Viability Analysis of Southeast Alaska and Yukon Economic Development Corridor

Skagway, Alaska to Whitehorse, Yukon

Presented to:

Department of Energy, Mines and Resources
Yukon Government

Alaska Energy Authority
State of Alaska

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InterGroup CONSULTANTS

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EXECUTIVE SUMMARY

The Southeast Alaska and Yukon Economic Development Corridor has existed primarily as a transportation corridor between the two regions for over a century: initially as a First Nations' trade route; then as a railway; and most recently as a public highway, providing access from the coast to the Yukon interior. It was determined at the outset of the current study that the particular focus would be the incorporation of a proposed electrical transmission interconnection and telecommunication link to this economic development corridor. This electrical transmission interconnection is referred to as the "Project" in the current study. The telecommunication link has been assessed previously as a fibre optic link study prepared for Yukon Government (Planetworks, 2014). The scope of the telecommunication assessment in the current study was to determine if synergies existed with respect to the co-development of the transmission line and fibre optic link

The objective of the viability analysis for the Project is to assess:

1. Under what conditions does an electrical interconnection make sense?
2. If such conditions exist, does an interconnection of the systems make sense in the near future?

There is a wide array of options both in terms of energy supply and demand that could be considered in the viability analysis of the transmission interconnection. A set of "Development Scenarios" were prepared in order to conduct a defensible and reasonable assessment of the transmission interconnection in the foreseeable future. These Development Scenarios were developed jointly at the outset of the study by the project team members consisting of:

- Alaska and Yukon government representatives,
- Representatives of the three electrical utilities (Alaska Power & Telephone, ATCO Electric Yukon and Yukon Energy Corporation), and
- The technical consulting team.

The two Development Scenarios used in the viability analysis are:

Scenario 1: Development of a transmission line to supply hydropower from the proposed West Creek hydroelectric site near Dyea, Alaska in winter months.

Scenario 2: Development of a transmission line (independent of West Creek hydro) to supply Yukon hydroelectric surplus to Skagway cruise ship loads in summer months.

Based on the Development Scenarios prepared for this study, it is concluded that:

Technical Feasibility

1. Construction and operation of a transmission line over the rugged White Pass is technically feasible using existing and proven transmission line designs from Yukon and Alaska.
2. Capital cost for a new transmission line, without a fibre optic underbuild, is estimated at between $109 million and $123 million [CAD, 2014$] ($94 to $106 million US$2014[1]) depending on the alignment selected.

[1] Based on US-CAN dollar conversion at $1 US=$1.16 CAD as of January 2, 2015.

3. Combining the fibre optic link with the transmission project is more costly than burying the fibre optic cable separately from the transmission line. As there appears to be no economic benefit to combining the projects, this indicates that both projects can proceed independently of each other without raising concerns about missed opportunities.

West Creek Hydro

1. A high-level review of the West Creek hydroelectric site was conducted and it appears to be a reasonably attractive hydropower site. It was studied extensively in the early 1980's but has received little further study until recently by the Municipality of Skagway. There are multiple configurations that could be developed for the site resulting in a range of project costs and capacities. The current review of the site was carried out a component of the Development Scenarios to better understand the availability of public power from the West Creek site.
2. There has been no contemporary feasibility-level assessment of the capital cost for West Creek hydro development. For the purposes of the current study, the 1983 cost estimate for a 20MW project was inflated to 2014 dollars using the US Consumer Price Index (a sensitivity analysis was also conducted using the US GDP deflator as an alternative).

Financial Feasibility

1. Supply of cruise ship port electrification power, or "shore-side power," is fundamental to the viability of a southeast Alaska-Yukon electrical transmission interconnection under all reasonably foreseeable development scenarios. It is estimated that the cruise ships could consume up to 30 GWh/yr (during May to September) if all cruise ships utilized shore-side power. Loads of less than 30 GWh/yr would likely require external financial support.
2. Development of the transmission interconnection is financially viable in the near-future, without external financial support (subsidy) under Scenario 2. This is based on supply of the cruise ships with 30 GWh/yr of electricity during summer months primarily from surplus Yukon hydroelectricity.

Economic, Social and Environmental Benefits

There are substantive local economic development, social and environmental benefits from a transmission interconnection project beyond that which was monetized in this current study. Some of the key additional benefits include:

1. This study identifies that there is a reasonable, currently available and potentially financially viable energy supply option with the transmission line Project for the electrification of the Skagway cruise ship port.
2. Development of the transmission line could facilitate the development of additional hydropower projects in the region. There are at least 280 GWh/yr of known hydropower schemes (including West Creek) in the region that could utilize the transmission line. For some projects, such as Moon Lake hydro in northern BC, pre-development of the transmission line could reduce the previously estimated levelized cost of energy for the project by up to 25%.
3. Significant greenhouse gas emission reductions could be realized by the development of the electrical interconnection. These reductions could be on the order of 44,500 and 21,400 tonnes of CO_2e / year for Scenario 1 and 2 respectively.

It is recommended that:

1. Continued work on the assessment and development of the electrical transmission interconnection component of the Southeast Alaska and Yukon Economic Development Corridor is pursued. Given the international benefits of this project and multi-jurisdictional considerations, leadership from the Yukon and Alaska governments is warranted to advance the Project. This should include confirmation of the parties needed to move the project forward (Municipality of Skagway, utilities and possibly other private or new entities) and funding sources for the next steps to confirm feasibility. A reasonable goal could be the establishment of an MOU between the parties to confirm the items above, within the 2015 fiscal year.

2. A business case for the electrification of the Skagway cruise ship port be prepared to confirm the business case for the transmission project under Scenario 2. This business case should include, but not be limited to:
    a) Engineering and costs estimates for shore-side power infrastructure;
    b) Arrangements as needed for adequate cruise ship purchase power volumes and rates to supply shore power by 2020 and for a reasonable period thereafter.

3. Other financial feasibility conditions for the Project (assuming Scenario 2) be confirmed, including:
    a) Arrangements as needed to define basic provisions for securing Yukon Energy surplus summer hydro and backup fossil-fuel (in particular LNG) based generation. The future capacity of such generation to supply the potential cruise ship loads (taking into account capacity related requirements for multiple concurrent cruise ship loads) needs to be determined; and
    b) Arrangements as needed to define basic provisions for the Project regarding ownership, financing, basis for rate charges for interconnection use (and how these may change as conditions change), and extent if any of external (government) funding to support.

4. Permitting and development requirements and timelines for the Project be confirmed for preparation of the required assessment and regulatory submissions. This would also require the preparation of engineering designs and feasibility-level cost estimates for the Project to support such submissions.

5. Future engineering work should also include further assessment of additional equipment required for the relatively low-capacity and exposed transmission system. This is to ensure the system reliability is acceptable, economies are realized, and operational coordination is achieved.

6. Future work on the transmission line assessment should include potential synergies with other power development opportunities (ie. Moon Lake) and system benefits such as grid redundancy and/or reinforcement in the Southern Lakes region. Future assessment should also consider a phased approach to development of the transmission line.

7. A contemporary feasibility-level cost estimate be prepared for West Creek hydro in order to re-evaluate the assumptions utilized in this current analysis.

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1 INTRODUCTION

1.1 PROJECT RATIONALE

The Southeast Alaska and Yukon Economic Development Corridor concept has been developed through collaboration between the State of Alaska and the Government of Yukon. The purpose of this Study is to explore the economic and technical feasibility of linking the respective power grids and to provide improvements in the telecommunications systems. The focus of this Study is to examine feasibility of a transmission connection, and to identify the most viable scenario that represents the greatest net benefit to both governments (with "net benefit" representing net positive impact after consideration of incremental benefits less incremental costs.) See Figure 1 for an overview of the study extents.

1.2 BACKGROUND AND SETTING

Common to both Alaska and Yukon is a desire to develop renewable energy sources and reduce reliance on (and costs) generating with fossil fuels such as diesel and natural gas. Presently, electricity is provided to communities in the upper Lynn Canal region, including Skagway, from both hydro and diesel generation sources. The demand for electricity in Skagway is highest during the summer when tourism peaks and thousands of cruise ship passengers visit the area. While docked in Skagway, the ships generate their own power, primarily using diesel, as there is no shore-side electricity available. The cruise ships were found to be the largest contributor to local air pollution in a study published in 2010, and investigations are now underway to see what hydroelectric opportunities are available to supply this need.

The potential West Creek hydro project is located at Dyea, near Skagway Alaska. A hydro project at this site could be capable of supplying the needs of both Skagway and Haines, including the cruise ship industry during the summer.

In Yukon, existing hydro generation is incapable of supplying all of the winter energy demand and fossil fuel generation is relied upon to provide additional energy when it is required. Although demand for electricity is predicted to grow in Yukon, currently there is some surplus hydro capacity during the summer. Furthermore, the Yukon Government is studying the long-term development of additional hydropower resources in its Next Generation Hydro initiative. Should new hydroelectric generating facilities be developed as a result of this initiative, then summer surplus hydropower would continue to persist. The opportunity exists, therefore, to match the seasonal supply of energy (from West Creek and Whitehorse) to future electrical demand in both Yukon and Southeast Alaska (specifically Skagway and the upper Lynn Canal area).

1.3 REPORT ORGANIZATION

This report describes the technical feasibility of the transmission intertie project, and includes a high-level review of the power potential of West Creek hydro. In addition, the report includes a summary of the two "development scenarios" (the Scenarios) that were identified during a multi-stakeholder workshop in June 2014. These scenarios set out the specific combinations of demand forecast and supply options that are considered in evaluation of the economic feasibility of the transmission intertie, and represent the basis for the preliminary cost estimates used in the technical analysis. This report concludes with the financial feasibility analysis of the transmission interconnection and also provides a high-level overview of associated economic, social and environmental benefits and impacts

Figure 1: Study Overview Map

2 DEVELOPMENT SCENARIOS

The Development Scenarios were the primary topic of discussion at a workshop held on June 18th, 2014. At that time the Development Scenarios, as described below, were discussed in the context of a number of initial assumptions and considerations about route options, design criteria for the transmission line, generation capability of West Creek hydro, and so forth. The technical work that has now been completed and is discussed in Sections 3 and 4 of this report, has either confirmed, or in some instances modified the earlier assumptions that were made in the following Development Scenarios.

2.1 WORKSHOP SUMMARY

The workshop focused on identifying development scenarios for the Southeast Alaska and Yukon Economic Development Corridor Study (the "Study"). These scenarios are ones that could potentially provide long term benefits to both Yukon and Alaska in terms of seasonal supply of renewable energy. Other benefits could include improved telecommunication reliability and capability. The workshop was held in Whitehorse, Yukon and included representatives from both Alaska and Yukon:

Yukon Government
- Ryan Hennessy, Energy Branch
- Shane Andre, Energy Branch

Alaska
- Robert Venables, Southeast Conference
- Gene Therriault (by phone), Alaska Energy Authority

Electrical Utilities
- Jason Custer, Alaska Power & Telephone
- Darren Belisle, Alaska Power & Telephone
- Lawrence Joudry, Yukon Energy Corporation
- Yesh Sharma, ATCO Electric Yukon

Consulting Team
- Forest Pearson, Morrison Hershfield
- Kathleen Wood, Morrison Hershfield
- Greg McNeil, Morrison Hershfield
- Cam Osler, InterGroup
- Mona Pollitt-Smith, InterGroup
- Greg Huffman, Dryden & LaRue

Materials were prepared to facilitate discussion at the workshop and were distributed to workshop participants; these materials are found in Appendix B, including:

- Workshop Background Papers
  - Background Paper #1 – Long Term Fossil Fuel Generation Requirement Scenarios
  - Background Paper #2 – Supply Options
  - Background Paper #3 – Initial Transmission Corridor Cost Estimate
  - Background Paper #4 – Alaska-Yukon Fibre Optic Corridor Link
- Preliminary Development Scenarios [as reviewed at June 18 workshop]
  - Summary description
  - Detailed description
- Other Workshop Materials
  - Assessment of Simulated West Creek Generation
  - Map of Southeast Alaska and Yukon Economic Development Corridor

In order to assess the viability of a transmission interconnection between Whitehorse and Skagway/SE Alaska, the Study must consider specific conditions (loads, system reliability, other potential uses of the corridor such as telecommunications link) that would be required to make development of an electrical interconnection work.

2.2 PRELIMINARY TECHNICAL CONSIDERATIONS

The transmission line would be designed to transmit approximately 25 MW of electricity from Alaska to Yukon (and vice versa) with a 138 kV line voltage. Previous work considered a 69 kV line; however, this lower voltage line is unlikely to provide any material capital cost savings relative to 138 kV. Furthermore, a 69 kV line would limit capability and the ability to integrate with the Yukon's existing 138 kV transmission grid.

A 138 kV line would facilitate system stability which is of critical importance when moving small loads over long distances between two relatively small electrical systems. Whether an AC or DC[2] transmission connection should be considered was discussed. It was suggested that a DC link might enhance stability (it would be operated as an isolated section of the transmission system) and avoid inter-jurisdictional regulatory requirements that otherwise must consider the effects of a system connection on system stability. A DC transmission connection, however, would incur greater initial costs compared to the AC option and could also preclude connections to other projects (generation IPPs or loads/customers) along the length of the DC line. It was noted that there is a need (separate from this study) to clarify the regulatory implications of an AC connection in Yukon and Alaska. This may include gathering more information regarding the federal regulatory and legal implications pertaining to export of electricity from both Canada and the United States.

