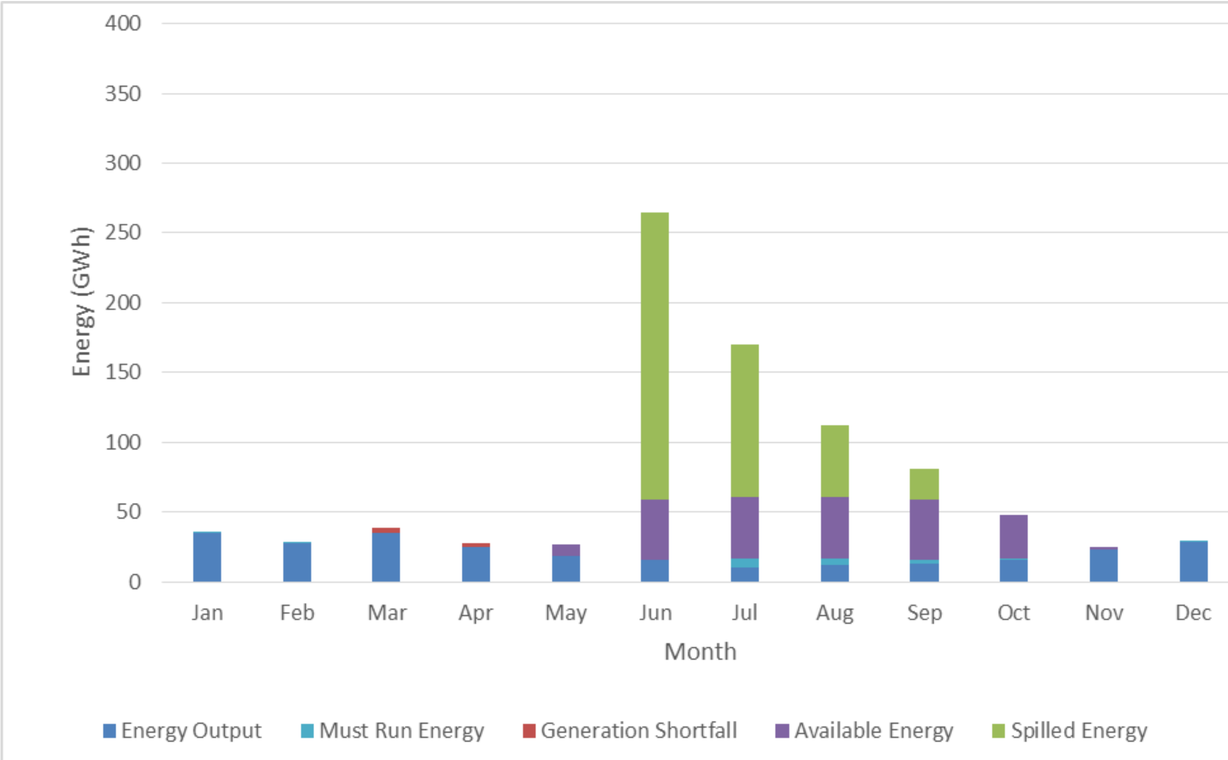
Project Component	Cost Estimate ($ Million)
2035 - Initial Dam	444
2050 - Scalability Upgrade	16
Post 2065 - Optional Upgrade	32
Transmission Line and Access Road	164
Miscellaneous Owners Cost	50
Contingency (30%)	212
Total	**919**

In addition to capital costs, the operating and maintenance costs of the dam facility, transmission line and road are estimated at $8.5 Million/year ($2015).

3.4.13 *2065 Energy Output*

The Two Mile Canyon energy in Figure 22 shows that Two Mile Canyon is able to provide 97% of the forecasted 2065 Baseline 265 GWh gap (259 GWh), it generates 14 GWh of must run energy, and is able to provide an additional 216 GWh of available energy beyond the 2065 Baseline Energy Gap.

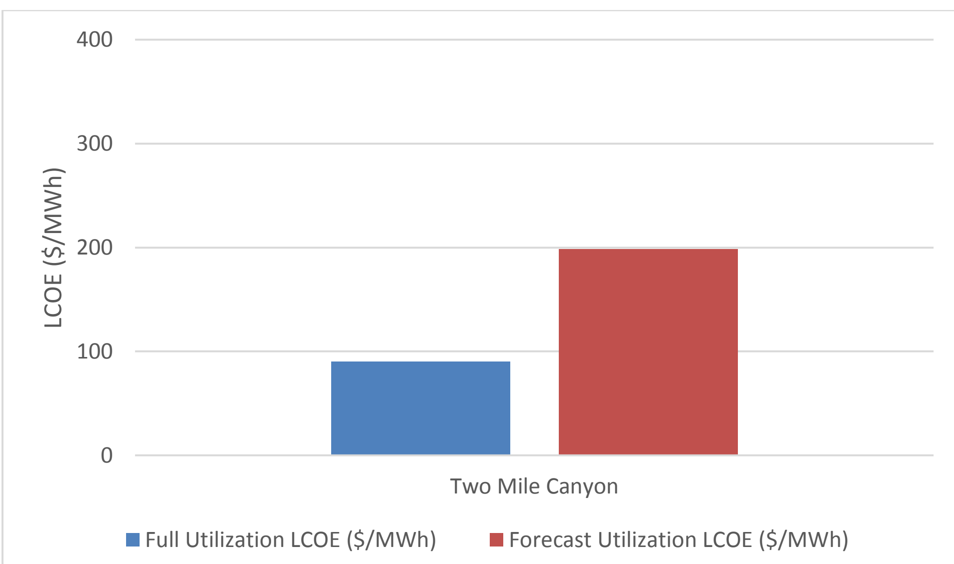
Figure 22: Two Mile Canyon 2065 Energy Summary



3.4.14 LCOEs

The project Full Utilization LCOE is $90/MWh and the Forecast Utilization LCOE is $199/MWh as shown in Figure 23.

Figure 23: Two Mile Canyon LCOEs



3.5 False Canyon + Middle Canyon ROR [LIARD-FRANC-0696 + LIARD-FRANC-0670-B]

False Canyon + Middle Canyon Run of River (ROR) is a cascade of two sites with False Canyon located upstream on the Frances River providing both generation and water storage, and Middle Canyon ROR located downstream operating as a ROR facility with no water storage (but a headpond required to create head for generation purposes). The ROR operates similarly to the Whitehorse facility, where the headpond water level remains constant and electricity is generated only from water flowing in rather than from the stored water. For Middle Canyon, the water flowing in is from the water released from generation and spill at False Canyon.

3.5.1 False Canyon [LIARD-FRANC-0696]

False Canyon is a potential hydroelectric project on the Frances River, located in the Liard River Basin, approximately 75 km north of Watson Lake. The total drainage area is estimated at 12,200 km^2.

The major components of the preliminary project layout are listed in Table 18. The project components are shown in Figure 24 and described in more detail as per sections listed in Table 18.

Table 18: False Canyon Major Project Components

Component	Drawing Item	Description Section
Intake Structure	①	3.5.2
Dam	②	3.5.3
Spillway	③	3.5.4
Reservoir	④	3.5.5
Power Tunnel and Penstock	⑤	3.5.6
Powerhouse	⑥	3.5.7
Fish Conveyance[21]	See Note 21	See Note 21
Switchyard	⑦	3.5.8
Transmission Line	⑧[22]	3.5.9
Access Infrastructure (Roads & Bridge)	⑨	3.5.10
Temporary Construction Works	⑩	3.5.11

[21] At this stage of study, upstream fish passage is expected to be facilitated via fish ladder. During subsequent phases of development, different alternatives may be considered including, but not limited to, mechanical lifts or trap-load-haul operations. Downstream fish passage is expected to be facilitated through fish friendly turbines (e.g. Kaplan Turbine).

[22] The transmission line is not shown on the drawing but is expected to follow approximately the access road from the switchyard to the interconnection point.

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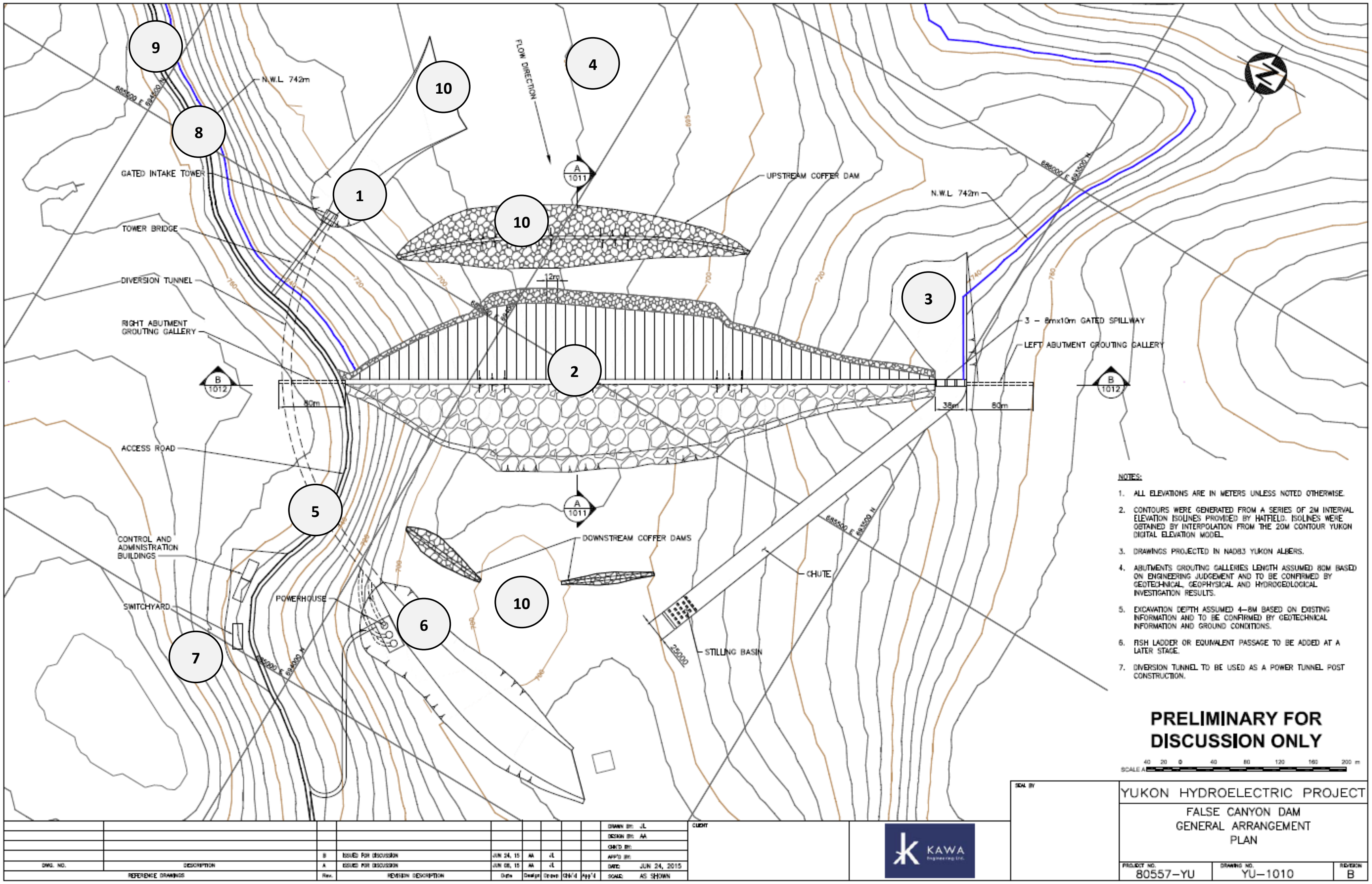
Figure 24: False Canyon Layout



3.5.2 Intake

The water intake is a concrete tower structure located on the river-right (west) bank and is based on a rock foundation which requires between 4 to 8 m of excavation. The structure will be accessed via a 120 m long bridge connected to the project access road. The intake tower is connected to the diversion tunnel that will convey water for electric generation during operation for the full plant design flow of approximately 130 m^3/s.

The main components of the intake include:

1) Trash Racks - To prevent driftwood and other floating debris such as ice and leaves from being entrained by the water conveyance structures.

2) Trash Rack Cleaning Equipment - To allow for clearing of entrained debris.

3) Head Gate Structure - To provide the ability to stop water flow into the water conveyance structures for regular maintenance or emergency purposes.

4) Intake to Tunnel Transition - To convey water from the intake box into the penstock while providing enough submergence to avoid vortex formation and ice.

3.5.3 Dam

The project is designed with a 65 m high Concrete Faced Rockfill Dam (CFRD). The dam structure is primarily composed of a rock core with filter layers of fine materials finished with an upstream concrete face to provide water impermeability to the structure. The dam is classified in the “High” hazard category and is designed for a 2475-year seismic event. The design includes 3 m of freeboard for flood retention and to prevent overtopping, and a spillway to pass high flow events such as floods and summer peak flows. The dam crest is assumed to be 6 m wide to allow for operations and maintenance access along the top of the dam. The dam structure also includes a 60 m long grouting gallery on both sides of the river to consolidate the foundation during and after construction. The dam structure is founded on rock which will require between 4 to 9 m of excavation to fully uncover the bedrock. The dam structure is attached to the bedrock foundation by means of rock anchors which are typically 4 to 6 m long.

3.5.4 Spillway

The dam includes a gated concrete spillway structure on the river-left (east) bank that controls water flow releases during high flow periods. The spillway is designed to release flows up to PMF flow. The spillway structure includes a concrete inlet channel with three 8 m x 10 m gates and a concrete chute which returns the water to the river. The foot of the spillway and area immediately downstream includes a stilling basin designed to withstand the erosive effects of the spillway water flows and to dissipate the energy contained in the flowing water.

3.5.5 Reservoir

The proposed dam creates a reservoir upstream of the dam site. The estimated FSL of the False Canyon water reservoir is 742m ASL which floods a total area of approximately 262 km^2 (including 109 km^2 of existing lake area). The ADL of the water reservoir is 737m ASL thus the reservoir water level fluctuates by 5 m over an average year. A project reservoir map at FSL and ADL is shown in Appendix B: Reservoir Map.

3.5.6 Power Tunnel and Penstock

The river-right (west) diversion tunnel connects the water intake tower to the powerhouse via an 80 m long steel penstock. The 11 m diameter tunnel is approximately 500 m long and will be grouted post excavation for erosion protection.