[2] AC refers to alternating current and is currently used in the transmission grid; DC refers to direct current

ATCO Electric Yukon is one of the Yukon's two electrical utilities. ATCO has an existing 34.5 kV line extending from Carcross to Whitehorse which was considered but this concept was rejected for the following reasons:

- The existing 34.5kV line does not have the capacity to transmit 25 MW of power. The current line has the capacity to transmit on the order of 17 MW and the existing load in Carcross is about 4 MW.
- Transforming the voltage from 138 kV to 34.5 kV at Carcross would require an additional substation (estimated at approximate cost of $8-10 million).
- A 138 kV line voltage can be accommodated at the Riverside substation in Whitehorse without adding significant new equipment and transformer(s); this would save $8-10 million in substation upgrading costs.

The key technical considerations relating to the Project that were discussed at the workshop included:

- Using the existing Riverside substation (in Riverdale) as the terminus for the new 138 kV line would avoid the need for a new substation in Whitehorse.
- Several possible locations for a new substation in Skagway exist; none of the existing substations would accommodate a new 138 kV line without significant upgrade.
- The voltage of a new transmission line would need to be 138 kV to transmit a load of 20-25 MW.
- Line would be mostly constructed of wood poles, with steel structures used in more challenging terrain and through avalanche zones.

Preliminary considerations concerning route options for the transmission line included:

- Routes for a line between Skagway and Whitehorse were previously studied and identified a preferred route along the Klondike Highway. Due to poor road access and concern about visual impact to railway tourism a route following the White Pass railway ROW is considered less desirable. An old pipeline alignment occupies the railway ROW for the majority of its length and therefore the railway and pipeline ROW can be considered as a single ROW for the purposes of this study.
- Three route options to be considered between Carcross and Whitehorse:
    a) a new ROW following the Klondike Highway
    b) Use of the existing ATCO Electric ROW (re-building on the existing 34.5kV line);
    c) a new ROW following the White Pass and Yukon Railway.

2.2.1 Tagish Road/Jakes Corner Alignment

A fourth option was also discussed that would continue east from Carcross along the Tagish Road as far as Jakes Corner and then north to Whitehorse adjacent to the Alaska Highway. Workshop participants confirmed that this option should be noted, but given the longer distance (and therefore higher costs), it would not be assessed at this time. The Carcross-Jakes-Whitehorse option is longer at 122 km from Carcross to Whitehorse versus 70 km for the Carcross valley routes. Thus it is reasonable to assume that the Jakes Corner option will be proportionally more costly (75% more) for the Carcross to Whitehorse segment. It is an option for future consideration in the context of improved system reliability and other potential hydro/transmission developments in the southern lakes region, such as the Atlin Hydro Expansion (Pine Creek Hydro). Future studies of this project should re-assess synergistic opportunities considering a Jakes Corner alignment.

2.3 Other Economic Opportunities in the Whitehorse-Skagway Corridor

This Study also considers potential synergies between development of the transmission line and a new fibre optic link between Whitehorse and Skagway. The following was noted:

- If the timing of the two projects were coordinated, significant cost savings related to stringing the fibre optic line along the transmission line might be realized (as compared to burying the fibre optic cable in its own designated easement).
- If the timing of the two projects could not be coordinated (and the fibre optic link proceeded independently and ahead of the transmission line) there are still potential positive synergies related to securing concurrent easements and rights of way for both projects.

The workshop broadly discussed the economic development corridor between Southeast Alaska and Whitehorse and examined other economic development opportunities besides the transmission and fibre optic link. It was noted that highway and rail elements of this corridor have existed for over a century, providing year-round transportation linkages between Whitehorse and Southeast Alaska (and at one time an oil pipeline also paralleled the railway right-of-way). The workshop participants concluded that at this time, there are no tangible specific market opportunities to be assessed such as a new pipeline connection or any other elements beyond the transmission line and fibre optic cable. In addition, it was acknowledge that there are other hydropower opportunities in the region. However there are no projects that have been proposed at this time and therefore they are not included in the scope of this analysis. It was noted that the viability assessment report should include a high-level discussion around the scope (and what was not included) of this “economic development corridor”. This general discussion of other economic opportunities, including nearby potential hydropower sites, is provided in section 7.1 of this report.

2.4 Two Development Scenarios

The following two development scenarios represent the findings of the Workshop. These scenarios form the basis for the viability assessment. Note that these scenarios represent the development of a complete interconnection Project to assess overall project viability. Should it be decided to pursue the Project further, it is possible to consider the Project being developed with a phased approach.

Scenario 1 – Development of transmission line with West Creek hydro generation

This scenario is focused on development of the transmission corridor that would supply power to Whitehorse from the proposed West Creek hydro project near Skagway, displacing growing thermal generation (diesel & LNG) on the Yukon grid in the winter. In other words, there needs to be an electrical demand in the Yukon for additional renewable energy.

Scenario 1 - Development with West Creek Hydro Generation

Whitehorse, Yukon	**Skagway, Alaska**
← About 54 GW.h/yr from Alaska to Yukon	
Need sufficient fossil fuel displacement opportunity New loads needed on grid of 25-50 GW.h/yr to proceed within next decade	Confirm West Creek Hydro volumes, timing and costs About 134 GWh/yr generation, less 80 GW.h/yr June to Nov (not needed in Yukon)
Financial & Economics viability issues (beyond timing): Expected cost savings from fossil fuel displacement Competitive renewable cost options (e.g., other hydro sites) Supply security & charges for delivered West Creek hydro	Financial & Economics viability issues (beyond timing): Net power charges to cruise ships & sustainability of loads Overall capital costs for new hydro & transmission Financing, ownership and cost recovery arrangements

In summary, Scenario 1 originally assumed the following:

- Potential generation from West Creek hydro estimated at 134 GWh/year
- Potential summer Cruise Ship Load estimated at up to 30 GWh/Year in Skagway
- Potential power from West Creek hydro would meet Yukon's projected winter load requirements of 54 GWh/Year (see Appendix B for details).

Scenario 2 – Development of transmission line with Yukon summer hydro surplus supplying Skagway cruise ship loads

This development scenario is focused on development of the transmission corridor well in advance of any new hydropower projects in the upper Lynn Canal area (such as West Creek) being developed. The transmission corridor would be developed to transmit surplus summer power from Whitehorse to Skagway to displace cruise ship diesel generation loads as soon as shore-power is available in Skagway and Haines. There are no other proposed near-term potential industrial loads in the vicinity of the transmission line corridor.

Scenario 2 - Development with YEC Summer Hydro Surplus & Skagway Cruise Ship Loads

Whitehorse, Yukon	**Skagway, Alaska**
About 30 GW.h/yr from Yukon to Alaska →	
Surplus Hydro (early June through September) Assume up to about 34-38 GW.h surplus summer hydro with current generation & loads - need LNG backup	Energy for Cruise Ships (early May through September) About from 30 GW.h per season with peak load 6.5 to 32.5 MW in different weeks over the period
Financial & Economics viability issues (beyond timing): Charges for hydro power supplies Charges for LNG back up generation Factors that reduce hydro surplus Upper limit on viable transmission charges	Financial & Economics viability issues (beyond timing): Diesel cost saved by ships Shore power connection costs Factors that limit cruise ship diesel displacement volumes Competitive cost option (LNG generation at Skagway)

In summary:

- Potential surplus generation of 34 to 38 GWh/year is available in Yukon from early June to end of September.[3.] It is assumed that AP&T's hydro facilities do not have significant summer surplus as they report diesel electric generation on the Upper Lynn Canal system during all summer months.
- Concerns were noted that surplus hydro capacity (MW) is only between 4 to 15 MW, yet cruise ship capacity requirements are 25 MW or more. YEC LNG generation could be considered as backup supply, subject to pricing arrangements.

[3] Yukon load forecasts indicate that by 2018, summer surplus hydro (without new mine loads) ranges from 34 to 38 GWh, with average weekly surplus ranging from 4 to 15 MW over the summer period. Any new mining loads would reduce this summer surplus.

3 TECHNICAL FEASIBILITY OF TRANSMISSION INTERCONNECTION

3.1 SYSTEM INTERCONNECTION STUDY

One of the key components of this technical review was to assess the technical feasibility of the proposed interconnection between the electrical system in the Skagway – Haines area and the electrical system in the Yukon. In November 2014, a study was undertaken by Mr. S. Boutillier (consultant to Yukon Energy Corporation) to examine the technical implications of connecting the Yukon and Skagway electrical grids and the associated electrical requirements if the project proceeds (see Appendix C). This study was reviewed by Dryden & LaRue's partner Electric Power Systems and confirmed that the study findings are reasonable for a feasibility study. The results of this review are provided in this section of the report.

The proposed interconnection is based on expected economic benefits due to energy transfers between the two systems, and based on expected improvements in reliability of the two systems. The interconnection will also facilitate supplying shore power at Skagway when cruise ships are present, combined with the construction of the West Creek hydro facility.

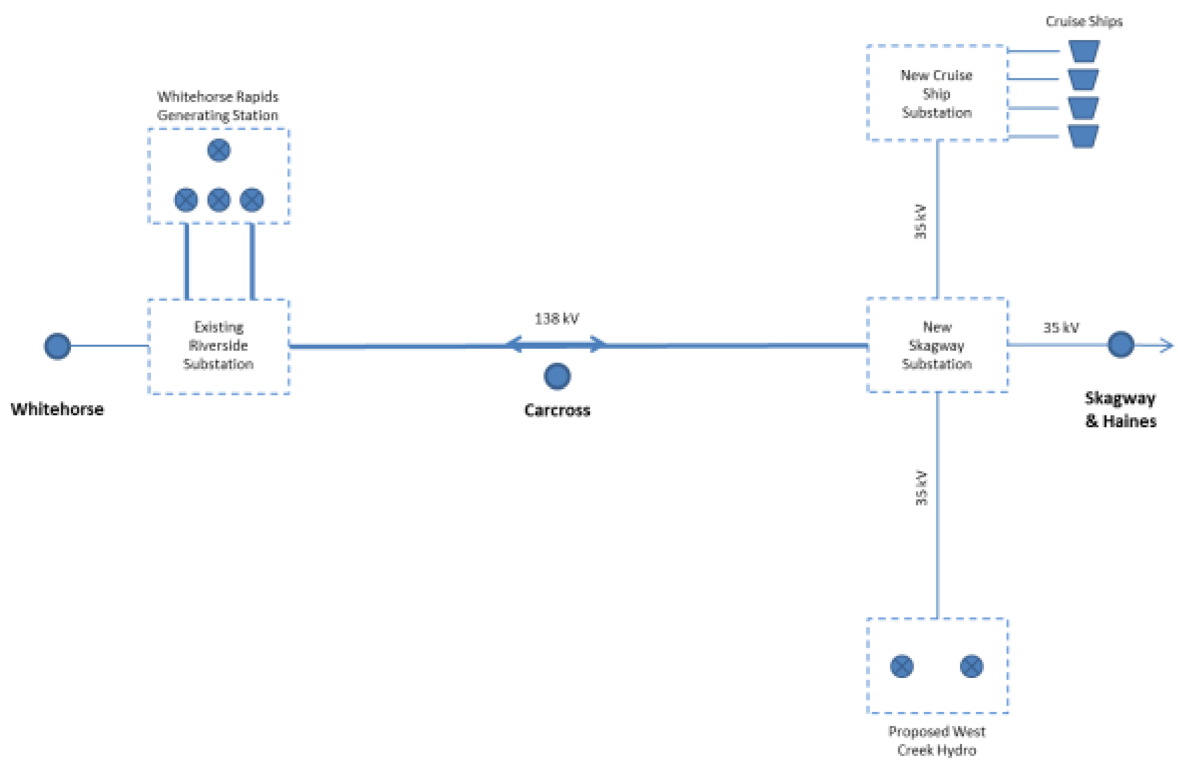

Figure 2: Simplified schematic of the proposed transmission interconnection.

The intent of the study was to identify the technical feasibility of the interconnection of the two electrical systems. Specifically, the study assessed the normal and emergency operation of the interconnected system. Whenever the conditions (normal or emergency) within the two systems was unacceptable, the study tried to identify any additional equipment or modifications to existing equipment, that would be necessary to make the interconnected system work properly. In essence the study purpose was to identify any critical flaws that would impact the overall economic viability of the proposed interconnection and recommend any changes or adjustments that should be considered to facilitate the successful development of the project. The assessment confirmed that the interconnection would be capable of transferring up to 25MW of power in both directions with suitable facilities included in the development.

The technical study was focused on voltage and frequency response of the system while interconnected and during separation events (ie. if one part of the system experiences an outage, what is the effect on the other parts of the system?) Voltage and frequency are the two dominant characteristics of an electrical system that directly indicate reliability and robustness of the system. When the voltage or frequency deviates from normal, system controls attempt to restore the voltage and/or frequency back within acceptable limits, via automatic controls. The study investigated the voltage and frequency for the expected range of different system conditions, including light and heavy load conditions, summer and winter conditions, and energy transfer conditions in both directions along the proposed interconnection.

The study identified the need for additional equipment to control voltage, including under-load tap changing transformers, reactive compensation along the proposed line, and possible tuning of generator excitation systems.

The study also identified some issues associated with the frequency response of the system during emergency or contingency conditions. These items included tuning of the under-frequency based load shedding (UFLS) relays and tuning of generator controls (governors). The study also assessed the ability of the interconnected system to accept a transfer of power from the grid to the cruise ships in a controlled manner.