3.5.7 Powerhouse

The surface powerhouse is located downstream of the dam on the river-right (west) bank. The powerhouse is designed to house three equally-sized Kaplan turbines that each have a design flow capacity of approximately 50 m^3/s fed via the intake and power tunnel arrangement described above. The three-unit powerhouse has an installed capacity of 56 MW and is expected to generate 242 GWh per year based on the Baseline 2065 Forecast. However, the three base units are able to generate 365 GWh per year in an average water year.

The powerhouse also contains all required operational, maintenance, and protection and control equipment required to operate the facility. Loading bays and an overhead crane will allow for maintenance access during operations. A tailrace channel directs water from the submergence pool back to the river.

3.5.8 Switchyard

The switchyard is a fenced area which contains transformers and electrical protection equipment (such as circuit breakers and disconnect switches). The electricity produced via the turbine-generators inside the powerhouse is conveyed at an intermediate voltage to the switchyard located adjacent to the powerhouse. In the switchyard, the intermediate voltage is transformed up to a 138kV transmission voltage and transported to the Yukon electrical grid via a 138kV transmission line.

3.5.9 Transmission Line

If a future 415 km long 138 kV transmission line between Faro and Watson Lake is assumed to exist, less than 10 km of new 138 kV transmission line is required to interconnect the project. The 138 kV transmission line connects the powerhouse (via the switchyard) to the Yukon electrical grid. The point of interconnection is expected to be a tap on the future transmission line connecting Faro and Watson Lake. The RoW of the transmission line corridor connecting the project to the future transmission line connecting Faro and Watson Lake is estimated to be approximately 50 m wide and impact less than 1 km^2 of land.[23] The RoW of the transmission line corridor connecting Faro and Watson Lake is estimated to be approximately 50 m wide and impact about 21 km^2 of land. [23]

Without a pre-existing transmission line between Faro and Watson Lake, an additional 343 km of new 138 kV transmission line is required to interconnect the project to the Yukon grid.[24] The point of interconnection is expected to be at the substation near Faro. The RoW of the transmission line corridor connecting the project to Faro is estimated to be approximately 50 m wide and impact about 18 km^2 of land.[23]

3.5.10 Access Infrastructure

Less than 10 km of new gravel road is required to access the project from the Robert Campbell Highway. Approximately 30 km of new gravel road is required to build the transmission line interconnecting Faro and False Canyon. The proposed access infrastructure is required for both construction activities (e.g. moving of heavy equipment and materials) and operations activities (e.g. operator access). The road alignment will approximately follow the transmission line corridor and is expected to cross one valley which will require a bridge crossing.

3.5.11 Temporary Construction Works

As with the construction of any hydroelectric project, various temporary construction works are required during construction. The largest temporary construction works is a diversion scheme on the river-right (west) bank which allows the river to flow naturally during construction while maintaining a dry area for construction. The diversion scheme includes:

1) An 11 m diameter diversion tunnel,
2) An upstream cofferdam which may remain or be removed before operation, and
3) Two downstream cofferdams which will be removed before operation commences.

Additionally, a number of temporary construction phase facilities are anticipated during the construction period, including:

1) Site Office and Construction Camp
2) Workshops, labs, and testing facilities
3) Fabrication shops

[23] Land impacts include First Nations settlement lands, settled lands and lands set aside for First Nations.

[24] It is likely that the entire 415 km long transmission line corridor from Faro to Watson Lake would be built if a transmission line was required to interconnect False Canyon and/or Middle canyon to Faro.

4) First aid / safety / safety stations
5) Staging / lay down areas
6) Waste water treatment plant
7) Concrete batch plants
8) Truck washing stations
9) Explosives storage
10) Fuel storage and refuelling

3.5.12 Middle Canyon ROR [LIARD-FRANC-0696]

As the downstream project in the cascade, Middle Canyon is a potential ROR hydroelectric project on the Frances River, located in the Liard River Basin, approximately 40 km northwest of Watson Lake. The total drainage area is estimated to be 13,000 km^2.

The major components of the preliminary project layout are listed in Table 19. The project components are shown in Figure 25 and described in more detail as per sections listed in Table 19

Table 19: Middle Canyon Major Project Components

Component	Drawing Item	Description Section
Intake Structure	①	3.5.13
Dam	②	3.5.14
Spillway	③	3.5.15
Reservoir	④	3.5.16
Penstock	⑤	3.5.17
Powerhouse	⑥	3.5.18
Fish Conveyance[25]	See Note 25	See Note 25
Switchyard	⑦	3.5.19
Transmission Line	⑧[26]	3.5.20
Access Infrastructure (Roads & Bridge)	⑨	3.5.21
Temporary Construction Works	⑩	3.5.22

[25] At this stage of study, upstream fish passage is expected to be facilitated via fish ladder. During subsequent phases of development, different alternatives may be considered including, but not limited to, mechanical lifts or trap-load-haul operations. Downstream fish passage is expected to be facilitated through fish friendly turbines (e.g. Kaplan Turbine).

[26] The transmission line is not shown on the drawing but is expected to follow approximately the access road from the switchyard to the interconnection point.

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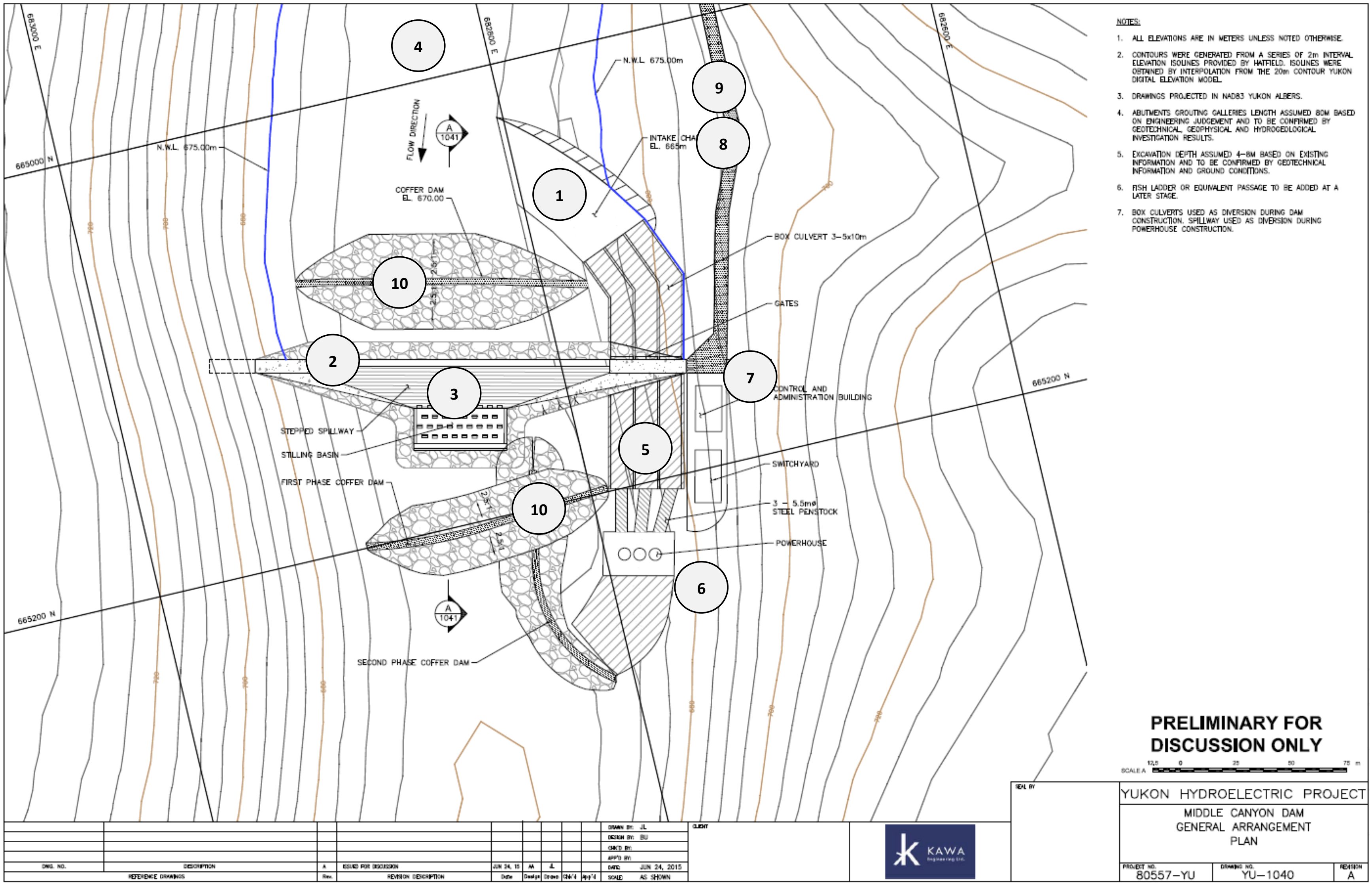
Figure 25: Middle Canyon Layout



3.5.13 Intake

The water intake is a concrete structure located on the river-left (east) bank and is based on a rock foundation which requires approximately 4 to 8 m of excavation. The intake structure is connected to penstocks that convey water for electric generation during operation up to the full plant design flow of approximately 265 m^3/s.

The main components of the intake include:

1) Trash Racks - To prevent driftwood and other floating debris such as ice from being entrained by the water conveyance structures.

2) Trash Rack Cleaning Equipment - To allow for clearing of entrained debris.

3) Head Gate Structure - To provide the ability to stop water flow into the water conveyance structures for regular maintenance or emergency purposes.

4) Intake to Penstock Transition - To convey water from the three 5 m x 10 m intake culvert box into the penstock while providing enough submergence to avoid vortex formation and ice.

3.5.14 Dam

The project is designed with a 17 m high Roller Compacted Concrete (RCC) dam. RCC is a concrete placement method that is widely used in gravity dams because of its higher installation rate (i.e. greater construction quantities in a shorter period of time), and lower curing / forming costs compared to conventional concrete placement. The dam is classified in the “High” hazard category and is designed for a 2475-year seismic event. The design includes 3 m of freeboard for flood retention, and a stepped spillway to pass high flow events such as floods and summer peak flows. The dam crest is assumed to be 6 m wide to allow for operations and maintenance access along the top of the dam. The dam structure also includes two 80 m long grouting galleries on each sides of the river to consolidate the foundation during and after construction. The dam structure is founded on rock which will require approximately 4 m of excavation to fully uncover the bedrock. The dam structure is attached to the bedrock foundation by means of rock anchors that are typically 3 to 6 m long.

3.5.15 Spillway

The dam includes a stepped concrete spillway structure at the center of the dam to control water flow releases during high flow periods. The spillway is designed to release flows up to PMF flow. The spillway structure includes two 12 m x 8 m radial gates and concrete chutes which return the water to the river. The foot of the spillway and area immediately downstream includes a stilling basin designed to withstand the erosive effects of the spillway water flows and to dissipate the energy contained in the flowing water.

3.5.16 Reservoir

The estimated FSL of the water reservoir is 672 m ASL, flooding a total area of approximately 1 km^2 just downstream of the Robert Campbell highway. The drawdown is considered negligible for ROR projects. A project reservoir map at FSL is shown in Appendix B: Reservoir Map.

3.5.17 Penstock

On the river-left (east) bank, three 5.5 m diameter steel penstock conveys water from the intake to the powerhouse. The penstock will split three ways and is approximately 25 m long.

3.5.18 Powerhouse

The surface powerhouse is located downstream of the dam on the river-left (east) bank. The powerhouse is designed to house three equally-sized Kaplan turbines. Each Kaplan turbine has a design flow capacity of approximately 90 m^3/s fed via the intake and penstock arrangement described above. The three-unit powerhouse has an installed capacity of 22 MW and is expected to generate 22 GWh per year based on the Baseline 2065 Forecast. However, the three base units are able to generate 86 GWh per year in an average water year.

The powerhouse contains all required operational, maintenance, and protection and control equipment required to operate the facility. Loading bays and an overhead crane will allow for maintenance access during operations. A tailrace channel directs water from the submergence pool back to the river.

3.5.19 Switchyard

The switchyard is a fenced area which contains transformers and electrical protection equipment (such as circuit breakers and disconnect switches). The electricity produced via the turbine-generators inside the powerhouse is conveyed at an intermediate voltage to the switchyard located adjacent to the powerhouse. In the switchyard, the intermediate voltage is transformed up to a 138kV transmission voltage and transported to the Yukon electrical grid via a 138kV transmission line.

3.5.20 Transmission Line

If a pre-existing 415 km long 138 kV transmission line between Faro and Watson Lake is assumed, less than 10 km of new 138 kV transmission line is required to interconnect the project. The 138 kV transmission line connects the powerhouse (via the switchyard) to the Yukon electrical grid. The point of interconnection is expected to be a tap onto the future line connecting Faro and Watson Lake. The RoW of the transmission line corridor connecting the project to the future transmission line connecting Faro and Watson Lake is estimated to be approximately 50 m wide and impact less than 1 km^2 of land.[27] The RoW of the transmission

[27] Land impacts include First Nations settlement lands, settled lands and lands set aside for First Nations.

line corridor connecting Faro and Watson Lake is estimated to be approximately 50 m wide and impact about 21 km^2 of land.[27]

Without a pre-existing transmission line between Faro and Watson Lake, an additional 30 km of new 138 kV transmission line is required to interconnect the project to the 335 km required to interconnect False Canyon to Faro.[28] The 138 kV transmission line connects the powerhouse (via the switchyard) to the Yukon electrical grid. The point of interconnection is expected to be a tap into the transmission line at False Canyon. The RoW of the transmission line corridor connecting the project to Faro is estimated to be approximately 50 m wide and impact less than 2 km^2 of land.[27]

3.5.21 Access Infrastructure

Assuming a transmission line between Faro and Watson Lake pre-exists, less than 10 km of new gravel road is required to access the project. The proposed access infrastructure is required for both construction activities (e.g. moving of heavy equipment and materials) and operations activities (e.g. operator access). The road alignment will approximately follow the transmission line corridor and is not expected to cross terrain that will require a bridge crossing.

Without a pre-existing transmission line between Faro and Watson Lake, less than 10 km of new gravel road is required to access the project in addition to the 40 km of new road required for False Canyon.

3.5.22 Temporary Construction Works

As with the construction of any hydroelectric project, various temporary construction works are required during construction. The largest temporary construction works is a diversion scheme on the river-left (east) bank which allows the river to flow naturally during construction while maintaining a dry area for construction. The diversion scheme includes:

1) An upstream cofferdam which may remain or be removed before operation, and
2) Two downstream cofferdams:
    - The first stage downstream cofferdam will be used during the dam construction.
    - The second stage cofferdam is built after the first stage cofferdam is removed which will be used during the powerhouse construction. The second stage cofferdam will be removed before operation commences.

Additionally, a number of temporary construction phase facilities are anticipated during the construction period, including:

1) Site Office and Construction Camp

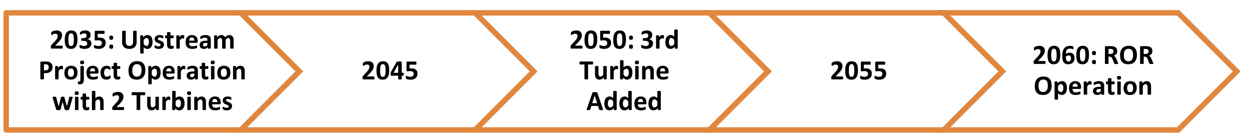
[28] It is likely that the entire 415 km long transmission line corridor from Faro to Watson Lake would be built if a transmission line was required to interconnect False Canyon and/or Middle canyon to Faro.

2) Workshops, labs, and testing facilities
3) Fabrication shops
4) First aid / safety / safety stations
5) Staging / lay down areas
6) Waste water treatment plant
7) Concrete batch plants
8) Truck washing stations
9) Explosives storage
10) Fuel storage and refuelling

3.5.23 Build Out Timeline

The scalability timeline for a cascaded False Canyon + Middle Canyon ROR is shown in Figure 26 with False Canyon built at full size in 2035 with two turbine generators, a 3rd turbine generator (and supporting infrastructure) added in approximately 2050, and the Middle Canyon ROR with 2 turbine generators built in 2060.

Figure 26: False Canyon + Middle Canyon ROR Build Out Timeline



3.5.24 Cost Estimate

The estimated capital costs for False Canyon + Middle Canyon ROR with and without the Faro-Watson Lake transmission line are shown in Table 20 and Table 21 respectively. A detailed cost estimate is included in Appendix C: Cost Estimates.

Table 20: False Canyon + Middle Canyon ROR w/ Faro-Watson Lake Cost Estimate

Project Component	Cost Estimate ($ Million)
2035 - False Canyon Dam	833
2050 - Scalability Upgrade	27
2060 - Middle Canyon Dam	220
Transmission Line and Access Road	18
Miscellaneous Owners Cost	50
Contingency (30%)	344
Total	**1493**

Table 21: False Canyon + Middle Canyon ROR w/o Faro-Watson Lake Cost Estimate

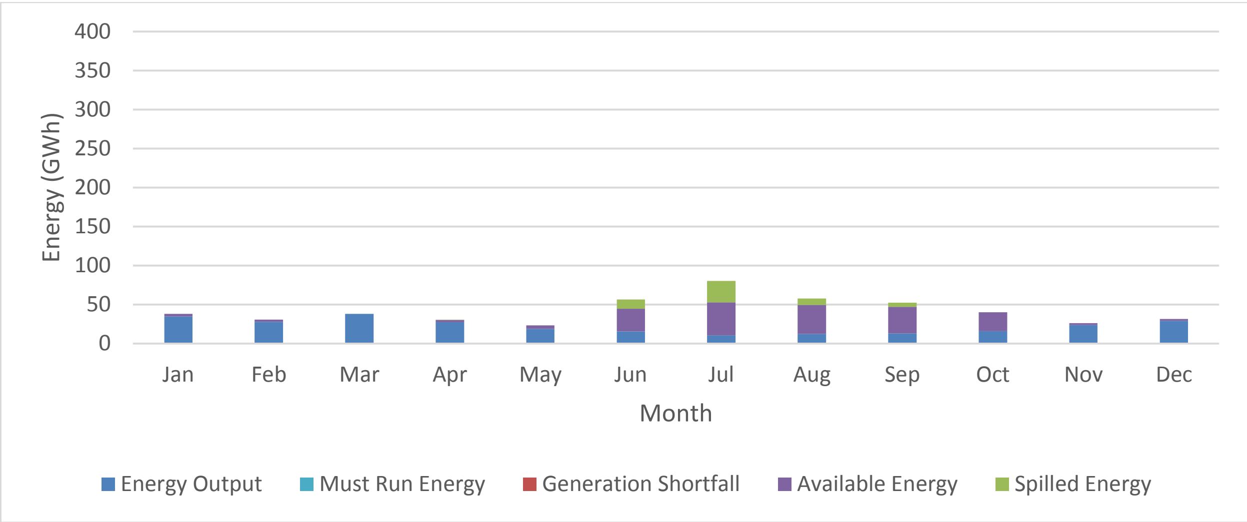
Project Component	Cost Estimate ($ Million)
2035 - False Canyon Dam	833
2050 - Scalability Upgrade	27
2060 - Middle Canyon Dam	220
Transmission Line and Access Road	377
Miscellaneous Owners Cost	50
Contingency (30%)	452
Total	**1959**

In addition to capital costs, the operating and maintenance costs of the dam facility, transmission line and road are estimated at $10.7 Million (2015)/year with an existing Faro-Watson Lake transmission Line and $12.5 Million (2015)/year without an existing Faro-Watson Lake transmission Line.

3.5.25 2065 Energy Output

The False Canyon + Middle Canyon ROR Canyon energy summary in Figure 27 shows that False Canyon + Middle Canyon ROR is able to provide 100% of the forecasted 2065 Baseline 265 GWh gap, and is also able to provide an additional 186 GWh of available energy beyond the 2065 Baseline Energy Gap.

Figure 27: False Canyon + Middle Canyon ROR 2065 Energy Summary

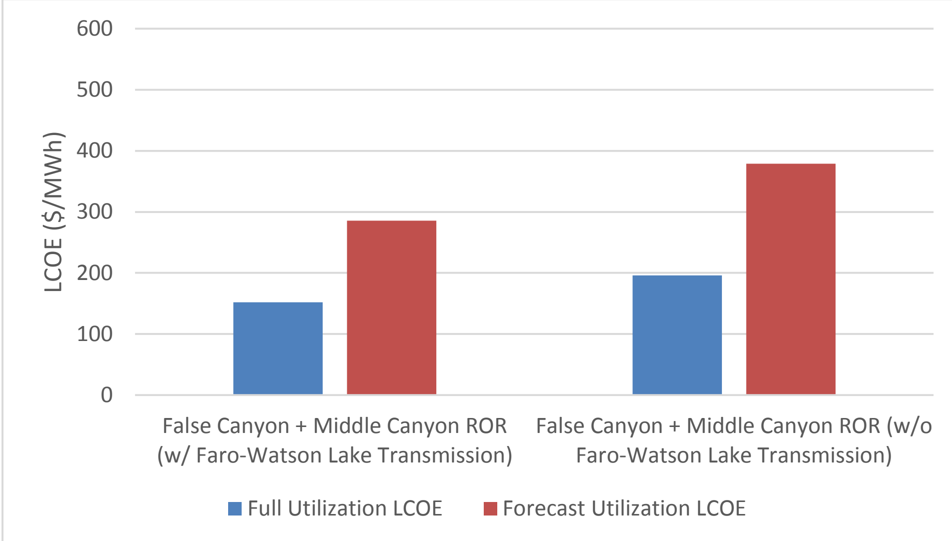


3.5.26 LCOEs

With a pre-existing Faro-Watson Lake transmission Line, the project Full Utilization LCOE is $152/MWh and its Forecast Utilization LCOE is $286/MWh as shown in Figure 28.

Without an existing Faro-Watson Lake transmission Line, the project Full Utilization LCOE is $196/MWh and its Forecast Utilization LCOE is $379/MWh as shown in Figure 28.

Figure 28: False Canyon + Middle Canyon ROR LCOEs



3.6 Slate Rapids + Hoole Canyon ROR [PELLY-PELLY-0847-B + PELLY-PELLY-0760-A]

Slate Rapids + Hoole Canyon ROR is a cascade of two sites with Slate Rapids located upstream on the Pelly River providing both water storage and generation, and Hoole Canyon ROR located downstream operating as a run-of-river facility with no water storage (but a headpond to create head for generation purposes). The ROR operates similarly to the Whitehorse facility, where the headpond water level remains constant and electricity is generated only from water flowing in rather than from the stored water. For Hoole Canyon, the water flowing in is from the water released from generation and spill at Slate Rapids.

3.6.1 Slate Rapids [PELLY-PELLY-0847-B]

Slate Rapids is a potential hydroelectric project on the Pelly River, located in the Pelly River Basin, approximately 75 km east of the community of Ross River. The total drainage area is estimated at 5,400 km^2.

The project includes two dams:

1) An upstream diversion dam to direct the river flow towards its eastern upstream arm down to the power dam. This diversion system restricts the reservoir from expanding into the river downstream western arm which would flood a larger area of the Yukon. Additionally, moving the diversion further downstream would require a larger (more expensive) dam.
2) A downstream power dam to generate electricity located approximately 13 km south of the diversion dam.

The major components of the preliminary project layout for both dams are listed in

Table 22. The project components are shown in Figure 29 and Figure 30 and described in more detail as per sections listed in Table 22.

Table 22: Slate Rapids Dams Major Project Components

Component	Diversion Dam Drawing Item	Power Dam Drawing Item	Description Section
Intake Structure	N/A	①	3.6.2
Dam	②	②	3.6.3
Spillway	③	③	3.6.4
Reservoir	④	④	3.6.5
Penstock	N/A	⑤	3.6.6
Powerhouse	N/A	⑥[29]	3.6.7
Fish Conveyance[30]	See Note 30	See Note 30	See Note 30
Switchyard	N/A	⑦[29]	3.6.8
Transmission Line	N/A	⑧[29]	3.6.9
Access Infrastructure (Roads & Bridge)	⑨	⑨	3.6.10
Temporary Construction Works	⑩	⑩	3.6.11

[29] The powerhouse, switchyard and transmission line are not shown on the drawing because their location is further downstream of the dam. The transmission line is expected to follow approximately the access road from the switchyard to the interconnection point.

[30] At this stage of study, upstream fish passage is expected to be facilitated via fish ladder. During subsequent phases of development, different alternatives may be considered including, but not limited to, mechanical lifts or trap-load-haul operations. Downstream fish passage is expected to be facilitated through fish friendly turbines (e.g. Kaplan Turbine).

Figure 29: Slate Rapids Diversion Dam Layout

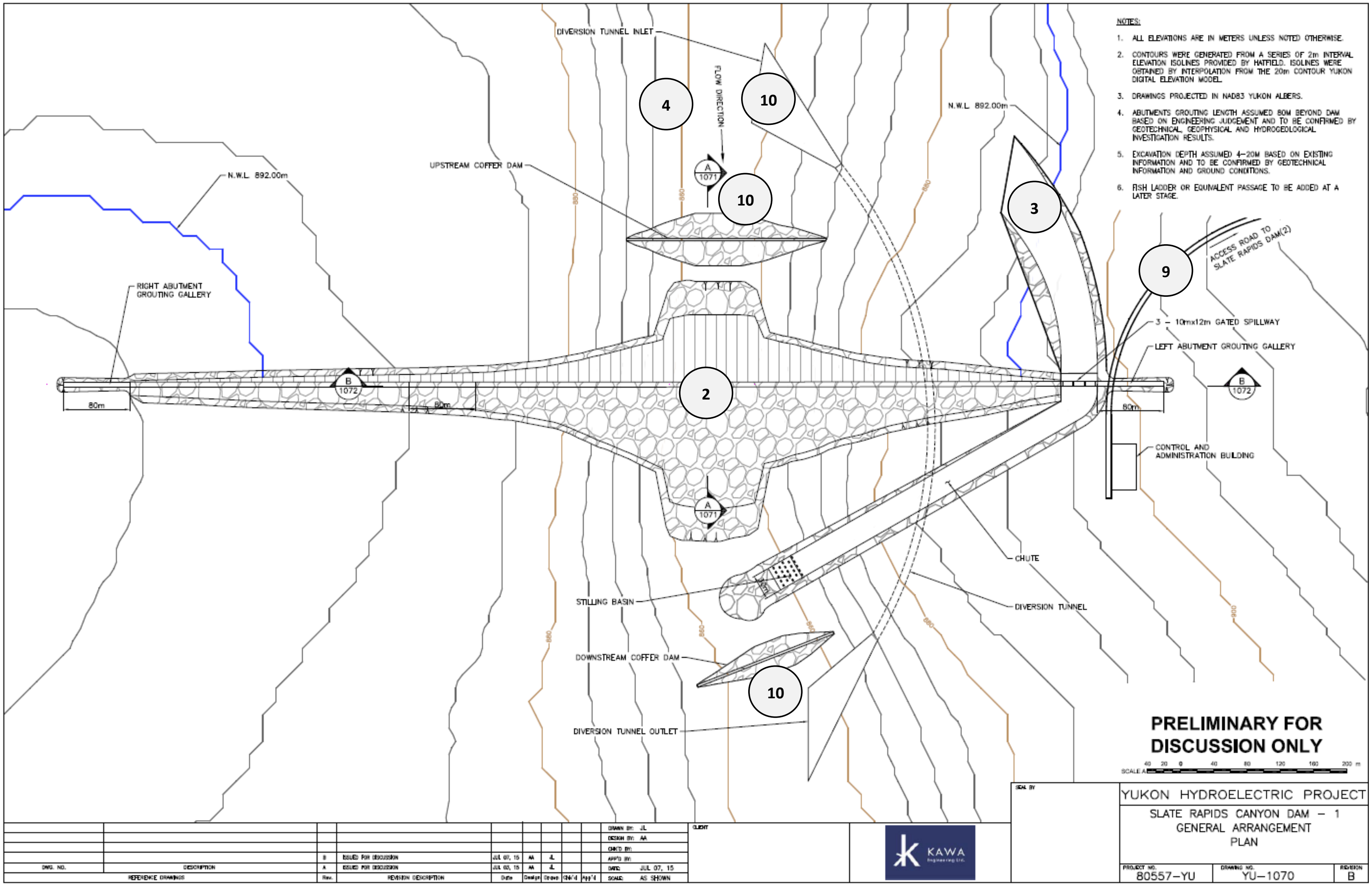
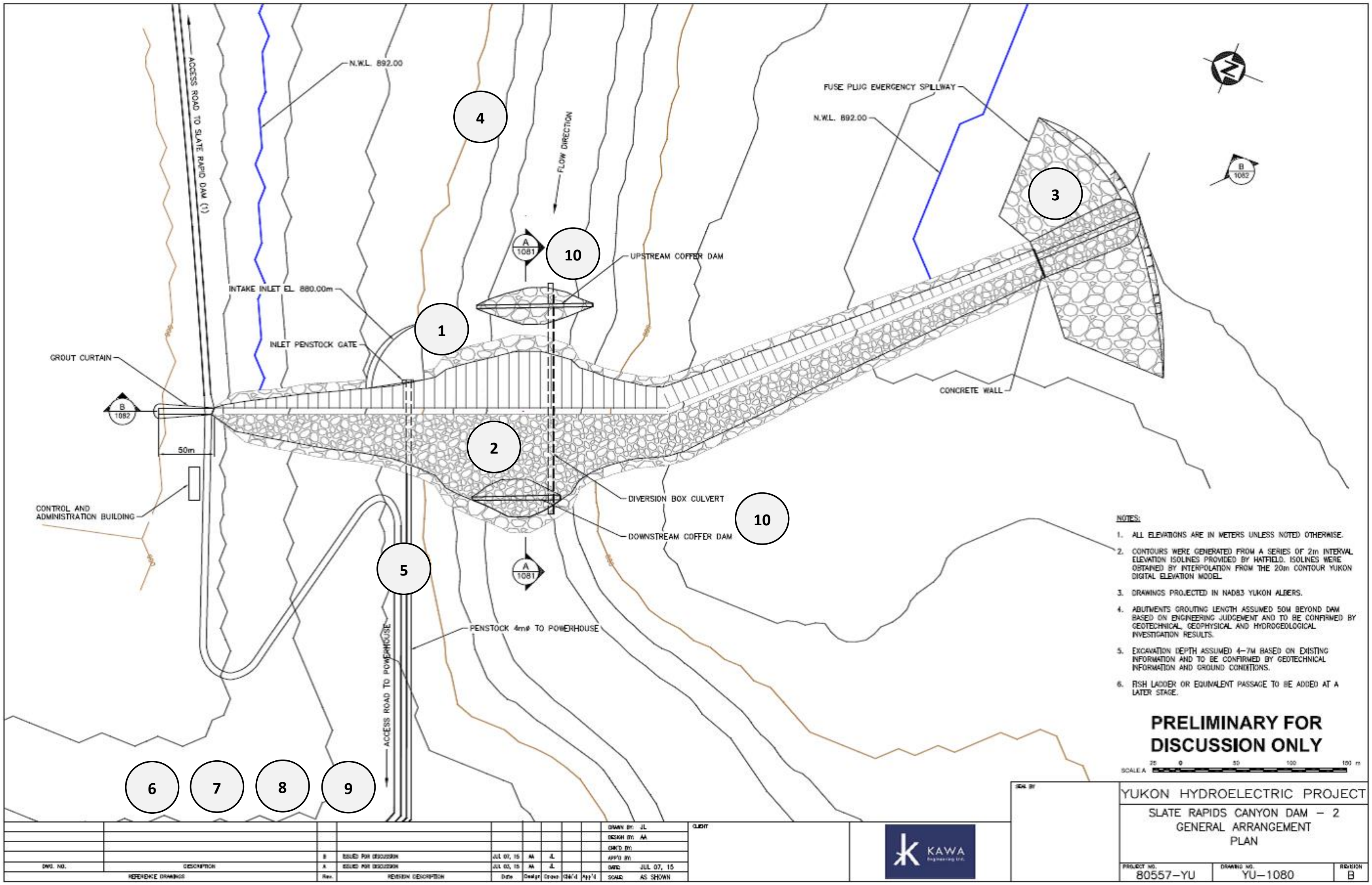