Electric Power Systems' review of the study confirmed that the approach used throughout the study was appropriate. The issues of voltage and frequency control are appropriate and are in line with typical expectations for isolated electrical systems of this size. With respect to voltage control, the use of reactive compensation is as expected and is reasonable. For the purposes of substation costing, cost allowance for a static VAR compensator (SVC) has been included to address the voltage control issue—see section 5.1.4.6 for further discussion.

With respect to frequency control, the load shedding design should be re-evaluated based on the interconnection and coordination for joined operations. The use of generator tripping and/or braking resistors during over-frequency conditions is reasonable and appears to be commonplace within the Yukon system. However, generator tripping is not as common within the Alaskan system, including the systems in Southeast Alaska. The use of braking resistors should be evaluated in detail during a follow-up system impact study for the proposed facilities. As an alternative to the braking resistor used in this study, the design of the West Creek hydro facility should investigate over frequency control measures in its design.

The load ramping assessment that looked at transferring cruise ship loads off ship generators and on to the grid, seems reasonable. Experience throughout Alaska indicates that the ramp rates evaluated in the study can be easily met under controlled conditions and may be easily increased.

In general, the conclusions of the system interconnection study are reasonable for a feasibility study. As mentioned in the report, additional items will need further study as the design of the facilities proceeds. Given the low capacity of the system, the significant transmission exposure and the lack of redundancy on the system, several aspects of the design of the transmission interconnection require particular attention as the project proceeds. Testing of some of the existing equipment is also necessary to refine the simulation models. This is required so that more precise evaluations can be made for the interconnection and for any additional equipment necessary to support the interconnection. The objective will be to ensure that the system reliability is acceptable, economies are realized and operational coordination is achieved.

3.2 TECHNICAL CONSIDERATIONS FOR TRANSMISSION ROUTE

The purpose of the route identification is to determine at least one technically feasible route for a transmission line between Skagway Alaska and Whitehorse Yukon. Route selection for the transmission line was based upon examination of a variety of mapping sources available for the area, including:

- National Topographic Database 1:50,000 map series (Yukon)
- Terrain Resource Information Management (TRIM) 1:20,000 topographic base maps (BC)
- US Geological Survey 1:25,000 topographical mapping (from National Geographic, 2010)
- Alaska land tenure data from State of Alaska Department of National Resources Alaska Mapper
- GeoEye 50cm multispectral satellite imagery for southern lakes region Yukon (provided by Geomatics Yukon). Image dates June 24 2009, July 8 2009, September 14 2009, June 21 2010, July 30 2010.
- Canada Lands Digital Cadastral Data for Yukon (from Canada Lands Survey NRCAN)
- Yukon land tenure datasets (license and land notations), Geomatics Yukon
- BC Land Tenure from DataBC including: TANTALIS Crown Tenures, Crown Land Rights-of-way, Surveyed Parcels and Surveyed Right-of-way Parcels.
- ATCO Electric Yukon electrical distribution system drawing for Southern Lakes (provided by ATCO Electric Yukon)
- Klondike Highway Avalanche Atlas (prepared for Yukon Department of Community and Transportation Services 1986) and Klondike Highway Avalanche Control Study (prepared for State of Alaska 1987)

In addition to the above, field observation of the route along the South Klondike highway route was completed on June 17th, 2014. Discussions were also held with the current manager of the avalanche control program on the south Klondike Highway[4] to confirm areas of avalanche terrain as identified in the 1986 Avalanche Atlas.

The identification of a feasible route considered the following technical elements:

- Proximity to existing linear corridors (i.e. transmission lines, highways, railway, pipeline easements)
- Risk posed by avalanches (through the Alaska, White Pass and Tutshi Lake portions of the corridor)
- Terrain (steepness, bedrock, water bodies, constructability)
- Access for construction and maintenance
- Land tenure (or land status)
- Viewscapes

Based on the information obtained, conceptual route option(s) were identified and mapped as shown on the route map series found in Appendix A. These options should be considered as preliminary routes, as the identification of a preferred route will require in-depth analysis of the terrain, land tenure and discussions with utilities, landowners, municipalities and other primary stakeholders along the route. These route options formed the basis for a preliminary cost estimate for a transmission line and the context and assumptions that were used in the technical and economic feasibility analysis of the corridor concept.

The route options are described in Section 3.5. In broad terms, there is one route option between Skagway and the US/Canada border that parallels the Klondike Highway. From the border to Carcross, there is generally one route option, again following along the highway. A short segment of alternative route through the Canadian portion of the White Pass area has been identified that would be less visible from the highway and could be considered in this scenic area. From Carcross to Whitehorse, three route options are identified, two of which would require new rights-of-way, and a third option that would utilize the existing ATCO Electric right-of-way.

Note that given the international nature of this project, international units of measure have been used throughout to ensure consistency across the project and reduce risk of error due to change in units. Imperial measurements are presented occasionally for convenience of the reader.

3.3 TRANSMISSION LINE TERMINUS

The line would run between Skagway and Whitehorse, with one substation at each end. The new line would connect the existing electrical systems in Skagway and Whitehorse. In addition, the Skagway terminus would connect a new power line from the West Creek hydro facility to the transmission line between Skagway and Whitehorse.

3.3.1 Skagway Terminus

The proposed terminus of the transmission line in Skagway is located at the junction of the Dyea Road and Klondike Highway, as shown in Appendix A, on Map 1. A new substation would be

[4]Pers. comm. Colin Mackenzie, May 21, 2014

required at this location as currently there is no existing substation in the vicinity of Skagway that could accommodate a new high voltage transmission line. There is adequate space available at the proposed substation location. Land ownership in the vicinity of the proposed substation location consists of Municipal lands (Skagway), Mental Health Trust lands and State lands.

In the event that the West Creek hydro site is developed, it was assumed that a new 34.5kV power line would be constructed between West Creek hydro and a new substation at Skagway. Power generated at West Creek would be distributed to Skagway (to supply cruise ships in summer) as well as to Whitehorse in the winter. The power line between West Creek hydro and the substation at Skagway, or any new power line into Skagway to serve the cruise ships, is assumed to be the responsibility of local utilities. The technical and financial feasibility of such lines are not within the scope of this study and would be included to those specific projects.

3.3.2 Whitehorse Terminus

Two options for the terminus of the transmission line in Whitehorse were initially reviewed, namely:

1. Yukon Energy Corporation's substation at Riverside, which is located in Riverdale on the east side of the Yukon River directly opposite Yukon Energy's hydro generating station; and
2. the existing Yukon Energy Takhini substation located north of Whitehorse, approximately 8 km north of the junction of the Alaska Highway and the North Klondike Highway.

The Riverside substation is the preferred terminus for the new transmission line, for the following reasons:

- Riverside has sufficient space to accommodate a new 138 kV transmission line connection
- There is no need for a new transformer at this substation; existing transformers will accommodate a new 138kV line
- The transmission line would be approximately 25 km shorter, and therefore less expensive, than a line extending through Whitehorse and north to the Takhini substation.

The existing transmission line that crosses the Yukon River may need to be reconfigured to accommodate the new transmission crossing between the Yukon

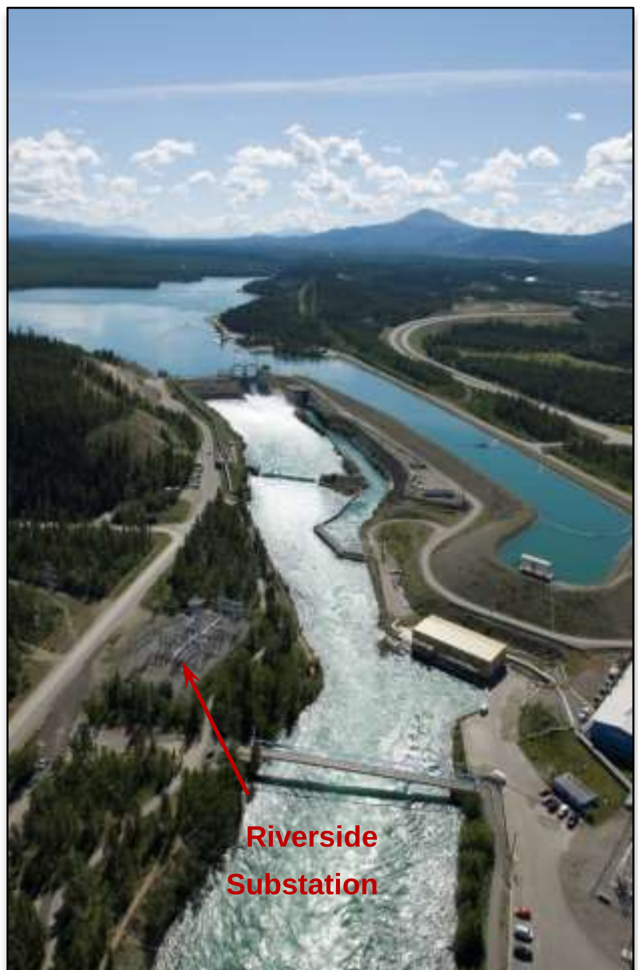

Photo 1. Whitehorse Rapids Generating Station and Riverside Substation (photo courtesy Yukon Energy Corporation)

Energy's yard and Riverside substation. Upgrading and some new equipment (e.g. breakers) would be required at this substation. Furthermore, there are numerous land uses and electrical lines in and around Yukon Energy's Whitehorse Rapids Generating Station. Construction of a new transmission line through this area will take careful planning; however no "showstoppers" were identified with respect to reaching the Riverside substation.

The Takhini Substation option would require a longer transmission line than terminating the line at Riverside. This option would incur additional costs for the line to extend another 25 km to the north, rather than if the line terminates at the Riverside substation. Routing the line through the built up areas along the Alaska Highway through Whitehorse would be challenging. The Takhini substation would require a new transformer to accommodate the new 138kV line.

Given the above considerations, the Riverside substation represents the preferred northern terminus for the transmission line. Having confirmed the location of the terminus in Whitehorse, route option(s) into the Riverside substation could be identified and analyzed.

3.4 Terrain Conditions

The economic development corridor and conceptual transmission line alignment runs from the Lynn Canal in southeast Alaska to Whitehorse, Yukon. The Lynn Canal is a steep sided fjord in the Coast Range. From there the route traverses the Boundary Ranges of the Coast Mountains via the White Pass. The White Pass has an elevation of approximately 990 m (or 3,200 ft). At the BC-Yukon border the route emerges from the Coast Mountains into the Intermountain Belt physiographic region of south-central Yukon Territory.

Photo 2. South Klondike Highway traversing steep terrain with exposed bedrock in the Skagway River valley

From Skagway to the summit of the White Pass, the terrain is characterized by the extremely steep, deeply incised valley of the Skagway River. Ground conditions are controlled by glacially scoured bedrock exposed at surface. The bedrock consists of very hard and competent early Tertiary aged granitic plutonic rocks (quartz monzonites and granodiorties, Wheeler and McFeely, 1981). There is almost no overlaying unconsolidated sediment or soil development. This makes for costly foundation conditions as all tower foundations will require rock drilling. Access from the Klondike Highway to tower locations will also be difficult due to steep terrain and cliffs bordering the highway.

On the Canadian side of the border, the White Pass is characterized by its iconic desolate landscape. Similar to the US side of the pass, the landscape is exposed granitic bedrock at surface with little to no overburden. The Canadian side of White Pass reflects gentler topography throughout a broader mountain valley. Conditions in this area will also mean more costly foundations as all towers will require drilling into hard, competent bedrock. Tower access will be less difficult due to the relatively gentler topography. Ground conditions are dominated by exposed granitic bedrock until the mouth of the Tutshi River, just before it discharges to the south end of Tutshi Lake (approximately km 47 of the alignment, see Map 3, Appendix A).

Photo 3. Canadian side of White Pass, looking north

North of the Tutshi River to Carcross, the terrain remains steep and mountainous, with the Klondike Highway immediately adjacent to Tutshi Lake and Windy Arm. In this area unconsolidated sediments, typically sand, gravel, colluvium and till, are found at surface. Furthermore, bedrock conditions change to more friable meta-sedimentary rocks consisting of siltstones, shale and argillites. This bedrock can be more readily excavated with mechanical equipment. These conditions make foundations easier to construct with conventional augering or excavation similar to that used to construct power lines elsewhere in the Yukon. The majority of this area has well drained, granular soil; there are no extensive areas of permafrost, wetland or other soft ground conditions.

Photo 4. View of the avalanche path on Mt. Racine, just south of the BC/Yukon border. This represents one of the most significant avalanche locations along the corridor.

The most significant terrain hazard in this section of the alignment is the numerous avalanche paths along both Tutshi Lake and Windy Arm. See the following section for a discussion of avalanche hazards.

From Carcross north to Whitehorse, the topography is characterized by a gentler, broad rolling valley. Terrain conditions are primarily well drained, unconsolidated sediments consisting of glaciofluvial and fluvial sand and gravel and glacial till. Bedrock is exposed at, or near, surface for less than 10% of the alignment between Carcross and Whitehorse. There are very few areas of soft ground or wetlands for alignments in proximity to the South Klondike Highway. There are more areas of wetlands near the railway alignment, particularly south of Rat Lake and Cowley Lake. These areas represent less than 5% of the total alignment and do not represent a significant constraint to the transmission line. Overall the terrain conditions for the Carcross to Whitehorse segment are amenable to conventional transmission line construction methods.