Figure 30: Slate Rapids Power Dam Layout



3.6.2 Intake

The water intake is a concrete structure located on the river-right (west) bank of the power dam and is based on a rock foundation which requires between 4 to 7 m of excavation. The intake tower is connected to the penstock that conveys water for electric generation during operation up to the full plant design flow of approximately 65 m^3/s.

The main components of the intake include:

1) Trash Racks - To prevent driftwood and other floating debris such as ice and leaves from being entrained by the water conveyance structures.

2) Trash Rack Cleaning Equipment - To allow for clearing of entrained debris.

3) Head Gate Structure - To provide the ability to stop water flow into the water conveyance structures for regular maintenance or emergency purposes.

4) Intake to Penstock Transition - To convey water from the intake box into the penstock while providing enough submergence to avoid vortex formation and ice.

3.6.3 Dams

The project is designed with a 57 m high diversion dam and a 36 m high power dam, both of Concrete Faced Rockfill Dam (CFRD) type. The dam structures are primarily composed of a rock core with filter layers of fine materials finished with upstream concrete faces to provide water impermeability to the structures. Both dams are classified in the “High” hazard category and are designed for a 2475-year seismic event. The designs include 3 m of freeboard for flood retention and to prevent overtopping, and spillways to pass high flow events such as floods and summer peak flows. The dam crests are assumed to be 6 m wide to allow for operations and maintenance access along the top of the dams. The diversion dam structure includes an 80 m long grouting gallery on both sides of the river to consolidate the foundation during and after construction. The power dam grouting gallery is 50 m long. To expose the underlying bedrock for the dam structure foundations, between 4 to 20 m of excavation for the diversion dam and 4 to 7 m of excavation for the power dam is required. The dam structures are attached to the bedrock foundation by means of rock anchors that are typically 4 to 6 m long.

3.6.4 Spillways

The diversion dam includes a gated concrete spillway structure on the river-left (east) bank which is the main control of water flow releases during high flow periods. The spillway is designed to release flows up to PMF flow. The spillway structure includes a concrete inlet channel with three 10 m x 12 m gates and a concrete chute which return the water to the river. The foot of the spillway and area immediately downstream includes a stilling basin designed to withstand the erosive effects of the spillway water flows and to dissipate the energy contained in the flowing water.

The power dam includes an emergency spillway as secondary control of water flow release during high flow periods.

3.6.5 Reservoir

The proposed dams creates a reservoir upstream of the dam sites. The estimated FSL of the water reservoir is 892 m ASL, flooding a total area of approximately 168 km^2 (34 km^2 of which is the existing Fortin and Pelly Lakes). The ADL of the water reservoir is 887 m ASL resulting in reservoir water level fluctuations of 5 m over an average year. A project reservoir map at FSL and ADL is shown in Appendix B: Reservoir Map.

3.6.6 Penstock

At the power dam, a steel penstock connects the intake on the river-right (west) bank to the powerhouse. The 4 m diameter penstock is approximately 1 km long and will require anchor blocks to restrain it at bend locations. The penstock splits into a bifurcation at the powerhouse to feed the two turbine and generator units.

3.6.7 Powerhouse

The surface powerhouse is located downstream of the power dam on the river-right (west) bank. The powerhouse is designed to house two equally-sized Kaplan turbines. Each Kaplan turbine has a design flow capacity of approximately 33 m^3/s fed via the intake and power tunnel arrangement described above. The two-unit powerhouse has an installed capacity of 42 MW and is expected to generate 186 GWh per year based on the Baseline 2065 Forecast. However, the three base units are able to generate 229 GWh per year in an average water year.

The powerhouse contains all required operational, maintenance, and protection and control equipment required to operate the facility. Loading bays and an overhead crane will allow for maintenance access during operations. A tailrace channel directs water from the submergence pool back to the river.

3.6.8 Switchyard

The switchyard is a fenced area which contains transformers and electrical protection equipment (such as circuit breakers and disconnect switches). The electricity produced via the turbine-generators inside the powerhouse is conveyed at an intermediate voltage to the switchyard located adjacent to the powerhouse. The intermediate voltage in the switchyard is transformed to a 138 kV transmission voltage and transported to the Yukon electrical grid via a 138 kV transmission line.

3.6.9 Transmission Line

If a pre-existing 415 km long 138 kV transmission line between Faro and Watson Lake is assumed, less than 10 km of new 138 kV transmission line is required to interconnect the project. The 138 kV transmission line connects the powerhouse (via the switchyard) to the Yukon electrical grid. The point of interconnection is expected to be a tap onto the future line connecting Faro and Watson Lake. The RoW of the transmission line corridor connecting the project to the future transmission line connecting Faro and Watson Lake is estimated to be approximately 50 m wide and impact less than 1 km^2 of land.[31] The RoW of the transmission line corridor connecting Faro and Watson Lake is estimated to be approximately 50 m wide and impact about 21 km^2 of land. [31]

Without a pre-existing Faro and Watson Lake transmission line, an additional 161 km of new 138 kV transmission line is required to interconnect the project. The 138 kV transmission line connects the powerhouse (via the switchyard) to the Yukon electrical grid. The point of interconnection is expected to be a connection at the substation near Faro. The transmission line corridor RoW is estimated to be approximately 50 m wide and impact about 8 km^2 of land.[31]

3.6.10 Access Infrastructure

Less than 10 km of new gravel road is required to access the project from the Robert Campbell Highway. Approximately 20 km of new gravel road is required to build the new transmission line interconnecting Faro to Slate Rapids. The proposed access infrastructure is required for both construction activities (e.g. moving of heavy equipment and materials) and operations activities (e.g. operator access). The road alignment will approximately follow the transmission line corridor and is expected to cross a valley that will require a bridge crossing. The Faro to Watson Lake corridor requires 40 km of new gravel road.

3.6.11 Temporary Construction Works

As with the construction of any hydroelectric project, various temporary construction works are required during construction. The largest temporary construction works is a diversion scheme on the river-left (east) bank which allows the river to flow naturally during construction while maintaining a dry area for construction. The diversion scheme includes:

1) A diversion box culvert,
2) An upstream cofferdam which may remain or be removed before operation, and
3) A downstream cofferdam which will be incorporated into the dam construction.

[31] Land impacts include First Nations settlement lands, settled lands and lands set aside for First Nations.

Additionally, a number of temporary construction phase facilities are anticipated during the construction period, including:

1) Site Office and Construction Camp
2) Workshops, labs, and testing facilities
3) Fabrication shops
4) First aid / safety / safety stations
5) Staging / lay down areas
6) Waste water treatment plant
7) Concrete batch plants
8) Truck washing stations
9) Explosives storage
10) Fuel storage and refuelling

3.6.12 Hoole Canyon ROR [PELLY-PELLY-0760-A]

Hoole Canyon ROR is a potential ROR hydroelectric project on the Pelly River, located in the Pelly River Basin, approximately 30 km upstream of the community of Ross River. The total drainage area for the dam is estimated to be 9,900 km^2.

The major components of the preliminary project layout are listed in Table 23. The project components are shown in Figure 8 and described in more detail as per sections listed in Table 23.

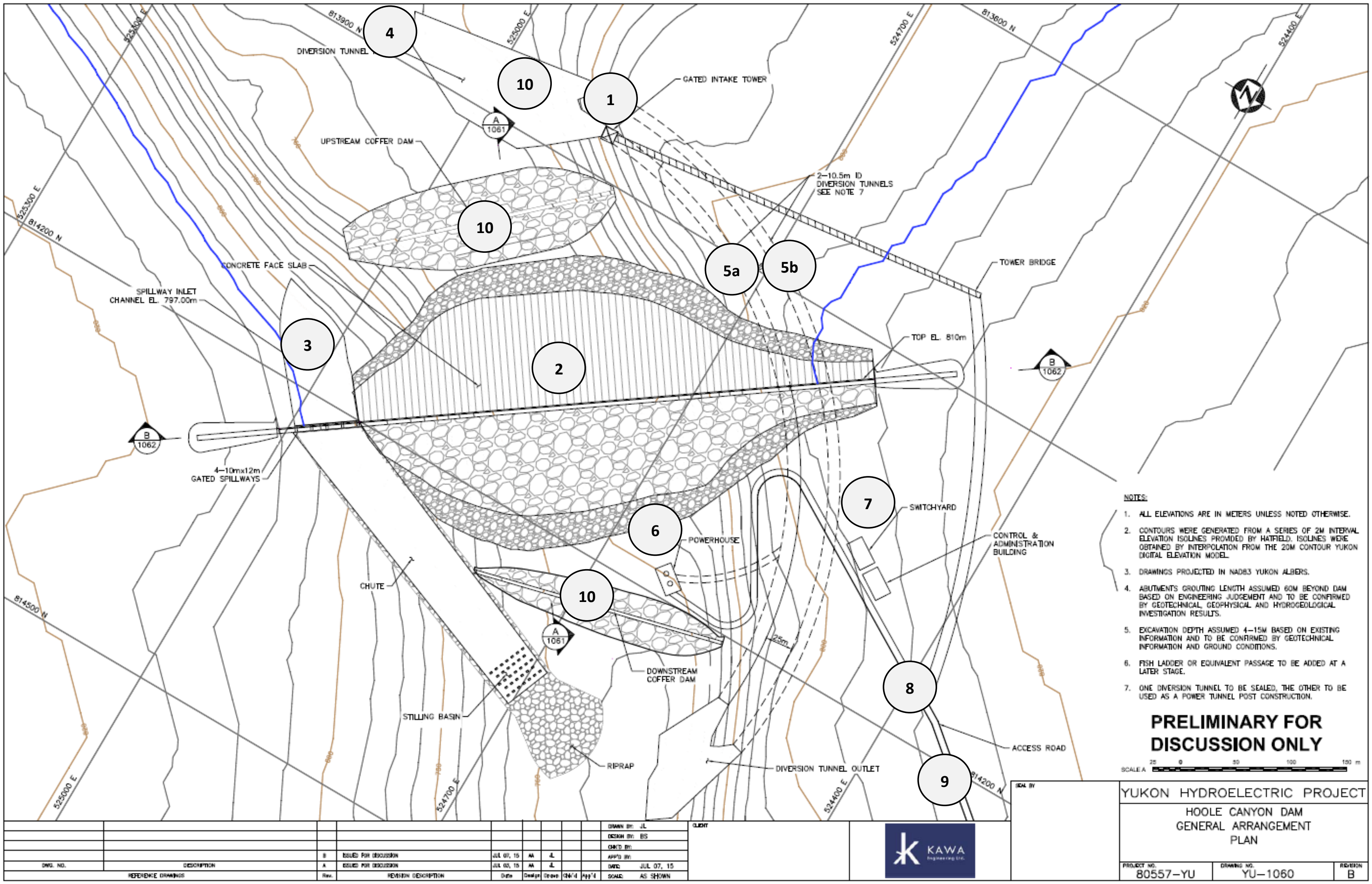
Table 23: Hoole Canyon Major Project Components

Component	Drawing Item	Description Section
Intake Structure	①	3.6.13
Dam	②	3.6.14
Spillway	③	3.6.15
Reservoir	④	3.6.16
Power Tunnel and Penstock	⑤	3.6.17
Powerhouse	⑥	3.6.18
Fish Conveyance[32]	See Note 32	See Note 32
Switchyard	⑦	3.6.19
Transmission Line	⑧[33]	3.6.20
Access Infrastructure (Roads & Bridge)	⑨	3.6.21
Temporary Construction Works	⑩	3.6.23

[32] At this stage, upstream fish passage is expected to be facilitated via fish ladder. During the subsequent phases of the projects, different alternatives may be considered including but not limited to mechanical lifts or trap-load-haul operations. Downstream fish passage is expected to be facilitated through fish friendly turbines (e.g. Kaplan Turbine).