3.4.1 Avalanche Hazards

Avalanches likely represent the most significant terrain hazard along the corridor. The avalanche risk has been well assessed and is actively managed during the winter months as part of maintenance of the South Klondike Highway. The transmission line alignment was selected to parallel the highway for constructability and ease of long-term maintenance. Avalanche paths have been mapped previously (Acres & Stethem,1987; Stethem and EBA Engineering, 1986) and are shown on the maps in Appendix A. The avalanche paths have been classified as high, medium or low risk based on the reported frequency of avalanches. This classification is based on the "Avalanche Hazard Index" reported in the Klondike Highway Avalanche Control Study. For the Canadian portion of the alignment, the classification was generally as follows:

- High risk paths are areas where avalanches occur annually;
- Moderate risk areas represent avalanche frequency of 1 in 2 or 1 in 5 years;
- Low risk areas represent avalanche frequency of 1 in 10 years or greater.

Avalanche prone areas are found:

- on the Alaska side of White Pass (km 8 -19 / mile 5 to 12);
- near Summit Lake on the Canadian side of White Pass (km 21-23);
- between Fraser and Log Cabin (km 33-37);
- along the south end of Tutshi Lake (km 52-56); and
- at the south end of Windy Arm (km 72-78).

In total, there are approximately 17 km of avalanche terrain traversed by the alignment. In most locations the avalanche terrain cannot be avoid given the constraints presented by the topography.

There are several approaches to structural avalanche defense. These include restricting avalanche release in the starting zone with supporting structures such as retarding fences and snow barriers, or terracing the land; altering the course of avalanche runout zones using deflecting berms or catchment dams; and installing direct protection structures such as splitting wedges or impact berms. Usually, some combination of these alternatives is able to reduce but not completely eliminate the risk exposure.

High risk areas that cannot be avoided will require defense structures. Moderate risk areas would warrant defense structures or strong transmission line structures, but not as costly as those required in high risk areas. For the purposes of this study, the specific avalanche defense has not been defined, however additional cost allowance has been made for the segments of transmission line traversing the high and moderate risk avalanche terrain.

A description of some of the methods for protecting transmission lines with avalanche defense structures is as follows:

Supporting Structures

Supporting structures consist of securely anchored latticed fences, wire rope nets, or vertical rakes that hold the snowpack in place within the starting zone to inhibit avalanche release. Because of their expense, maintenance and work outside (uphill) the transmission line corridor, there are usually better choices for protecting transmission structures.

Deflecting Berms, Retarding Mounds, and Catchment Dams

Avalanche deflecting berms, constructed of earth fill, concrete, or steel, are designed to alter the direction of avalanche flow in the runout zone in order to protect facilities that might otherwise be hit. Retarding mounds are large piles of earth (7.5 – 10.5m high) built in a series of staggered rows across the width of the runout zone at right angles to the direction of avalanche flow. Catchment dams are large earthen berms with an upslope containment area designed to retard and catch flowing snow and reduce avalanche runout distance. Though effective with small to moderate-sized flowing slides on lower gradient slopes, retarding mounds and catchment dams tend to be over-ridden by large, fast-moving powder avalanches. They are generally ineffective for paths that produce multiple slides in a given year, thus decreasing the effective retaining qualities of the catchment structures. Additionally, they require a large area for construction and major re-contouring of the local topography.

Direct Protection Structures

Direct protection structures for transmission line structures include reinforced splitting wedges, impact structures and direct reinforcement of the transmission structure itself. Built using steel pile, reinforced concrete, or earthen-filled wood crib construction, these structures are designed to provide complete protection from avalanche impact and depositional loads. Their advantage is that they require only a small space to construct, usually within the transmission right of way and can be designed using available materials. Their disadvantage is the cost, which can equal or exceed the cost of a transmission structure. Additionally, because of the massive forces to which they are subjected, the foundations and structures require special design considerations. If unstable soils or permafrost exist at the site, this complicates the issue and increases the cost.

Photo 5. Example of avalanche splitting wedge on Snettisham transmission line in Southeast Alaska.

For new structures placed in known avalanche zones, the transmission structures and foundation can be designed for anticipated avalanche forces. The disadvantage of doing this is a failure of the avalanche defense structure results in a failure of the transmission line.

For existing structures susceptible to avalanche damage, and for new structures placed in high impact zones, the preferred protection method usually is constructing a splitting wedge structure uphill of the transmission line structure.

3.5 Route Description

3.5.1 Skagway to US/Canada border (Map 1)

Only one route option was identified through this section of the transmission corridor, and is shown on Map 1. The route would run parallel to the Klondike Highway as it climbs up to White Pass and crossing it at two locations (km 4 and 16.5 (mile 2.5 and mile 10)) to take advantage of preferred terrain/avoid constraints. Commencing at the proposed substation at the Dyea Road junction with the highway, the transmission line would be located between the highway and the Skagway River as it traverses the flatter portion of the valley floor. Near km 4 (mile 2.5), the line would cross the highway and up onto the hillside above the highway. From here the route would continue to traverse the hillside above the highway crossing several avalanche paths that flow down from higher elevations along the ridges at Porcupine Hill, as shown on the map. The route continues to climb up to the summit, crossing the highway at about km 16.5 (mile 10) to the east side. The lands crossed by the transmission line consist primarily of State lands, and some Municipal lands (Skagway) and Mental Health Trust Lands located closer to Skagway.

As the first 4 km (2.5 miles) out of the substation can be reasonably accessed by new trails using tracked or wheeled vehicles, it is assumed that wood H-frame structures would be used. After this, the terrain steepens as the highway climbs to the summit. The highway has been cut into a rock mountainside with little room for a transmission line. This 15 km (9 mile) section is assumed to be constructed by helicopters, using rock anchor foundations and steel structures. As noted above, several avalanche paths are crossed as the line climbs up to the US/Canada border and in these areas, it may be advisable to provide defenses for structures in high risk areas (see example in Photo 5). As it is not feasible to avoid the avalanche paths entirely, the placement of structures near the runout zones will generally have lower risk than if structures are placed higher up the avalanche track. Final alignment and tower design will incorporate measures to appropriately manage risks of avalanches to the transmission line.

Photo 6. Example of installing Y-poles by helicopter in Southeast Alaska (Photo courtesy of Dryden & LaRue)

As most of the route is elevated above the highway and would only cross the highway in two locations, its visibility to vehicle traffic in either direction would be screened by vegetation to some degree.

3.5.2 US/Canada Border to Carcross (Maps 2 - 5)

This portion of the route traverses the mountainous terrain through the White Pass area and descends into Carcross, a distance of approximately 80 km. From the border to Fraser customs, two route options were identified along either side of Summit Lake: one generally following the Highway and the other generally following the White Pass railway. These two route options are shown on Map 2 (km 19- 30).

Key routing considerations for locating a transmission line between the US/Canada border and Carcross are: access for construction/maintenance; terrain and avalanche risk; and viewscapes.

While the highway option offers better accessibility, it is one of the most scenic portions of the South Klondike Highway and the lack of trees /vegetation in the sub-alpine area limits the ability to screen the transmission line from the highway traffic. Much of the non-motorized recreation in the White Pass area is concentrated on the northwest side of the highway whereas snow machine usage occurs extensively on both sides of the valley. Careful alignment and tower placement could help mitigate visual effects of the transmission line to a limited extent.

Option B (shown on Map 2) is an alternative route that may reduce visual effects *as seen from the highway*. The terrain in this area consists of shallow linear gullies oriented parallel to the railway (northeast-southwest). It may be possible to locate the transmission line along the bottom of these shallow gullies, thereby minimizing its prominence on the landscape. As there is presently no road access along Option B, access for construction and maintenance would be more difficult and therefore more expensive than Option A which is located close to the Klondike highway.

From Fraser to the south end of Tutshi Lake (km 30-50), a single route option is shown that follows the highway. The transmission route would adopt a straighter alignment than the highway, following the west and north sides of the highway (Map 3).

Given the rugged, exposed bedrock conditions between US/Canada border and Tutshi Lake it is assumed that a single-foundation steel Y-tower would be used to reduce foundation costs.

Continuing along Tutshi Lake and Windy Arm (Tagish Lake), only one route option is identified (see Maps 3 – 5). From km 50 to km 95, the transmission route would follow the west (uphill) side of the Klondike Highway. Throughout this area, options for locating a transmission line are constrained by the highway and the lake(s) and must traverse the steep, avalanche prone slopes above the highway. Avalanches start high above the highway and at times the runout zones extend across the highway and out onto the lake. The areas prone to avalanches affect approximately 13.5 km of the route, and are shown on Maps 2, 3 and 4. Given the steep topography through this area, there are no feasible options that entirely avoid the avalanche zones. Careful route alignment, design of structures and their placement will be key to managing risks to the transmission line from avalanche activity.

Land tenure or land status in this portion of the route consists primarily of Crown lands and Settlement Lands (specifically the large Carcross-Tagish First Nation parcel R-12A that covers Montana Mountain) in the Yukon portion. The portion of the transmission line that is in British Columbia, a distance of approximately 55 km, is primarily on Crown lands; there are a few parcels of tenured land at Fraser, Log Cabin and a tourist facility overlooking the Tutshi River rapids at km 42.

The White Pass & Yukon Railway and Klondike Highway rights-of-way are established, tenured transportation corridors. Parks Canada manages the Chilkoot Trail National Historic Site, and the egress from the Chilkoot Trail at Log Cabin. The suggested alignment is outside of the boundaries of the Chilkoot Trail National Historic Site.

3.5.3 Carcross (Map 5)

Land tenure and land use are the primary challenges in locating a transmission line route through the community of Carcross. As shown on Map 5, there is little vacant land in the centre of the community. Both Settlement and private lands surround much of Carcross.

Starting at km 95, just south of Carcross, three options have been identified for routing a transmission line through, or around, Carcross. These are shown as Options A, B, and C on Map 5, and are described below.

Option A would cross Nares Lake near the narrows (about km 96) and run along the northeast side of Nares Lake, crossing the Tagish Road about 2 km east of Carcross. This option would circumvent much of the built up part of Carcross itself, but would be in close proximity to the Chootla subdivision. The crossing of Nares Lake would be an overhead span, unless circumstances require a more expensive underwater crossing.

Option B starts at approximately km 98, span the Nares River on the east side of the highway bridge and weaves through the town, staying as much as possible on Crown lands (see Map 5 inset). This option would avoid, as much as possible, crossing tenured lands, by following existing utility and/or transportation easements. Option B would converge with the ATCO Electric easement in Carcross.

Option C starts at km 95 and follows a former easement for the power line that used to connect to Venus Mine (now abandoned). This option would involve a submerged crossing of Bennett Lake, and join up with the railway right-of-way.

Settlement lands and private lands are common to all three options in Carcross, and discussions with the Carcross Tagish First Nation, private land owners, and the Carcross community will be necessary to properly identify a preferred route through the community.

3.5.4 Carcross to Whitehorse (Maps 5-8)

From Carcross to Whitehorse, a distance of approximately 70 km, three route options were identified. These three options from Carcross to Whitehorse are described as follows:

- *Option A* : A new route that generally parallels the South Klondike highway north of Carcross until Kookatsoon Lake, where it would converge with Option C. From there it would follow the White Pass railway to Yukon Energy's property at the Whitehorse Rapid Generating Station where it crosses the Yukon River to the Riverside Substation. This option is generally similar to that presented previously in the 1983 Whitehorse-Skagway transmission feasibility study (FMS Engineers) but takes into consideration the now greater extent of land ownership and development along the South Klondike Highway.

- *Option B*: The existing ATCO Electric easement would be rebuilt and upgraded to accommodate both the new higher voltage transmission line and the lower voltage distribution line on the same poles, using the existing easement. This option continues along the Klondike Highway to its junction with the Alaska Highway, and from there continues towards Whitehorse to km 168 where it drops down toward the Yukon River and Yukon Energy's facility (and would then cross to the Riverside substation).
- *Option C:* A new route that would generally follow the existing White Pass & Yukon Route (WP&YR) railway. Options A and C converge just south of Mary Lake subdivision and from there a single option would continue along the railway and across to Riverside Substation (as described for Option A).

At this stage of route identification, the options shown are not intended to depict precise alignment, as it is understood that detailed route alignment would be done in the next phase of work, assuming the project is found to be viable.

A new easement created for a transmission line would cross numerous Settlement Lands in various locations, but the alignments shown largely avoid crossing private lands. During detailed route planning, careful selection of the alignment would minimize these overlaps. Specific parcels crossed are not determined at this stage of the study other than to determine that crossing of First Nations' Settlement land cannot be avoided by any of the alignment options. To the extent that existing rights-of-way or easements (i.e. highway, WP&YR and ATCO Electric Yukon) can be partially/wholly utilized, the footprint/clearing required for a new transmission line could be reduced and existing linear infrastructure could also be utilized for access during construction and maintenance. In this regard, access for line construction and maintenance would be somewhat more challenging along the WP&YR as compared to the other options that generally parallel the highway.

North of Kookatsoon Lake (km 146-150), options A and C would converge, and continue toward Whitehorse parallel to the WP&YR railway, thereby avoiding the residential development at the junction of the South Klondike and Alaska highways, the CTFN residential subdivision east of the Cowley Creek subdivision, and the multitude of residential, commercial and other land uses along the Alaska Highway to Robert Service Way in the City of Whitehorse. A new country residential subdivision is being planned for the area west of Kookatsoon Lake (McGowan Lands subdivision proposal). Depending on the configuration of this planned development, it may be desirable to re-route Option A to avoid this planned subdivision area or make allowances for a future transmission line right-of-way.

As noted above, Option B would utilize the existing ATCO Electric easement, replacing existing poles with taller structures. The clearing width for the taller structures would likely extend beyond the existing easement in order to conform to current standards. It is expected that the existing 12 m easement would need to be widened to 16 m to accommodate the new, taller structures.

Table 1 provides a summary of the route options for the entire length of the transmission line, and the approximate distances for each segment.

Table 1: Summary of Transmission Conceptual Alignment Options

Approximate KMP	Route Description	Option A	Option B	Option C
0-19 (mile 0 to 12)	Skagway to US/Canada Border	Klondike Highway	n/a	n/a
19-30	Border to Fraser	Klondike Highway	Option B east of WP&YR[1]	n/a
30 - 95	Fraser to near Carcross	Klondike Highway	n/a	n/a
95 -105	Carcross area	Crosses Nares Lake[2]	Klondike Highway	Submerged crossing of Bennett Lake
105-170	Carcross to Whitehorse	New ROW along Klondike Highway[3]	Existing ATCO Electric Yukon ROW[4]	New ROW along WP&YR

Notes:

[1] Options for traversing scenic White Pass area are identified on maps, but costing assumptions are same for each route option in this area.

[2] This could also be a submerged crossing, but a long overhead span is feasible and less expensive.

[3] Option A and C converge south of Mary Lake and continue as single route into Riverside substation.

[4] Existing ATCO Electric Yukon easement may require widening to accommodate higher voltage transmission.

3.6 Transmission Line Design

Preliminary research was done in order to anticipate the design criteria for the project. This information was used to assist in selecting preliminary line characteristics for this Study, such as conductor size and structure configuration. Due to varied climatic conditions and right-of-way restrictions along the proposed transmission line, several different structural configurations were considered, including single wood pole "wishbone" structures, double wood pole H-frame structures, and steel pole "Y" towers. In addition, the Government of Yukon wished to examine the possibility of an under-build [5] supporting a communication fibre to address a communication intertie between Whitehorse and Skagway.

Conductor sag, tension loads and structure loads were estimated based on the anticipated climatic load data (see Appendix D for Design Criteria). These loads were then used to determine preliminary structure framing configurations, heights, weights and spans. This information forms the basis of the project construction cost estimate in this Study.

[5] Under-build refers to using the same structures (poles) to support both the electrical transmission and the fibre optic cable, thus avoiding cost of burying the fibre cable in a separate easement.

As noted elsewhere in this report, further investigation of local site and climatic conditions will be required in order to complete the detailed engineering design for the project. All criteria and line configurations assumed in this study shall be subject to review if the project proceeds to the implementation stage.

3.6.1 Wires

3.6.1.1 Electrical Conductors

336.4 kcmil 30/7 "Oriole" ACSR conductor was assumed for this feasibility study due to its ability to meet the requirements of voltage drop for the project. The final choice of conductor size would be made at the detailed design stage, depending on the financial acceptability regarding losses along the line.

3.6.1.2 Fibre-Optic Under-build

For the fibre option under-build scenario, a CC-57/465 OPGW w/ 24-36-48 Corning SMF-28E single mode fibre was assumed in this study due to its favourable sag characteristics compared to other overhead fibre-optic cables such as all-dielectric self-supporting (ADSS) cable. It is expected that this wire will meet the requirements outlined in the report, "Feasibility Study for Alternative Yukon Fibre Optic Link – Summary Report" (Planetworks, February 2014); however, it would need to be reviewed during detailed design to ensure that it meets the final design requirements of the communication line.

3.6.1.3 Overhead Shield Wire (OHSW)

Based on information provided in the Northern Canada Power Commission "Whitehorse – Skagway Transmission line Feasibility Study" (FMS Engineers, 1983), it was determined that due to the area's very low isoceraunic level[6], only the first 1.6 km south of Whitehorse requires an overhead shield wire. On the Alaskan side, it was assumed that OHSW would be required for 1.6km out of the Skagway substation, as was also assumed in the above referenced 1983 study.

3.6.2 Insulators

Standard 138 kV porcelain insulator sets were assumed for this study. Insulator design would be revisited during the detailed design stage, following electrical review. Particular areas of concern include high-altitude and high-moisture regions.

[6] Isoceraunic: Indicating or having equal frequency or intensity of thunderstorm activity. An isoceraunic line is a line drawn through geographical points at which some phenomenon connected with thunderstorms has the same frequency or intensity; used for lines of equal frequency of lightning discharges.

3.6.3 Wood Pole Structures

Several types of wood pole structures were considered for the proposed transmission line. In areas with sufficient right-of-way width, two-pole H-frame structures were considered, while single-pole “wishbone” structures were considered for areas with limited space such as the ATCO Electric Yukon easement. These structures are illustrated in the following subsections below. For each structure type, two configurations are considered: 138 kV conductors with or without a communication fibre. By code, the communication fibre must be placed in a third-party communication space below the electrical conductors to facilitate safe maintenance of the fibre cable. Structures with a fibre under-build must also conform to a higher grade of construction than those without the fibre under-build, resulting in stronger structures or shorter spans to accommodate the greater structural load requirements. The shorter spans required with the fibre underbuild may also reduce the line’s ability to span avalanche zones in some area. In general, Western Red Cedar poles have been assumed because of their greater availability on the west coast.

Structures used in the Alaskan portion of the route are assumed to be wood pole H-frames in the first 4 km (2.5 miles) along the valley bottom and thereafter steel structures for the next 15 km (9 miles) up to the US/Canada border, as discussed in section 3.5.1. These steel structures would be continued through White Pass to Tutshi Lake due to terrain conditions and associated foundation costs. See section 3.6.4 for a discussion of the steel structures. Wood pole structures that would be appropriate for the portion of the route between Tutshi Lake and Carcross, and between Carcross and Whitehorse are discussed in the following sub-section.

Table 8 provides a summary of the types of structures that would most likely be used in different portions of the route.

<u>South End Tutshi Lake to Carcross</u>

For the portion of the route between the south end of Tutshi Lake and Carcross (km 51-100), wood H-frame structures are well suited to portions of the alignment with low avalanche risk, granular or cohesive soils and sufficient right-of-way to accommodate their wider footprint. H-frame structures will also accommodate the relatively high climatic loads of the area. H-frame structures would be used for most of this portion of the route, although steel towers, as described in section 3.6.4, are likely to be used across avalanche slopes.

The H-frame structures are anticipated to consist of two Western Red Cedar poles joined by a top horizontal cross arm and steel cross-bracing. For H-frames with and without a fibre under-build, it is expected that 21.3m (70 ft.) poles will provide an economical design. Figure 3 illustrates the H-frame structures, with and without a fibre under-build.

The estimated allowable spans for H-Frames with and without a fibre under-build are summarized in Table 2. The effect on right-of-way width of inclined grade and sidehill slope would be accounted for in the detailed design, but it is expected to have a negligible effect on the material costs for the project.

Table 2: Anticipated Allowable Spans for Double-Pole H-Frame Structures – White Pass to Carcross

	No Fibre Under-Build	Including Fibre Under-Build
Basic Span (m)	180	150
Max Wind Span (m)	280	280
Max Weight Span (m)	1,230	1,230
Max Span - Wire Ground Clearance-Governed (m)	200	170

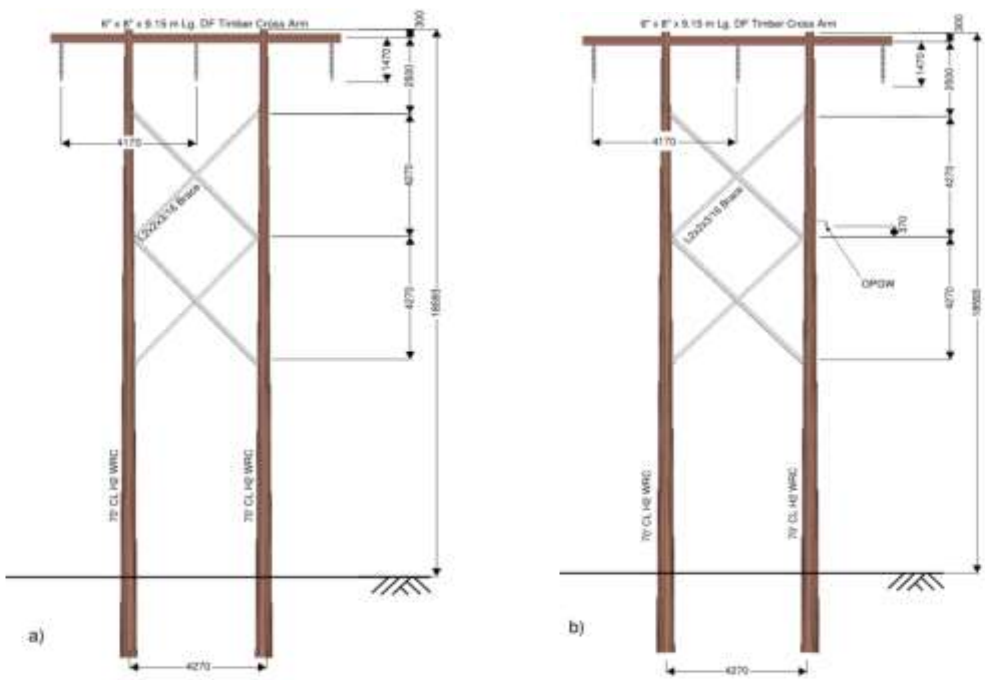

Figure 3: Double Pole H-Frame Structures White Pass to Carcross: a) with and b) without Fibre Under-build

<u>Carcross to Whitehorse</u>

Between Carcross and Whitehorse (km 100-170), double-pole H-frame structures were considered for Options A and C (see Maps 5-8) because they are well suited to the rolling, open terrain and soil conditions. As H-frame structures require wider right-of-way width than single-pole wishbone structures, the H-frame structures are most suitable for Options A and C where a new right-of-way is considered. Economy can be obtained through the use of longer spans and fewer structures, provided that sufficient right-of-way is available and they are founded in granular or cohesive soil rather than rock.

The H-frame structures would be similar to those described above for the route south of Carcross, but a shorter height (see Figure 4). The poles would be 18.3m (60ft.) tall without a fibre under-build, and 19.8m (65ft.) tall with a fibre under-build. The estimated allowable spans for H-Frames with and without a fibre under-build are summarized in Table 3 below for horizontal line angles up to a maximum of 4^{o} and flat ground.

Table 3: Anticipated Allowable Spans for Double-Pole H-Frame Structures – Carcross to Whitehorse

	No Fibre Under-Build	Including Fibre Under-Build
Basic Span (m)	225	180
Max Wind Span (m)	354	345
Max Weight Span (m)	2,000	2,000
Max Span - Wire Ground Clearance-Governed (m)	250	200

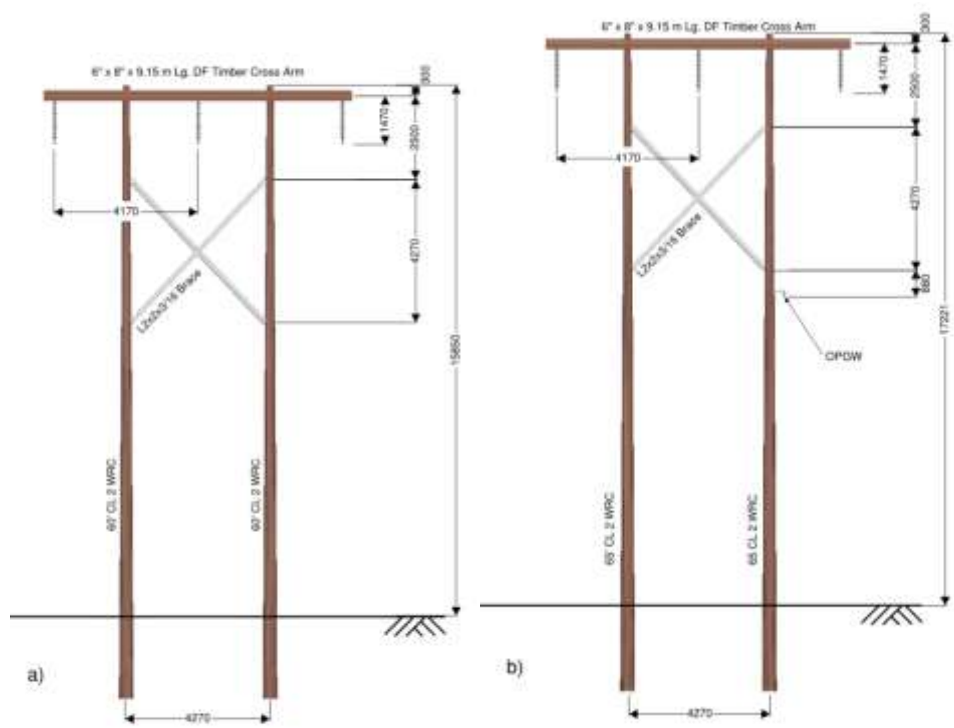

Figure 4: Double-Pole H-Frame Structures Carcross to Whitehorse: (a) with, and (b) without Fibre Under-build

Option B (see Maps 5-8 in Appendix A) would utilize the existing ATCO Electric Yukon easement. For this option, single-pole wishbone structures were considered because their shorter spans, lower height and narrower horizontal spacing between conductors are well-suited a narrower right-of-way (16 m) with frequent changes in horizontal alignment. Under this option, the structures would accommodate a possible fibre under-build, as well as the 34.5kV distribution line under-build.