[33] The transmission line is not shown on the drawing but is expected to follow approximately the access road from the switchyard to the interconnection point.

Figure 31: Hoole Canyon Layout



3.6.13 Intake

The water intake is a concrete tower structure located on the river-left (west) bank and is based on a rock foundation which requires between 4 to 15 m of excavation. The intake structure is accessed via a 350 m long bridge connected to the project access road. The intake structure is connected to the east diversion tunnel (Drawing item 5a) that conveys water for electric generation during operation up to the full plant design flow of approximately 160 m^3/s.

The main components of the intake include:

1) Trash Racks - To prevent driftwood and other floating debris such as ice and leaves from being entrained by the water conveyance structures.

2) Trash Rack Cleaning Equipment - To allow for clearing of entrained debris.

3) Head Gate Structure - To provide the ability to stop water flow into the water conveyance structures for regular maintenance or emergency purposes.

4) Intake to Penstock Transition - To convey water from the intake box into the penstock while providing enough submergence to avoid vortex formation and ice.

3.6.14 Dam

The project is designed with a 71 m high Concrete Faced Rockfill Dam (CFRD). The dam structure is primarily composed of a rock core with filter layers of fine materials finished with an upstream concrete face to provide water impermeability to the structure. The dam is classified in the “High” hazard category and is designed for a 2475-year seismic event. The design includes 3 m of freeboard for flood retention and to prevent overtopping, and a spillway to pass high flow events such as floods and summer peak flows. The dam crest is assumed to be 6 m wide to allow for operations and maintenance access along the top of the dam. The dam structure also includes 60 m long grouting galleries on both sides of the river to consolidate the foundation during and after construction. The dam structure is founded on rock which will require between 4 to 15 m of excavation to fully uncover. The dam structure is attached to the bedrock foundation by means of rock anchors that are typically 4 to 6 m long.

3.6.15 Spillway

The dam includes a gated concrete spillway structure on the river-right (east) bank that controls water flow releases during high flow periods. The spillway is designed to release flows up to PMF flow. The spillway structure includes a concrete inlet channel with four 10 m x 12 m gates and concrete chutes which return the water to the river. The foot of the spillway and area immediately downstream includes a stilling basin designed to withstand the erosive effects of the spillway water flows and to dissipate the energy contained in the flowing water

3.6.16 Reservoir

The proposed dam creates a reservoir upstream of the dam site. The estimated FSL of the water reservoir at the main power dam is 807 m ASL, flooding a total area of approximately 23 km^2. The drawdown is considered negligible for ROR projects. A project reservoir map at FSL is shown in Appendix B: Reservoir Map.

3.6.17 Power Tunnel and Penstock

The east diversion tunnel (Drawing item 5a) connects the water intake tower to the powerhouse via a steel penstock while the west diversion tunnel (Drawing item 5a) will be sealed before operations commence. The 10.5m diameter east tunnel is approximately 350 m long and will be grouted post excavation for erosion protection.

3.6.18 Powerhouse

The surface powerhouse is located downstream of the dam on the river-left (west) bank. The powerhouse is designed to house two equally-sized Kaplan turbines. Each Kaplan turbine has a design flow capacity of approximately 80 m^3/s fed via the intake and power tunnel arrangement described above. The two-unit powerhouse has an installed capacity of 65 MW and is expected to generate 80 GWh per year based on the Baseline 2065 Forecast. However, the two base units are able to generate 259 GWh per year in an average water year.

The powerhouse contains all required operational, maintenance, and protection and control equipment required to operate the facility. Loading bays and an overhead crane will allow for maintenance access during operations. A tailrace channel directs water from the submergence pool back to the river.

3.6.19 Switchyard

The switchyard is a fenced area which contains transformers and electrical protection equipment (such as circuit breakers and disconnect switches). The electricity produced via the turbine-generators inside the powerhouse is conveyed at an intermediate voltage to the switchyard located adjacent to the powerhouse. The intermediate voltage in the switchyard is transformed to a 138 kV transmission voltage and transported to the Yukon electrical grid via a 138 kV transmission line.

3.6.20 Transmission Line

If a pre-existing 414 km 138 kV transmission line between Faro and Watson Lake is assumed, less than 2 km of new 138 kV transmission line is required to interconnect the project. The 138 kV transmission line connects the powerhouse (via the switchyard) to the Yukon electrical grid. The point of interconnection is expected to be a tap onto the future transmission line connecting Faro and Watson Lake. The RoW of the transmission line connecting the project to the Faro to Watson Lake line is estimated to be approximately 50 m wide and impact less than 1 km^2 of land. The RoW of the transmission line corridor connecting Faro and Watson Lake is estimated to be approximately 50 m wide and impact about 21 km^2 of land.[34]

Without a preexisting Faro to Watson Lake transmission line, less than 2 km of new 138 kV transmission line is required to interconnect the project to the 150 km of new transmission line required to interconnect the project at Slate Rapids to the Yukon grid. The point of interconnection is expected to be a tap onto the 138 kV line connecting Slate Rapids to Faro. The transmission line RoW is estimated to be approximately 50 m wide and impact about less than 1 km^2 of land on top of the 8 km^2 corridor RoW connecting Slate Rapids to Faro.[31]

3.6.21 Access Infrastructure

Less than 2 km of new gravel road is required to access the project. The proposed access infrastructure is required for both construction activities (e.g. moving of heavy equipment and materials) and operations activities (e.g. operator access). The road alignment will approximately follow the transmission line corridor. Temporary Construction Works

3.6.22 Temporary Construction Works

As with the construction of any hydroelectric project, various temporary construction works are required during construction. The largest temporary construction works is a diversion scheme on the river-left (west) bank which allows the river to flow naturally during construction while maintaining a dry area for construction. The diversion scheme includes:

1) Two 10.5 m diameter diversion tunnels,
2) A upstream cofferdam which may remain or be removed before operation, and
3) A downstream cofferdam which will be removed before operation commences.

Additionally, a number of temporary construction phase facilities are anticipated during the construction period, including:

1) Site Office and Construction Camp
2) Workshops, labs, and testing facilities
3) Fabrication shops
4) First aid / safety / safety stations
5) Staging / lay down areas
6) Waste water treatment plant
7) Concrete batch plants

[34] Land impacts include First Nations settlement lands, settled lands and lands set aside for First Nations.

8) Truck washing stations
9) Explosives storage
10) Fuel storage and refuelling

3.6.23 Build Out Timeline

The scalability timeline for a cascaded Slate Rapids and Hoole Canyon is shown in Figure 32 with Slate Rapids at full size in 2035 with two turbine generators, and the Hoole Canyon ROR with 2 turbine generators built in 2050. Slate Rapids reaches its capacity limit at the same time it reaches its energy limit.

Figure 32: Slate Rapids + Hoole Canyon ROR Build Out Timeline

3.6.24 Cost Estimate

The estimated capital costs for Slate Rapids + Hoole Canyon ROR with and without the Faro-Watson Lake transmission line are shown in Table 24 and Table 25. A detailed cost estimate is included in Appendix C: Cost Estimates.

Table 24: Slate Rapids + Hoole Canyon ROR with Faro-Watson Lake Cost Estimate

Project Component	Cost Estimate ($ Million)
2035 - Slate Rapids Dam	1330
2050 - Hoole Canyon Dam	730
Transmission Line and Access Road	16
Miscellaneous Owners Cost	50
Contingency (30%)	638
Total	**2764**

Table 25: Slate Rapids + Hoole Canyon ROR without Faro-Watson Lake Cost Estimate

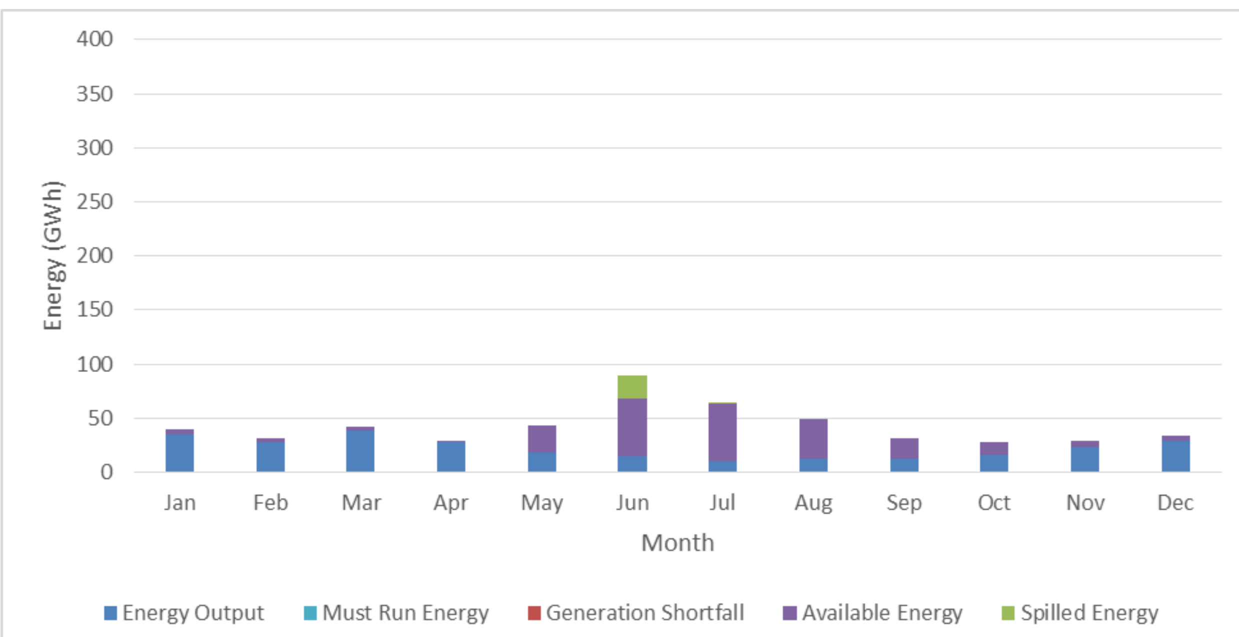
Project Component	Cost Estimate ($ Million)
2035 - Slate Rapids Dam	1330
2050 - Hoole Canyon Dam	730
Transmission Line and Access Road	169
Miscellaneous Owners Cost	50
Contingency (30%)	684
Total	**2962**

In addition to capital costs, the operating and maintenance costs of the dam facility, transmission line and road are estimated at $15.2 Million (2015)/year with an existing Faro-Watson Lake transmission Line and $15.9 Million (2015)/year without an existing Faro-Watson Lake transmission Line.

3.6.25 2065 Energy Output

The Slate Rapids + Hoole Canyon ROR energy summary in Figure 27 shows that Slate Rapids + Hoole Canyon ROR are able to provide 100% of the forecasted 2065 Baseline 265 GWh gap, and also able to provide an additional 222 GWh of available energy beyond the 2065 Baseline Energy Gap.

Figure 33: Slate Rapids + Hoole Canyon ROR 2065 Energy Summary

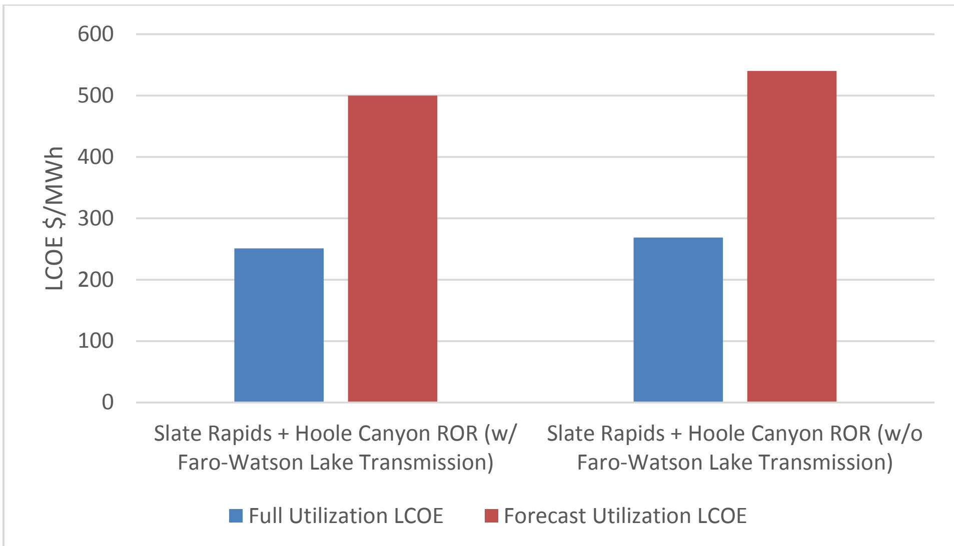


3.6.26 LCOEs

With an existing Faro-Watson Lake transmission Line, the project Full Utilization LCOE is $251/MWh and its Forecast Utilization LCOE is $500/MWh as shown in Figure 34.

Without an existing Faro-Watson Lake transmission Line, the project Full Utilization LCOE is $269/MWh and its Forecast Utilization LCOE is $540/MWh as shown in Figure 34.

Figure 34: Slate Rapids + Hoole Canyon ROR LCOEs



4 Summary

The Scalability Shortlists projects have been sized for the common goal of providing at least 95% of the Forecast Baseline 2065 Gap. Therefore, the projects present a similar energy output, with the standalone projects being able to provide lower cost energy because they generally offer a better head, flow and storage combination. Table 26 shows the projects energy outputs in 2065.

Table 26: Scalability Shortlist Projects Energy Output

Project	2065 Installed Capacity (MW)	2065 Forecast Energy Output (GWh)	2065 Must Run Energy (GWh)	Post 2065 - Additional Available Energy (GWh)	Max Potential Energy Output (GWh)
Detour Canyon	60	265	22	300	587
Fraser Falls	57	265	30	268	563
Granite Canyon	57	265	51	272	588
Two Mile Canyon	54	259	14	216	489
False Canyon + Middle Canyon ROR	78	265	0	186	451
Slate Rapids + Hoole Canyon ROR	107	265	0	222	487

While their energy outputs are similar, the capital cost of these projects varies by over $2 Billion with the lowest estimated at $847 Million (Granite Canyon) and the highest estimated at $2.9 Billion (Slate Rapids + Hoole Canyon ROR). The costs are dependent on site specifics factors such as location, topography, foundation conditions, availability of construction material, distance from interconnection point etc. The cascades have larger capital costs than the standalone projects because they require the construction of two facilities; whereas, standalone projects only require one facility. The cascades also require longer transmission lines than the standalone projects which is another significant cost component. Table 27 shows the estimated capital costs for the six shortlisted projects.