The wishbone structures are anticipated to consist of a single Western Red Cedar pole supporting two steel cross arms at the top of the pole and a wooden cross arm at the distribution under-build elevation (see Figure 5.) It is expected that 16.8m (55 ft.) poles will provide an economical design for poles with or without a fibre under-build. The estimated allowable spans for wishbone structures with and without a fibre under-build are summarized in Table 4 below for horizontal line angles up to a maximum of 3^{o} and flat ground.

Table 4: Anticipated Allowable Spans for Single-Pole Wishbone Structures – Carcross to Whitehorse

	No Fibre Under-Build	Including Fibre Under-Build
Basic Span (m)	65	55
Max Wind Span (m)	72	62
Max Weight Span (m)	413	414
Max Span - Wire Ground Clearance-Governed (m)	80	75

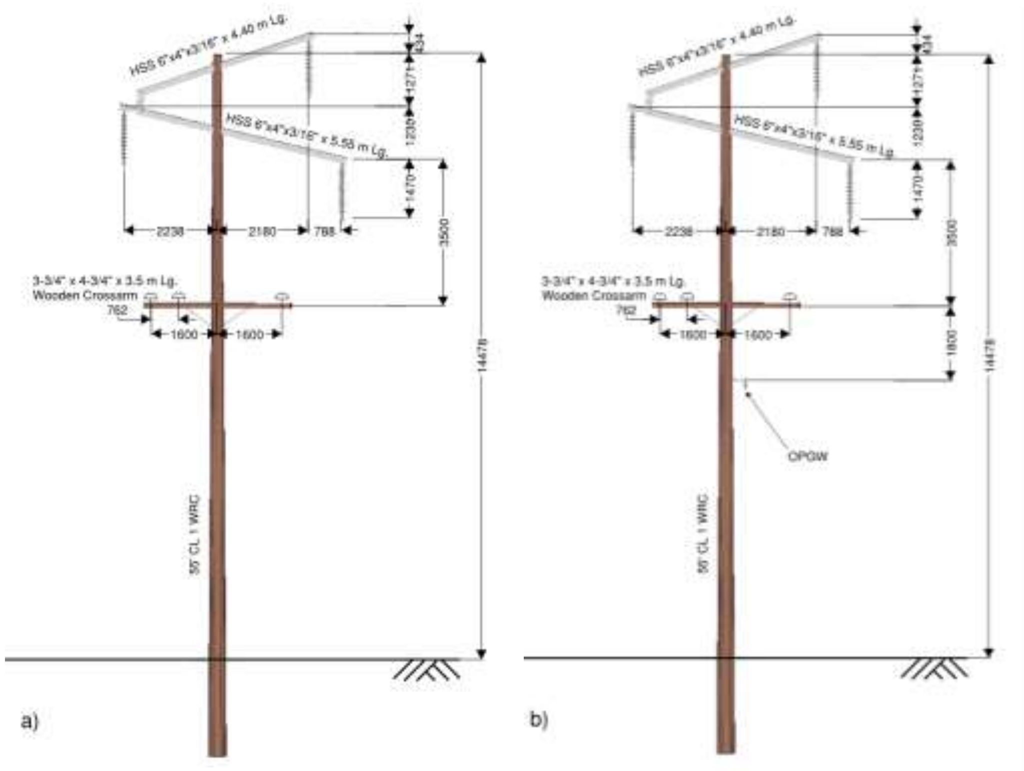

Figure 5: Wishbone Structures: (a) with, and (b) without Fibre Under-build

3.6.4 Steel Structures

Self-supporting steel Y-Pole structures (see Figure 6) were considered as an alternative to wood structures for portions of the proposed alignment south of Carcross, from the Alaskan border to the south end of Tutshi Lake and along all areas of medium to high avalanche risk. Steel structures are well suited to this segment of the alignment given their greater strength for the high climatic loads and avalanche risk, suitability for helicopter installation in remote locations and ability to be founded directly on rock using rock anchors, or into soil through a single concrete caisson per pole.

Three different steel Y-Pole structures were considered, based on their application: basic towers with and without a fibre under-build and a taller higher-strength tower for regions of moderate avalanche risk. Towers with a fibre under-build must be constructed to a higher grade which results in stronger structures or shorter spans to accommodate the greater structural load requirements. It should be noted that although the individual tower weight for the fibre under-build configuration is less than that of the tower without fibre, the corresponding spans are significantly less, resulting in overall greater tower weight per kilometre.

The total estimated weights and allowable spans for the different steel Y-Pole tower applications are summarized in Table 5 and Table 6 below for horizontal line angles up to a maximum of 4^{o} and flat ground. The effect of inclined grade and sidehill slope would be accounted for as part of the detailed design, although it is expected to have a negligible effect on the material costs for the project.

Table 5: Estimated Weights of Steel Y-Pole Towers

Application	Tower Weight (kg)
Tangent Tower, No Fibre	3,060
Tangent Tower, Fibre Under-Build	2,730
Tangent Tower, Low to Moderate Avalanche Risk Areas	4,800

As discussed previously, the conceptual transmission line alignment traverses several known avalanche paths south of Carcross. The following sections are considered moderate to high avalanche risk (stations relative to the start of the Klondike Highway in Skagway, AK, see Appendix A for locations):

- Kilometre 57.8 to 60.0 (2.2 km - south end of Tutshi Lake)
- Kilometre 78.3 to 80.1 (1.8 km - Mount Racine)
- Kilometre 81.1 to 84.8 (3.7 km - Dail Peak)

Where it is not possible to avoid the avalanche-prone areas entirely, it is expected that moderate-risk avalanche areas will be accommodated by the installation of taller, higher-strength steel pole structures (anticipated heights 4.0 m taller and design loads double those which are required by code) and that structures in high-risk avalanche areas may be protected by separate defensive structures.

For the structure configurations assumed in this study, it is assumed that the entire length of the avalanche-prone regions identified above will have high-strength steel structures, while only a total of 1 km in the south Tutshi Lake region, 0.4 km in the Mount Racine region and 0.5km in the Dall Peak region may have separate defensive structures. For the detailed design of the transmission line, it is recommended that an avalanche specialist be retained to review the avalanche hazard areas and provide avalanche design criteria for the project.

Table 6: Anticipated Spans for Steel Y-Pole Structures (Low to Moderate Avalanche Risk)

	No Fibre Under-Build	Including Fibre Under-Build
Basic Span (m)	300	230
Max Wind Span (m)	330	260
Max Weight Span (m)	1,230	1,230
Max Span - Wire Ground Clearance-Governed (m)	325	250

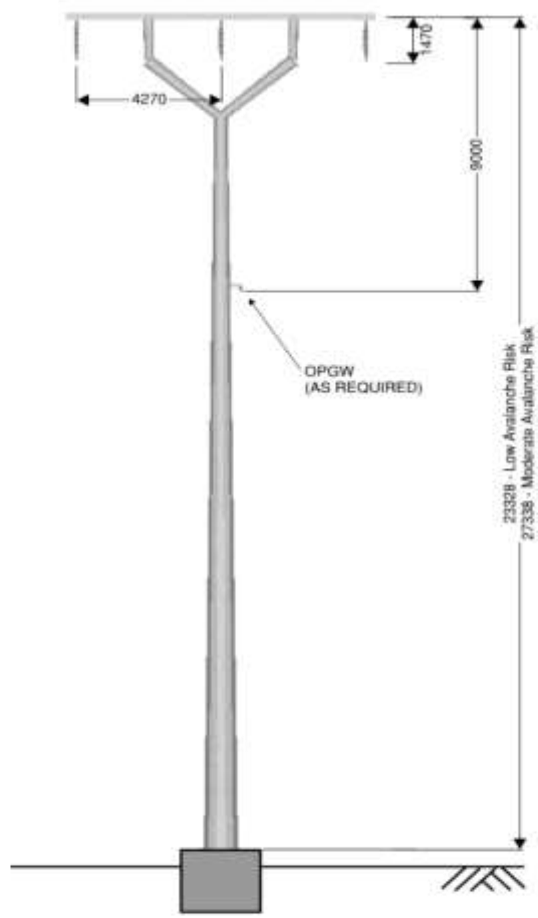

Figure 6: Steel Y-Pole Structures between White Pass and Carcross

3.6.5 Right-of-Way Requirements

The minimum right-of-way dimensions for the proposed 138 kV transmission line were estimated based on anticipated loading conditions and minimum horizontal clearance requirements associated with the assumed conductor sizes and spans for different structure configurations. Table 7 summarizes the minimum right of way widths estimated for different portions of the alignment. Note that the increased right of way width requirement for steel Y-Poles without a fibre under-build stems from these poles having significantly longer spans and greater conductor side-sway under maximum wind conditions than Y-Poles with a fibre under-build.

Table 7: Minimum Right of Way Widths for Structures

Structure Type	Estimated Minimum Right of Way Width (m)
Wood Double-Pole H-Frame (with and without fibre under-build)	23
Wood Single-Pole "Wishbone" (with and without fibre under-build)	16
Steel Y-Pole (without fibre under-build)	34
Steel Y-Pole (with fibre under-build)	28

3.6.6 Summary of Transmission Line Structures

Table 8 provides a summary of the anticipated type of structure for various segments of the transmission route between Skagway and Whitehorse. Options A, B, and C correspond to the three route options identified for that portion between Carcross and Whitehorse (see Maps 5-8). Steel structures would be used in challenging terrain south of and throughout the White Pass area and in specific areas exposed to moderate to high avalanche risk.

Table 8: Summary of Structure Type, by Route Segment

Segment	KMP (approx.)	Option A New Right-of-Way	Option B ATCO Electric Easement	Option C New Right-of-Way
Alaska – lower Skagway valley	0-4 (mile 0-2.5)	Wood H-frame	n/a	n/a
Alaska – to White Pass	4-20 (mile 2.5-12)	Steel Y-poles	n/a	n/a
White Pass to Tutshi Lake	20- 51	Steel Y-poles	n/a	n/a
Tutshi Lake to Carcross	51- 100	Wood H-frame[1]	n/a	n/a
Carcross to Whitehorse	Km 100 to 170	Wood H-frame	Wood – Single Pole Wishbone	Wood H-Frame

Notes: [1] Steel structures assumed for avalanche terrain along Tutshi Lake and Windy Arm – total distance approximately 7.7 km

4 REVIEW OF WEST CREEK HYDRO POTENTIAL

4.1 BACKGROUND AND CONTEXT

The West Creek hydro site is a key factor in assessing the viability of a potential Skagway-Whitehorse transmission line. West Creek hydro could provide cruise ships in Skagway with power during the summer months and winter power to the Yukon via the transmission line.

A high-level review of the West Creek hydro site has been conducted to identify the hydro potential and value of the site as well as identify the main data gaps in earlier studies. The review conducted as part of this study was solely to inform (based on current information available to the study team) the analysis of the transmission corridor based on potential power availability from a West Creek hydro project.

The review was based on available reference studies, a site visit and professional opinion. The Municipality of Skagway reports that they are currently working through a Memorandum of Understanding with Alaska Power and Telephone (AP&T) to advance the Federal Energy Regulatory Commission (FERC) license submission for the West Creek initiative. The Municipality is currently conducting hydrologic analysis of the catchment in support of feasibility and licensing requirements and is also preparing a scope and budget to address the additional FERC licensing requirements. Accordingly, the following review does not necessarily represent the views or opinions of the Municipality of Skagway, Alaska Power & Telephone Company or their technical consultants.

The review included an estimate of the available power and energy potential at the site, a technical review of each of the major components (dam, powerhouse, conveyance, access and transmission) and provides recommendations for future alternatives that can be considered. The complete hydro potential review is included in Appendix E. A summary of the hydro potential review is presented herein.

The West Creek hydro site, as well as the upper Lynn Canal region of Southeast Alaska, have been the subject of numerous previous hydro potential studies since the 1960's. There is a substantive supporting data set, much of it completed in 1981 to support the West Creek hydro feasibility study of that time. It includes:

- detailed topographical mapping and aerial photography;
- a preliminary environmental study including supporting fieldwork;
- a geotechnical investigation program, that included geological mapping, diamond core drilling, water pressure testing, seismic refraction surveys and material testing.

A site reconnaissance was also conducted on August 19, 2014 by the project team's hydrotechnical and geological engineers. It included a helicopter flyover of the West Creek valley and a ground reconnaissance of the potential dam site and surroundings, with the observations focused on:

- Potential dam and powerhouse sites;
- Conveyance alternatives (penstock or tunnel) and alignments;
- Reservoir boundaries;
- Key geological features.

4.2 Hydrology and Power Studies

4.2.1 Hydrological Study

The power and energy generation potential of the West Creek site was estimated on a monthly basis. Hydrological data for West Creek were retrieved from 15 years of daily flows recorded from 1962 to 1977 by the United States Geological Survey (USGS). The flow gauge was located approximately 200 m upstream of the mouth of the creek. The catchment area at this station is approximately 112 km^2 (42.4 square miles).

Flow data measured at the West Creek gauging station were used to calculate flows in the catchment area upstream of the proposed dam site (96.3 km^2 or 37.4 square miles), resulting in a calculated average yearly flow of 8.2 m^3/s, for an average flow yield of 0.085 m^3/s per square kilometer.

Average historical monthly flows for West Creek at the dam site are presented in Table 9 and Figure 7.

Table 9: Average Monthly Flows on West Creek at Dam Site (1962-1977)

Month	Monthly average flow (m^3/s)
January	0.6
February	0.7
March	0.7
April	1.3
May	5.2
June	15.3
July	24.0
August	23.2
September	16.1
October	6.2
November	2.9
December	1.1
Yearly average	8.2

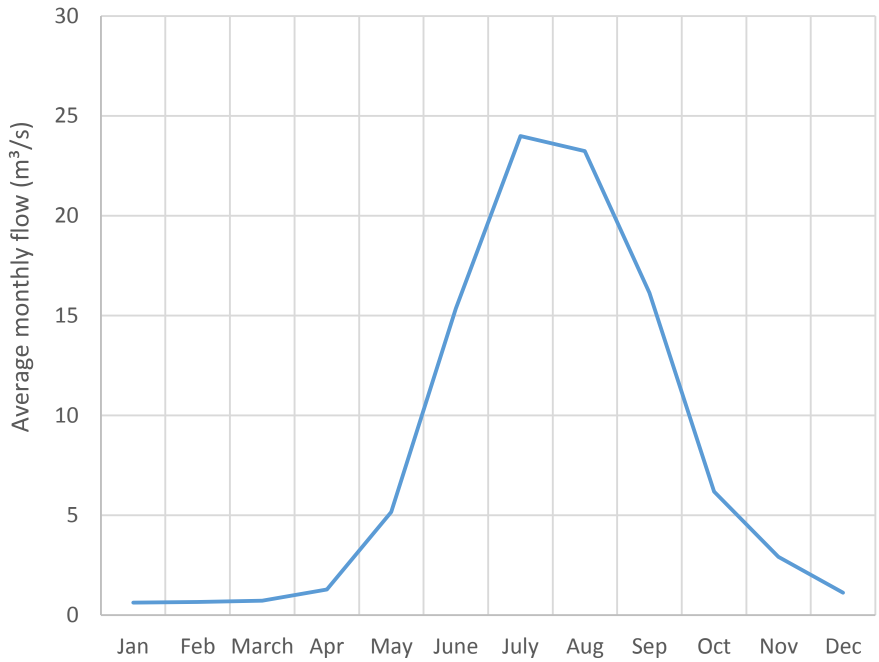

Figure 7: Average Monthly Flows on West Creek at Dam Site (1962-1977)

4.2.2 Power and Energy Estimates

The power and energy generation potential of the West Creek site was estimated. An installed capacity of 25 MW was assumed based on the recent FERC Application submitted by AP&T (2014). Calculations were performed by simulating the reservoir operations on a monthly basis. The reservoir volume was determined based on the 1982 feasibility study (R.W. Beck).

The storage volume available for power generation was estimated using the operating water levels for a 22.5 MW plant (determined in the updated 1983 feasibility study). Further optimization of the minimum and maximum operating water levels should be conducted; however, these 1983 values provide a reasonable estimate of power and energy generation for the purposes of this review. The following operating water levels and operation parameters were used for the simulations:

- Maximum operating water level = 238.4 m (782 ft)
- Minimum operating water level = 201.8 m (662 ft)
- Water level range of operation = 36.6 m (120 ft)
- Tailwater level = 11.2 m (38 ft)
- Storage volume in reservoir = 100 Mm^3
- Average net head = 200 m (estimated, including head losses)
- Turbine flow = 15 m^3/s
- Turbine efficiency = 85% (constant)
- Minimum environmental flow of 10% of average monthly flow

A turbine flow of 15 m^3/s was selected to match the proposed 25 MW installed capacity. It does, however, significantly exceed the average yearly flow of 8.2 m^3/s at the dam site. It appears that the optimal installed capacity at the site would be in the 15 to 18 MW range based on available flow data.

Reservoir operations were simulated to maximize winter energy generation and thereby maximize utilization of the transmission line to Yukon. Summer energy could be provided to Skagway while the highly-valued winter energy would be available to the Yukon during the winter months. A run-of-river type scheme was not considered because it would make very little power during winter months and therefore would not significantly utilize a transmission line to Yukon. It is estimated that West Creek could displace on the order of 47 GWh/yr of thermal generation during winter months based on the 2030 load forecast. See Attachment B of the Financial Feasibility memorandum (Appendix F) for the detailed analysis.

It is assumed that the reservoir would refill during the summer months (mainly June to August) and constant releases (when possible) were assumed during the winter months (from mid-November to mid-April) to increase the flows available for power generation. Calculations were made using a volume balance approach. This calculates the change in available storage and the associated monthly volume of water available for power generation. The following reservoir operational scheme was generally assumed in the calculations.

Summer filling (target volume to be retained in each month, if possible)

- June: 15 Mm^3
- July: 40 Mm^3
- August: 35 Mm^3
- September: 10 Mm^3

Winter releases from the reservoir

- November: 10 Mm^3
- December to March: 20 Mm^3 per month
- April: 10 Mm^3

Filling of the reservoir according to these simple rules occurred in all years except one of the flow series (14 years total). The calculated average monthly power production is presented in Table 10, while the average energy generated from the West Creek hydro site is presented in Figure 8.

Assuming the above operational scheme, total average yearly energy generation was estimated at 106 GWh, varying between 87 and 132 GWh over the duration of the 14 year flow series (see Figure 9). It should be noted that with the proposed scheme, the maximum average monthly power generated is 18 MW in September. The full 25 MW was only achieved (on a monthly average) 5 times in September over the duration of the flow series. Further optimization of the operational scheme or a change in priorities (i.e. favor summer energy over winter energy) could potentially result in a slight increase in total generation. A firm winter power between 11 and 13 MW can be achieved, if winter releases are optimized to achieve the largest possible firm power. Section 6 of this report provides an overview of West Creek utilization with the detailed analysis provided in Appendix F.

Table 10: Average Monthly Power Production; Calculated based on 1963-1977 Flows

Month	Average Power Production (MW)
January	13.2
February	12.9
March	12.8
April	8.5
May	7.4
June	9.6
July	10.7
August	14.5
September	18.1
October	9.3
November	13.5
December	13.9
Yearly average	12.0

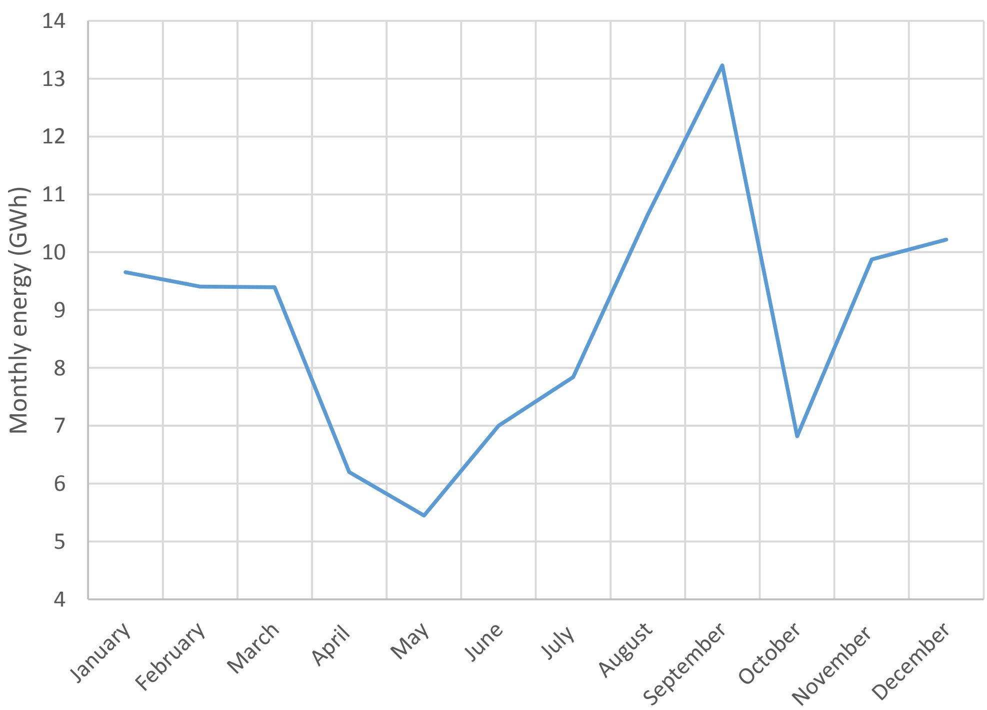

Figure 8: Average Monthly Energy with 25 MW Installed Capacity

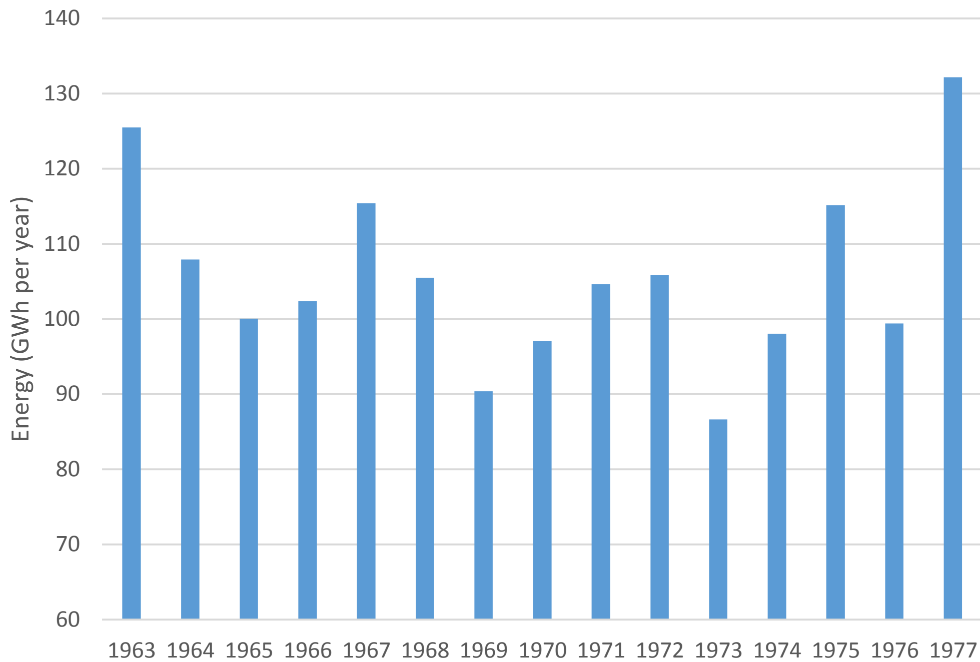

Figure 9: Energy Generation by Year; based on 1963-1977 Flow

Future Considerations

The available hydrological information on West Creek is adequate for preliminary power and energy estimates, but should be updated for future estimates. The available data set is limited (14 years) and dates back more than 30 years. All of southeast Alaska is experiencing significant climate change and a rapid melting of glaciers. Glaciers cover a substantive portion of the West Creek watershed. Hydrological monitoring is currently underway on West Creek and should continue until the project is developed. A single gauge near the mouth of the creek, or alternatively near the dam site, is adequate to measure flows. Meteorological and climate change studies would also help to understand and predict the hydrology of West Creek.

Based on the above calculations and the selected turbine flow (15 m^3/s) to match the proposed 25 MW capacity, it appears that the most economical installed capacity would be smaller, likely in the 15 to 18 MW range. Since one of the objectives of the West Creek hydro site is to provide shore power to the cruise ships visiting Skagway, 25 MW was originally proposed in order to fully meet that demand. Further studies based on power demand in both Skagway and Whitehorse are needed to determine the optimal installed capacity to develop at West Creek.

Reservoir operations should also be studied on a daily basis, incorporating the geometry of the proposed spill structures (overflow or gated). The reservoir size (and dam height) could be slightly increased, to generate more winter firm power at the site. There is sufficient inflow during the summer to achieve approximately 12 MW of firm winter power. The need for environmental flows below the dam, the resulting impact on the power and energy output of the site, would also need to be investigated.

4.3 Review of Site Development Layouts

Various potential layouts for the West Creek hydro site have been analyzed to develop between 5 and 25 MW of installed capacity, with a storage reservoir. The main project layout for the West Creek hydro site was included in the 1982-1983 feasibility study (R.W. Beck) which proposed a powerhouse near the mouth of West Creek on the Taiya River. In 2014, an alternate layout was proposed by AP&T with a powerhouse near tidewater on the Taiya Inlet. No technical information regarding the recent layout was made available for this review.

The following sections present a review of the proposed infrastructure, key challenges and potential alternatives that should be considered in further studies. A photo log of the site visit is presented in Appendix E, along with drawings of the proposed layouts.

4.3.1 Dam and Spillway

The proposed dam site is located approximately 3.5 km upstream from the mouth of West Creek. At this location the creek has a steep gradient and is flowing through a narrow valley between hills. This location is suitable for the construction of a dam, limiting the volume of material required for the structure and containing the reservoir behind the hills. Only one small closing dike (or saddle dam) on the left (north) abutment would be required for the largest development option (22.5 MW as proposed in the 1982 feasibility study). It was reported that bedrock at the dam site consists of a strong, massive granodiorite. This rock is suitable for supporting a dam at the site and also providing construction materials for the shells of an earth dam. Bedrock was observed near the surface at many locations during the site visit. It appears to be of fairly good quality, although foundation treatment is to be expected under the dam.

Photo 7. Potential dam site on West Creek, looking northeast towards the Tayia River valley.

An earthfill dam with a concrete face was first proposed in 1982. The absence of quality impervious material (i.e. till or clay) in the area was the main reason for proposing such a dam, instead of an earthfill dam with an impervious core. Studies in 1983 proposed a roller-compacted concrete (RCC) dam as the most economical dam type for the project. For both types of dams, it was proposed that a cutoff slab of about 60 cm in thickness and 3.5 m width and a grout curtain would allow a foundation water barrier and cutoff. The RCC type of dam was also the option presented in the 2014 FERC Application (AP&T).