Table 27: Scalability Shortlist Projects Cost

Project	Initial Dam	Scalability Upgrade 1	Scalability Upgrade 2	Post 2065 Upgrade	Trans. Line + Access Road	Capital Cost Estimate[35]
Detour Canyon	843	27	N/A	53	114	1413
Fraser Falls	753	27	N/A	54	64	1233
Granite Canyon	503	27	N/A	53	19	847
Two Mile Canyon	444	16	N/A	32	164	919
False Canyon + Middle Canyon ROR (w/ Faro-Watson)	833	27	220	N/A	18	1493
False Canyon + Middle Canyon ROR (w/o Faro-Watson)	833	27	220	N/A	377	1959
Slate Rapids + Hoole Canyon ROR (w/ Faro-Watson)	1330	730	N/A	N/A	16	2764
Slate Rapids + Hoole Canyon ROR (w/o Faro-Watson)	1330	730	N/A	N/A	169	2962

Given the similarity in energy outputs, the LCOEs are driven mainly by capital cost. Not surprisingly, the project with the lowest estimated capital cost (Granite Canyon), has the lowest LCOE ($68/MWh Full Utilization and $181/MWh Forecast Utilization). Similarly, the project with the highest estimated capital cost, Slate Rapids + Hoole Cayon ROR, has the highest LCOE ($269/MWh Full Utilization and $540/MWh Forecast Utilization). Table 28 shows the project LCOEs.

[35] Capital cost estimates include miscellaneous owner's cost and 30% contingency.

Table 28: Scalability Shortlist Projects LCOEs

Project	Full Utilization LCOE ($/MWh)	Forecast Utilization LCOE ($/MWh)
Detour Canyon	110	301
Fraser Falls	100	263
Granite Canyon	68	181
Two Mile Canyon	90	199
False Canyon + Middle Canyon ROR (w/ Faro-Watson Lake)	152	286
False Canyon + Middle Canyon ROR (w/o Faro-Watson Lake)	196	379
Slate Rapids + Hoole Canyon ROR (w/ Faro-Watson Lake)	251	500
Slate Rapids + Hoole Canyon ROR (w/o Faro-Watson Lake)	269	540

Environmental and socio-economic impacts, surface and subsurface tenure issues, constructability planning, and the overall economics will be studied in a future technical paper, *Positive and Negative Socio-Economic and Environmental Effects*.

Appendix A: LCOE Calculation

A.1 Forecast Utilization LCOE

The forecast utilization LCOE assumes a project:

- Generates only the energy needed towards the Forecasted Baseline Energy Gap.
- Is built following the Scalability Build Out Timeline

The Forecasted Baseline Energy Gap from 2035 to 2065 was taken from the *Yukon Electrical Energy and Capacity Need Forecast (2035 to 2065)* paper. The Baseline Energy Gap post 2065 was assumed to follow the same linear trend of 2035 to 2065 for the project life duration of 65 years (i.e. 2100).

The Baseline Energy Gap from 2035 to 2100 is shown in Table A-1.

Table A-1: Yearly Forecast Energy Gap

Year	Forecast Energy Gap (Gwh)	Year	Forecast Energy Gap (Gwh)	Year	Forecast Energy Gap (Gwh)	Year	Forecast Energy Gap (Gwh)
2035	103	2052	195	2068	274	2085	318
2036	108	2053	200	2069	277	2086	321
2037	114	2054	206	2070	279	2087	323
2038	119	2055	211	2071	282	2088	325
2039	125	2056	216	2072	285	2089	328
2040	130	2057	222	2073	288	2090	330
2041	135	2058	227	2074	291	2091	332
2042	141	2059	233	2075	294	2092	335
2043	146	2060	238	2076	297	2093	337
2044	152	2061	243	2077	299	2094	339
2045	157	2062	249	2078	302	2095	342
2046	162	2063	254	2079	304	2096	344
2047	168	2064	260	2080	306	2097	346
2048	173	2065	265	2081	309	2098	349
2049	179	2066	268	2082	311	2099	351
2050	184	2067	271	2083	313	2100	353
2051	189			2084	316		

A.2 Full Utilization LCOE

The Full Utilization LCOE assumes a project generates to its full potential including the energy output toward the Baseline Energy Gap, must run energy and available energy.

A.3 Assumptions

The following cost, operation and economic assumptions are assumed:

1) Loan Interest During Construction built on an assumed 60/40 debt-equity split[36], a levelized draw schedule, and a 6% short term debt rate:
    a. 5.55% increase to project costs for a three year construction schedule, or
    b. 3.75% increase to project costs for a two year construction schedule,
2) Project Lifespan: 65 years[37]
3) Real Discount Rate: 3.38% (based on a nominal discount rate of 5.45% and a 2% assumed inflation rate)
4) Levelized Cost of Energy Calculation Method: Discounts both costs (numerator) and energy (denominator) using the Real Discount Rate above (3.38%)
5) Contingency: 30% of project capital costs
6) Miscellaneous Owner's Cost: $50 Million (2015) were allocated to additional owner's cost (for First Nations & stakeholder engagement & specific studies, general project development).

[36] As per PDF Page 43 of the Yukon Energy Corporation's 2012/2013 General Rate Application. Source: http://yukonutilitiesboard.yk.ca/pdf/YEC_Revised_Compliance_Filing,_June_20,_2013.pdf

[37] As per Footnote 29 in the Yukon Energy Corporation's 20-Year Resource Plan: 2011-2030

Appendix B: Reservoir Map

Below are the projects reservoir maps at FSL and ADL. The natural river watercourse is shown in light blue, the reservoir area at FSL is show in navy blue and the reservoir area at ADL is shown in yellow. The drawdowns for ROR projects is considered negligible, therefore the ROR projects reservoir is only shown at FSL.

Figure B-1: Detour Canyon Reservoir

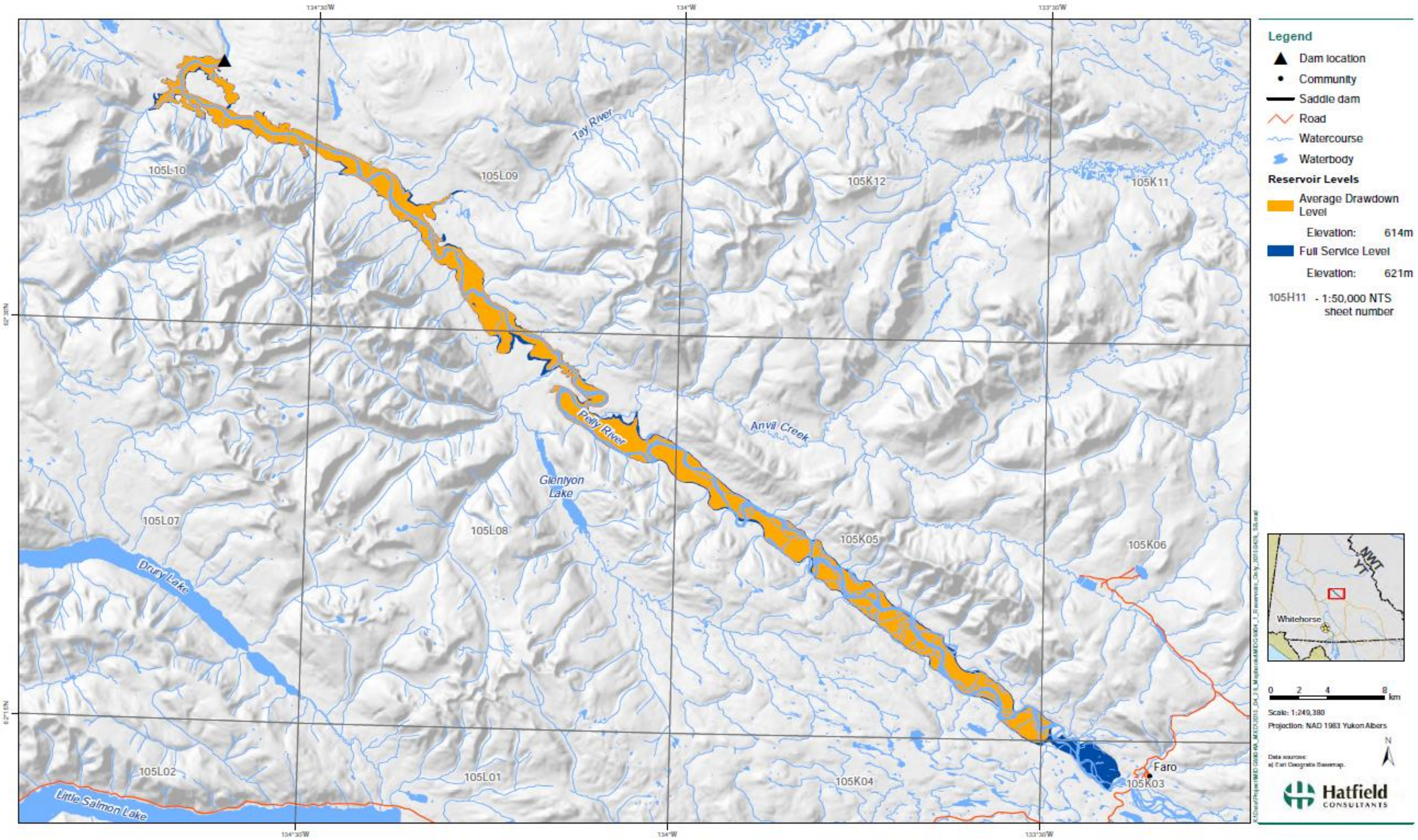


Figure B-2: Fraser Falls Reservoir

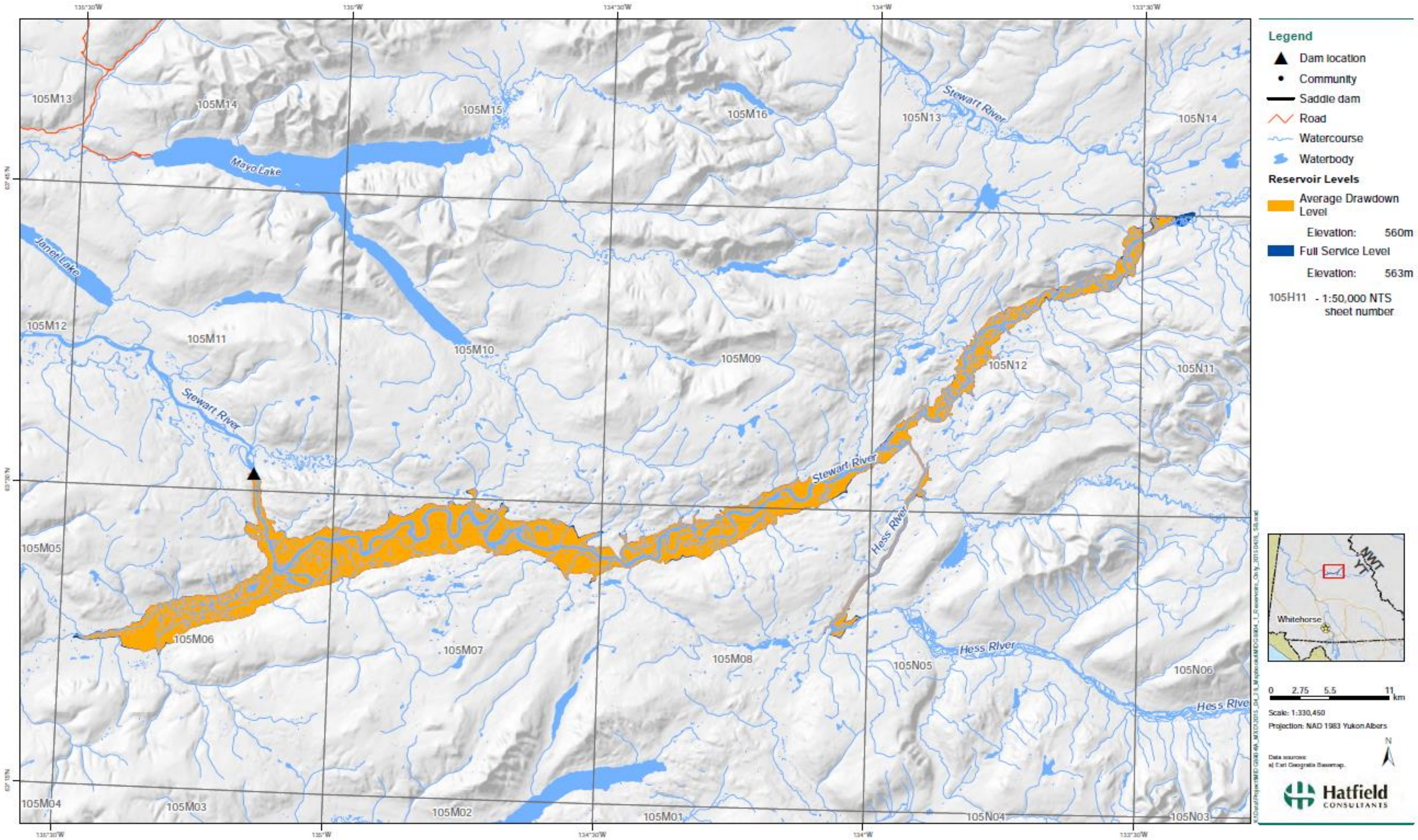


Figure B-3: Granite Canyon Reservoir

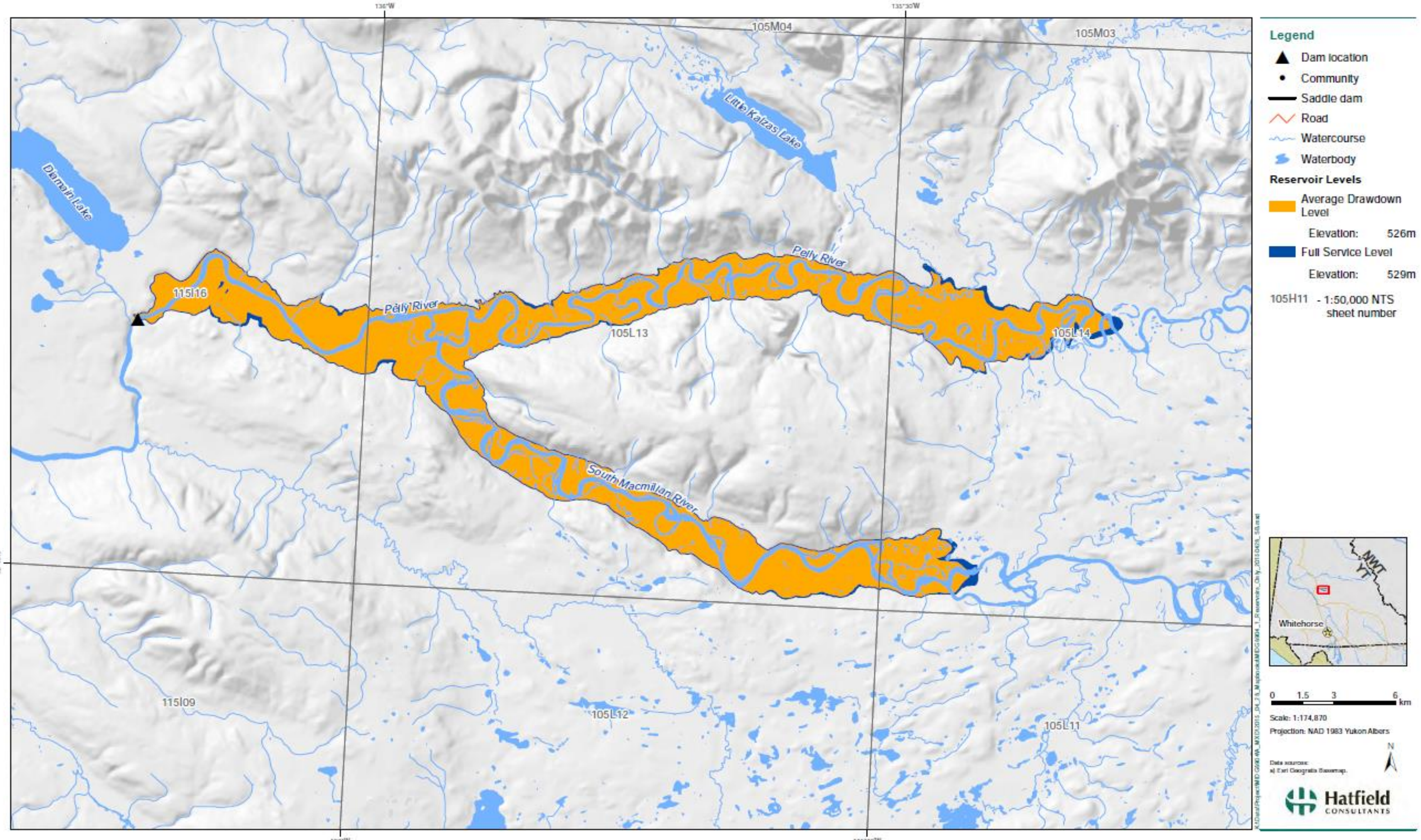


Figure B-4: Two Mile Canyon Reservoir

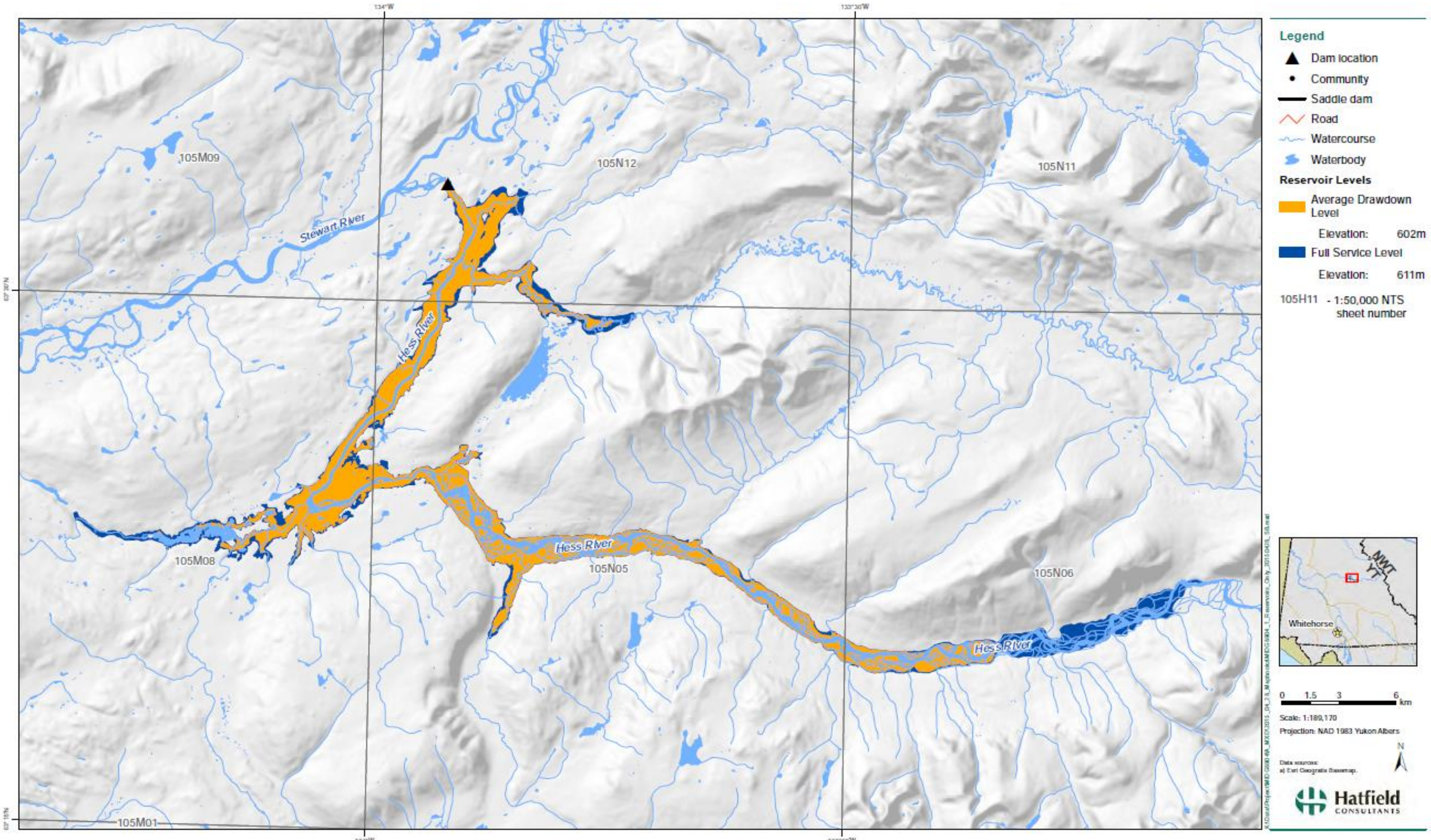


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Figure B-5: False Canyon Reservoir

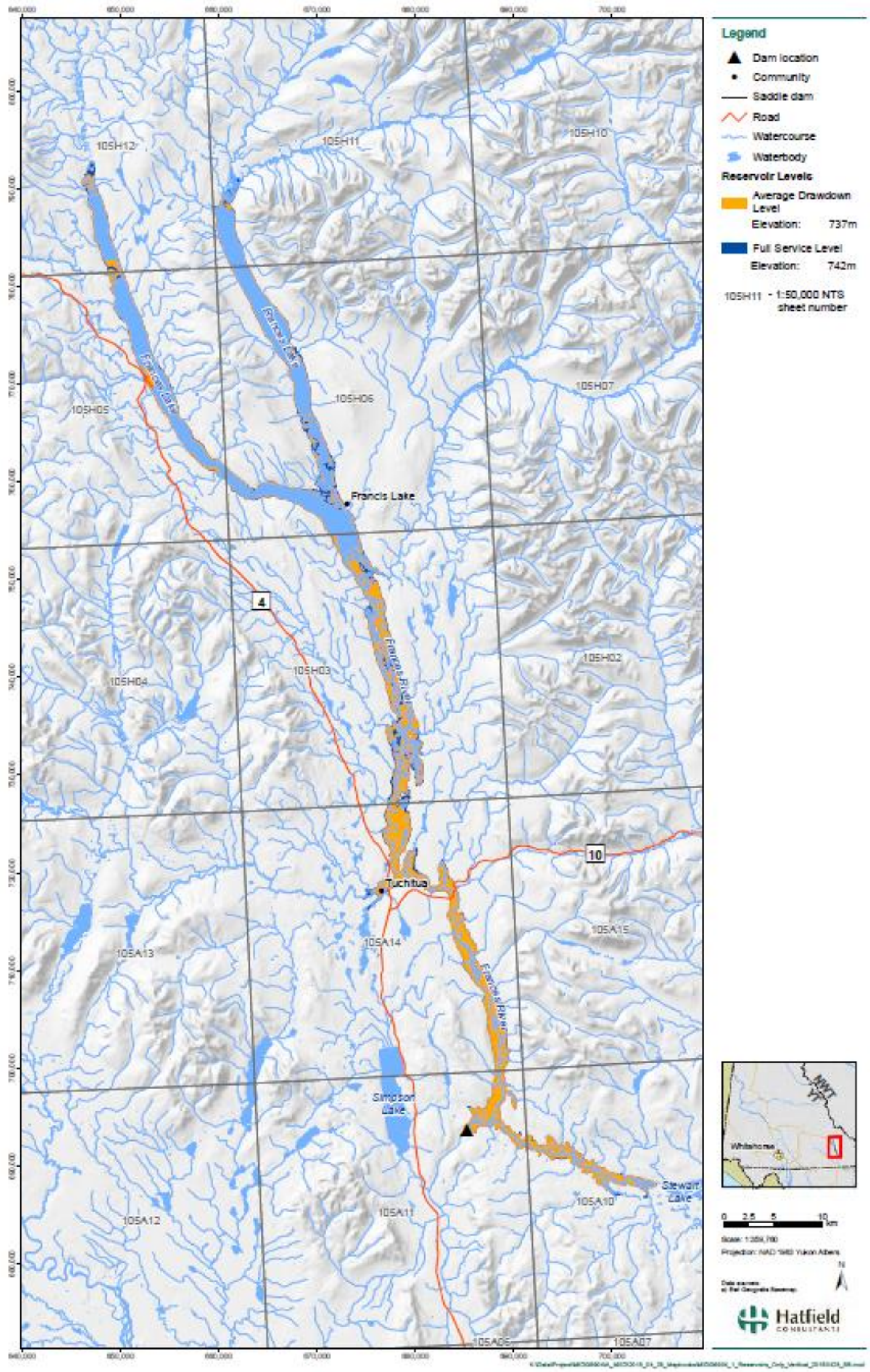


Figure B-6: Middle Canyon Reservoir

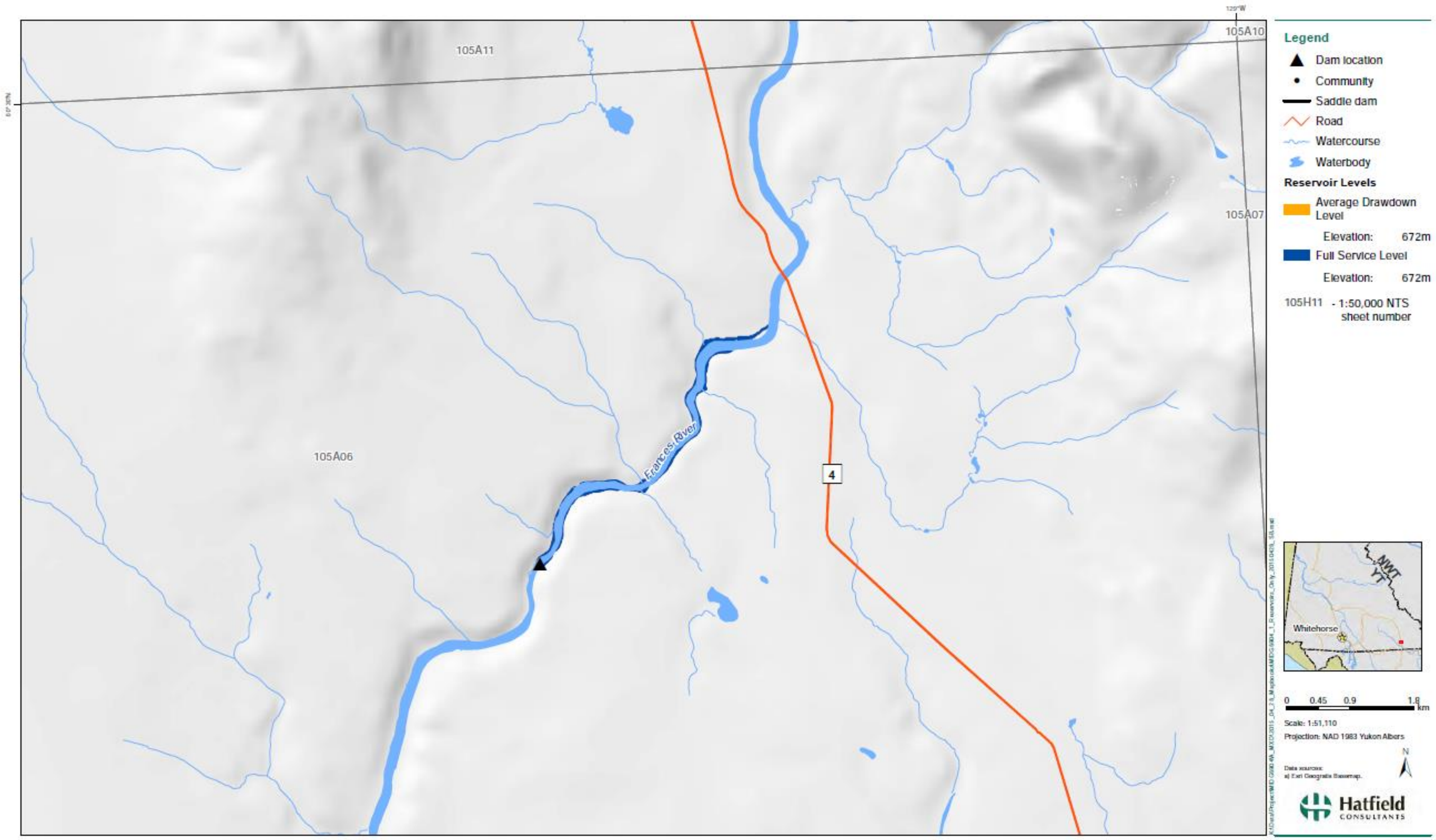


Figure B-7: Slate Rapids Reservoir

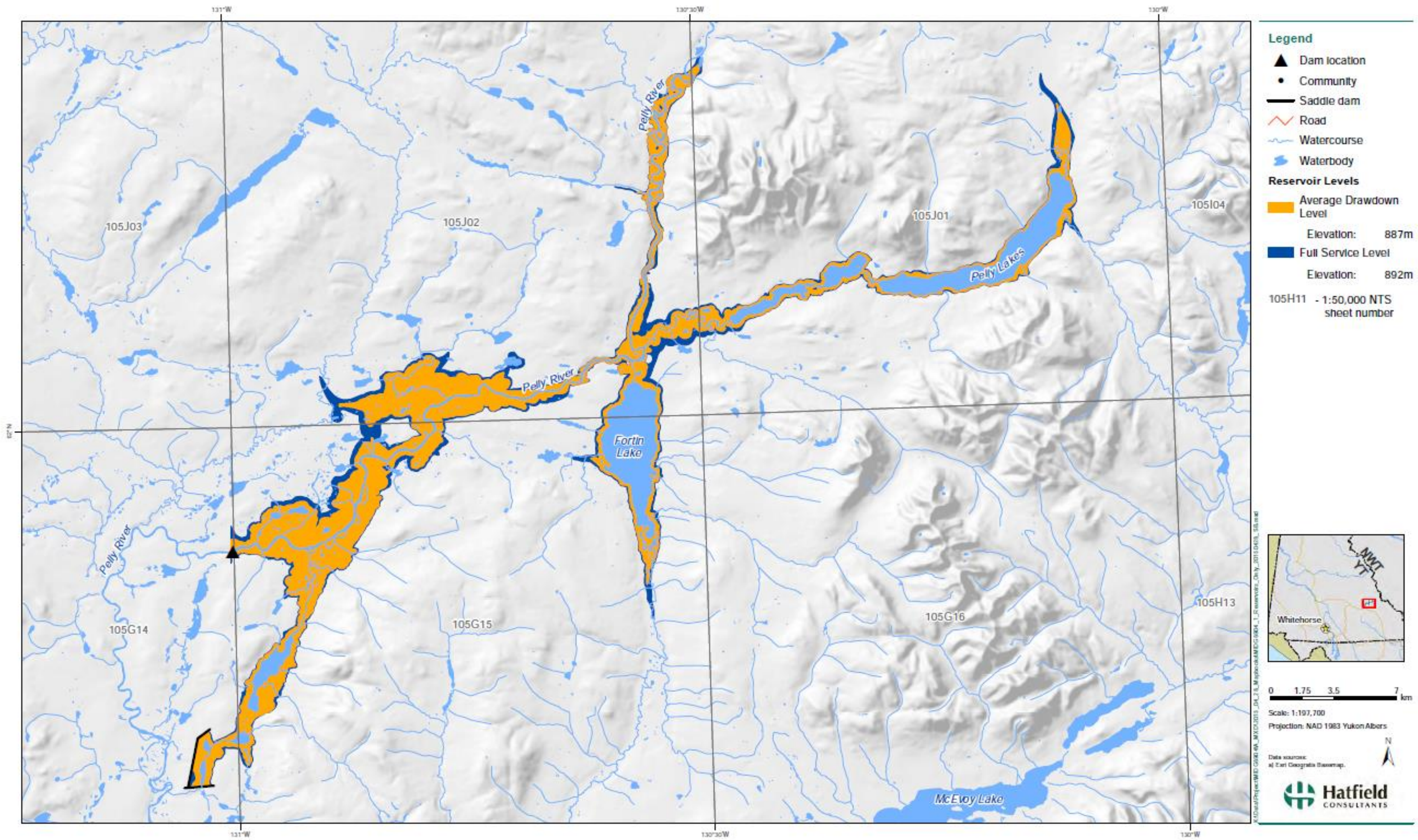
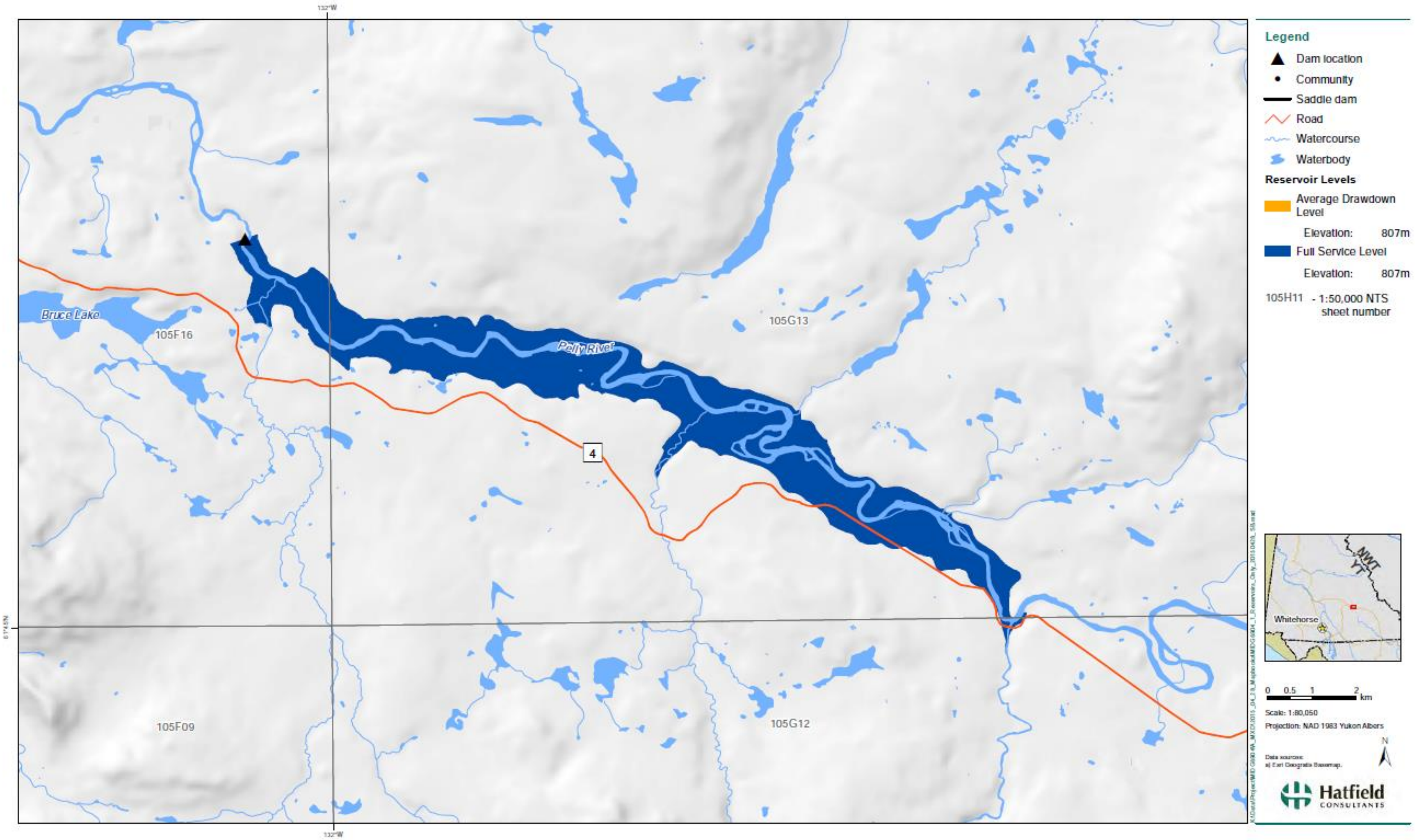


Figure B-8: Hoole Canyon Reservoir



Appendix C: Cost Estimates

The cost estimates for the project cost is the sum of:

1) Dam construction and development
2) Scalability upgrades including direct and indirect costs such as turbine and generator supply, installation, mobilization, demobilization, supervision, commissioning, permits, insurance, miscellaneous metals and water system.
3) Post-2065 upgrades including direct and indirect costs such as turbine and generator, mobilization, demobilization, supervision, commissioning, permits, insurance, miscellaneous metals and water system.
4) Transmission line and access road cost:
    a. Transmission lines are estimated at $946,080/km which includes 11.8% material, 42.7% design & construction, 28.4% brushing & access, 11.4% project & construction management and 5.6% common costs. The transmission line corridor terrain parameters (land cover, surficial geology, slopes etc…) were provided by JDMA as shown in Table C-1. The unit costs were estimated by Midgard based on known projects.
    b. Access roads are estimated at $400,000/km.
5) Miscellaneous owner's cost
6) Contingency at 30%

Not included in the cost estimates are:

1) First Nations land acquisition, participation, and compensation costs
2) Stakeholder land acquisition and compensation costs
3) Existing Yukon transmission system and network upgrade costs
4) Water rental costs

The cost estimate is a Class 5 cost estimate (-50%/+100%).

Table C-1: Transmission Line Corridor Terrain Statistics

ROUTE ALTERNATIVES STATISTICS SUMMARY
PROJECT: Midgard Yukon Hydroelectric Connection
DATE: 08 JULY 2015

	Faro to Watson Lake	Faro to Hoole Canyon	Hoole Canyon to Slate Rapids	Slate Rapids to False Canyon	False Canyon to Middle Canyon	Middle Canyon to Watson Lake	Detour Canyon	Hoole Canyon	Slate Rapids	False Canyon	Middle Canyon	Granite Canyon	Fraser Falls to Mayo	Two Mile Canyon to Fraser Falls
CONSTRUCTION														
Total centreline length (Km)	414.1	94.6	56.8	184.3	20.4	58.0	82.6	1.8	9.2	7.4	6.2	14.6	48.2	64.5
Total corridor area (Ha)	20867	4733	2840	9195	1027	3072	4049	79	454	162	294	734	2420	3212
Total # of deep valley / canyon crossings	5.0	1	2	1	0	1	3	0	1	1	0	0	3	3
Total # of major stream crossings	6.0	2	2	1	0	1	1	0	0	0	0	0	1	1
LAND COVER (Ha)														
Dense coniferous (>60% crown closure)	2618	523	340	743	280	731	247	9	196	40	74	10	53	83
Coniferous - open canopy (26-60% crown closure)	11322	1414	1624	5792	649	1843	1276	56	165	42	210	182	740	811
Coniferous - sparse (10-25% crown closure)	2892	934	605	1306	7	40	461	9	47	0	7	119	552	513
Dense broadleaf (>60% crown closure)	68	66	0	2	0	0	118	0	0	3	0	0	15	14
Broadleaf - open canopy (26-60% crown closure)	21	1	0	20	0	0	3	0	0	0	0	0	0	3
Broadleaf - sparse (10-25% crown closure)	6	0	0	6	0	0	0	0	0	0	0	0	0	0
Mixedwood - open canopy (26-60% crown closure)	238	12	0	118	37	71	139	0	10	26	2	0	16	36
Mixedwood - sparse (10-25% crown closure)	2	2	0	0	0	0	0	0	0	0	0	0	0	0
Riparian zones (15 m around wetlands, streams, waterbodies)	510	99	33	296	23	60	84	1	18	5	7	7	42	90
Open water (from CanVec)	167	85	20	52	3	8	27	1	7	0	0	4	13	64
Treed wetlands	56	0	0	23	7	26	0	0	0	0	0	1	6	0
Shrub wetlands	25	0	0	23	0	2	0	0	0	0	0	0	18	7
Herb wetlands	351	181	19	70	13	69	123	0	0	0	0	28	20	169
SURFICIAL GEOLOGY AND PERMAFROST (Ha)														
Aeolian	440	0	440	0	0	0	0	0	217	0	0	731	0	0
Colluvium	2	0	0	2	0	0	9	0	0	0	0	0	96	4
Fluvial	4791	951	939	1872	578	451	1588	30	141	139	39	3	301	361
Lacustrine	138	8	0	33	96	0	471	0	0	0	0	0	54	421
Moraine	12901	3238	1014	6157	353	2139	1726	26	93	23	254	0	1969	2427
Organic	2547	490	447	1128	0	483	71	23	4	0	0	0	0	0
Exposed bedrock	56	45	0	11	0	0	188	0	0	0	0	0	0	0
Thin layer (veneer <1 m thick) with bedrock as second unit	0	0	0	0	0	0	0	0	0	0	0	0	396	2344
Sporadic discontinuous permafrost	6078	0	0	1980	1026	3072	0	0	0	159	0	0	1	1
Extensive discontinuous permafrost	14789	4733	2840	7215	1	0	4049	79	454	3	294	734	2419	3211
SLOPE (Ha)														
Area of corridor on slopes 0 - 15°	20522.5	4586.9	2839.8	9013.2	1026.4	3056.2	3654.7	77.4	452.3	145.9	285.8	731.4	1966.4	2893.1
Area of corridor on slopes 15 - 30°	342.4	145.3	0.0	180.8	0.7	15.6	393.2	1.1	1.9	15.9	7.8	2.7	452.8	316.8
Area of corridor on slopes over 30°	2.1	0.9	0.0	1.2	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.9	2.2
FIRST NATIONS SETTLEMENT LANDS and SETTLED LAND (Ha)														
Category A	1952.8	0.0	672.8	1274.0	0.0	6.0	286.0	0.0	281.3	0.0	0.0	0.0	0.0	0.0
Category B	2866.7	662.2	112.1	819.3	461.8	811.3	1359.5	0.0	95.5	112.2	6.8	660.7	1663.6	936.9
Uncategorized FN lands	42.1	0.9	0.0	0.0	0.0	41.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fee Simple	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Interim Protected	4819.5	662.2	784.9	2093.3	461.8	817.3	1645.5	0.0	376.8	112.2	6.8	0.0	0.0	0.0
Urban land	1541.4	942.0	0.0	0.0	0.0	599.4	382.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LAND USES (Ha)														
Bridgehead	28.1	9.5	0.9	9.0	0.0	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Environment	4.3	0.0	0.0	0.0	4.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forestry	350.3	1.8	0.0	0.0	3.7	344.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garbage dump	0.0	0.0	0.0	0.0	0.0	12.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gravel Pit	641.5	104.3	108.4	304.5	12.1	112.2	28.0	0.0	0.0	5.1	0.0	0.0	0.0	0.0
Heritage	1.3	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Industrial	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Marine	1.3	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parks, Campground, or Recreational	1202.0	0.8	48.9	1150.1	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	24.7	0.0
Quarry	9.6	0.0	0.0	4.0	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rural residence	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trapping	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Utility	296.3	296.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	118.2	0.4	5.2
ROADS PARALLEL TO AND WITHIN CORRIDOR (Km)														
Paved road	56.3	14.5	0	3.7	0	38.1	0.7	0	0	0	0	0.5	0.6	0
Improved gravel road	314.5	71.7	42.1	168.3	20.1	12.3	0	0	0	0	0	0	0.2	0
Trail or resource road	6.7	2.9	0.1	0.6	0.4	2.7	0.5	0	0	0	0	0	1.5	0