Photo 8. West Creek valley and potential reservoir area upstream of dam site.

The reservoir lies in a fairly flat and narrow valley that is bordered by steep slopes coming down from high mountain peaks. A significant landslide has occurred upstream of the reservoir near the West Creek glacier in the last decade, however the location of this landside is upstream and above the potential reservoir limits. There are numerous visible avalanche paths on both sides of the reservoir. The risk of landslide or avalanche in the reservoir is a risk to the project to be considered in the design.

An ungated overflow spillway excavated into bedrock on the dam right abutment was first proposed in 1982. It is designed to accommodate the probable maximum flood (PMF). In 1983, a modified spillway incorporated in the middle of the main dam was selected. This latter option is only suitable if a RCC dam is selected. No gated spillway structure was proposed in either design.

Photo 9. Potential reservoir in the West Creek valley, with large avalanche paths on the north side.

Diversion during construction was proposed with two concrete pipes to convey the 1:10 year flood. Tunnel alternatives on the right and left abutment were also considered. The proposed dam site would require the construction of small cofferdams both upstream and downstream of the alignment to build the dam in the dry.

<u>Future Considerations</u>

The proposed dam location is the optimal one, within +/-200 meters. The final position should be confirmed based on additional geotechnical investigation and the type of dam selected (including dam height). From the available information and previous geological reports, it appears that the site geology is adequate to support a dam of the size proposed. A RCC dam is a suitable dam for the site but would be more expensive to build compared to an earthfill dam with impervious core. It may be worthwhile to investigate additional borrow sources for impervious material in the area or consider alternate core material.

Consideration should also be given to an asphalt core dam. This is an emerging technology first implemented in Scandinavian countries. Hydro-Quebec has recently built a series of asphalt core dams - the first such works in North America. The West Creek dam is large enough to merit consideration of this option which may potentially reduce project costs.

It is likely that a gated structure with a low invert would be required to discharge environmental flows below the dam site. It could also be used to flush sediment accumulation in the reservoir. Significant sediment build-up is not expected to occur on a regular basis, but the potential risk of landslides or avalanches deposited in the reservoir could affect sediment accumulation.

Furthermore, landslides or avalanches released into the reservoir could generate a large wave that could threaten (overtop) the dam crest. Such events are considerations that must be taken into account in selecting the dam type. Depending on the severity of the effects on the reservoir (resulting flood-wave), a certain dam type may be preferable.

4.3.2 Conveyance and Powerhouse

Various powerhouse locations were considered in the 1982-1983 feasibility study, all located near the mouth of West Creek. These locations would allow development of the full head available and to provide the shortest conveyance possible. The selection of the optimal location for the powerhouse was based on the results of the geotechnical investigations and the preferred route for the water conveyance. A 2.7 km long power tunnel was proposed for water conveyance. A 440 m steel penstock would complete the power conduit to the powerhouse. A surface powerhouse was proposed, equipped with two Francis turbines.

Photo 10. Mouth of West Creek with potential powerhouse locations.

The 2014 FERC Application (AP&T) proposed an alternate layout that included a powerhouse at the head of Taiya inlet near tidewater. A 4.9 km tunnel running down the Taiya River valley would convey the water from the intake structure at the dam to the powerhouse. This layout would avoid having the transmission line crossing through the Klondike Gold Rush National Historic Park. Note that AP&T already has a buried power line through the Park, extending almost to West Creek bridge.

Photo 11. Approximate location of proposed powerhouse on Taiya Inlet in FERC 2014 Application

The powerhouse location proposed in 1982-83 appears to be the optimal location, based strictly on a technical review of the available information and observations gathered during the site visit. It provides a shorter conveyance with fewer technical challenges, and the access to the powerhouse is much easier. A powerhouse on the Taiya Inlet would have many disadvantages:

- likely require a barge to access the site for construction;
- significant visual footprint on the road to Dyea and on the Dyea flats.
- large tailwater level variation that would be challenging to accommodate;
- longer conveyance that may have to cross fault zones (to be determined based on further site investigations).

A surface powerhouse is adequate based on the site characteristics for both sites, however the Taiya Inlet site would require a large bedrock cut into the steep mountain side at tidewater to accommodate the powerhouse. The use of Francis turbines also appears to be adequate for the proposed head and turbine flow, although Pelton turbines could still be considered. Finally, a surge chamber/tank will likely be necessary, based on the head to be developed at the site.

Future considerations

The land use challenges associated with constructing a powerhouse near the mouth of West Creek should first be determined and include discussions with land owners in the area and the National Historic Park. The location at the mouth of West Creek is the preferred location from a technical and cost perspective. A powerhouse on Taiya Inlet presents significant technical challenges and would likely be more costly to develop. This option cannot be eliminated at this stage, but an adequate geotechnical investigation program would be necessary to determine its feasibility.

As an alternative to a tunnel, a surface penstock for the full length of the water conveyance should be re-assessed. A power tunnel of the size required for the proposed turbine flow would likely be costly. An HDPE (plastic) penstock potentially could provide a lower cost alternative to a tunnel. The penstock could be buried to protect it against potential landslides or avalanches as well as against freezing. Based on topographical information, a penstock would be located on the north side of the creek, extending for about 3.4 km. The feasibility of locating the powerhouse on the north side of the creek would be assessed in parallel. Finally, the potential intake location is another factor that can influence the selection of a specific alignment or conveyance type for the site. Due to the large water level variations (37 m) in the reservoir, an intake excavated into bedrock is mandatory for stability purposes.

Optimization studies should consider all components described above as a package (intake structure, water conveyance and powerhouse), to determine the most optimal layout. Multiple alternatives should be re-assessed, since technologies have evolved and unit construction costs have increased significantly since the early 1980's.

4.3.3 Site Access

Road access to the West Creek hydro site already exists. Road access to Skagway is possible via the South Klondike Highway, and marine access is available via the Lynn Canal. There is an all-season road that runs from Skagway to Dyea that is suitable to bring machinery on site, although it is quite narrow with sharp curves. There is an old logging road that runs parallel to the creek on the north side and extends close to the proposed dam site (to within 300-400 m). This road could be upgraded for construction access and extended to the proposed reservoir for clearing.

Access to the south side of the creek could be required near the dam or near the mouth of the creek, depending on the selected location for dam components. A bridge over the creek could be built at the dam site if required, while existing road/trails near Dyea do give access to the south side of the creek.

If the powerhouse was located on Taiya Inlet, access would be more challenging as mentioned before. A barge would likely be used to access the powerhouse location, unless suitable road access could be established on the west side of the river. Such an access road would need to extend to the edge of the water on Taiya Inlet. If the use of a barge is selected, landing spots on each side of the inlet would need to be built and be able to accommodate large tides.

There are two options for a transmission line between the West Creek hydro site and Skagway:

- An overhead line parallel to the existing road and/or
- an underground line.

The costs associated with each would need to be assessed, along with land use and effects on viewsheds.

Future considerations

The cost associated with developing a new access road or the use of a barge should be factored into the selection of the powerhouse location (near the mouth of West Creek or at Taiya inlet). In general, access to the site is by virtue of the existing road network and only a few kilometers of new access road is required. Roads to the dam site and powerhouse site would be maintained for year-round access.

Preliminary recommendations for further technical evaluation of the West Creek hydro site and cost estimates are provided in Appendix E.

4.4 REVIEW OF ENVIRONMENTAL AND REGULATORY ISSUES ASSOCIATED WITH WEST CREEK HYDRO DEVELOPMENT

A cursory review of the environmental and regulatory issues associated with the proposed West Creek hydro project was undertaken by Travis/Peterson Environmental Consulting Inc. based in Anchorage Alaska. The purpose of this review was to identify any key environmental constraints and regulatory issues that are associated with the West Creek hydro development.

The following documents were reviewed:

1. R.W. Beck Feasibility Study 1981-82
2. Alaska Power and Telephone Company Federal Energy Regulatory Commission (FERC) Application, March 2014
3. The Alaska Department of Transportation and Public Facilities (COT&PF) Juneau Access Improvements Project EIS, April 2005; and
4. The Lynn Canal Conservation website.

Based on the information reviewed, the West Creek drainage is compatible with hydro power, as the valley has no endangered species, critical habitats, deer habitat, or salmon spawning. Five other issues were identified, however, that are likely to require considerable effort and resources to address. These are:

1. Complying with Executive Order 12114 ("Environmental Effects Abroad of Major Federal Actions",
2. Construction within the Klondike Gold Rush National Historical Park
3. Protecting Viewsheds
4. Compliance with Section 106 of the National Historic Preservation Act (NHPA); and
5. Acquiring Presidential approval to export electricity to Canada.

It was assumed that the West Creek hydro development and a transmission line between Alaska and Yukon are linked; one would not be built without the other (within a reasonable period of time). The following expands on each of these five issues.

<u>Executive Order 12114:</u> FERC will require an Environmental Impact Statement (EIS) for the West Creek hydro project. Executive Order 12114 mandates every Federal agency implementing the EIS process (i.e. FERC) to quantify the environmental effects outside the United States borders. Agencies must consult with the Department of State and the White House Office on Environmental Quality concerning any proposed mitigation procedures prior to implementing them. This coordination will complicate FERC approval of the EIS.

<u>Construction within the Klondike Gold Rush National Park:</u> The National Parks Service (NPS) manages the Klondike Gold Rush National Historic Park in Alaska. Since the powerhouse may be located on Park land or within the Park boundary, the NPS will be involved in the EIS process. The use of Park land for project-related infrastructure is only allowed if there are no feasible alternatives. Experience suggests that NPS is very protective of its lands and it is likely that an exhaustive study of alternatives will be needed to demonstrate that the use of Park land for any project structure is justified.

<u>Viewshed Protection:</u> The National Parks Service is extremely concerned about protecting viewsheds. They often require detailed modeling of viewsheds to assess the impact of developments on the viewshed within the Park. This involves complex computer simulations of the project infrastructure against photographs of the surrounding environment. The analysis of views is subjective, and as such, often controversial.

<u>Compliance with Section 106 of the National Historic Preservation Act (NHPA):</u> Section 106 of the NHPA will require extensive coordination with the State Historical Preservation Office (SHPO) and Keeper of the Historic Register given the historic districts near the West Creek site. The Keeper has the authority to ban any portion of the project from the Park, or in close proximity to structures that are on the National Historic Register, or have the potential to be on the Register. Impacting a viewshed of a structure on the Register requires mitigation. The SHPO and Keeper will require a detailed archaeological and cultural resource study of the project area that could take several years to complete.

Presidential Approval to Export Electricity to Canada: The Federal Power Act of 1935 requires a Presidential Approval to construct a transmission line to export power to Canada.[7] This is a formal permit process through the Department of Energy, Economic Regulatory Administration. It is not inconceivable that the West Creek project (and its associated export of power to Canada via the transmission line) could be stalled for some time, depending on the political appetite for such projects in Washington.

Other: Opposition to the development of West Creek may be anticipated from a number of organizations, such as the Lynn Canal Conservation group (a non-profit organization that opposes many developments in the Skagway/Haines area). There may be other organizations in both Alaska and Canada that will express concerns regarding the development of West Creek hydro, and the transmission line to the Yukon.

In summary, the issues identified are not considered insurmountable. However, these issues will likely take considerable time and resources to satisfy stakeholder concerns. Project scheduling and resource planning should take this into consideration.

[7] Approval to export electricity from Canada to the United States is also required under the Canadian National Energy Board Act, and is issued by the National Energy Board of Canada.

5 CONSTRUCTION AND OPERATING COST ESTIMATE

5.1 BASIS OF ESTIMATE

The capital, operating and maintenance costs are estimated for the three route options for the transmission line. The capital cost estimate was created using a bottom-up methodology based on a combination of industry-published labour rates and experience with similar projects. Operating and maintenance costs were based on current data provided by the Yukon Energy Corporation (YEC) and Southeast Alaska Power Agency (SEAPA). The estimate also used data from the following sources:

- Information supplied by YEC, including estimated Riverside substation modification costs and cost data for the existing Carmacks-Stewart Transmission Project.
- Information contained in the British Columbia Transmission Corporation’s Interior to Lower Mainland Transmission Project Alternative Cost and Schedule Report, November 2007, publicly available on the BC Hydro website.
- Information contained in the Southeast Alaska Intertie Study Phase 1 and Phase 2 reports, December 2003, prepared by D. Hittle & Associates, Inc.
- Current in-house data
- Historical data

This estimate incorporates items and experience specific to transmission line construction projects in the southern Yukon and southeast Alaska region. These include:

- Construction materials
- Construction labour and equipment
- Clearing and access roads
- Allowance for winter work
- Contractor overhead and profit

5.1.1 Currency

All values in this estimate are in Canadian Dollars ($CAD). The US Dollar ($USD) to Canadian Dollar exchange rate used in this estimate was $1 USD = $1.16 CAD based on the exchange rate as of January 2, 2015.

5.1.2 Federal, Provincial and State Tax

The applicable GST, PST, state and federal taxes are not included in this cost estimate.

5.1.3 Insurance

The estimate does not include provisions for Builder’s All Risk Insurance, Liability Insurance, or any other insurance required for a construction project of this type. It is expected that all suppliers, vendors and contractors will obtain and carry insurances appropriate to their level of responsibility and scope of work as per the specifications and supporting documentation. Additional studies may be required to determine the feasibility of purchasing project insurance coverage that would be applicable to suppliers, vendors and contractors so that the lowest cost of insurance is obtained.

5.1.4 Direct Capital Costs

The capital costs are based on the combination of direct and indirect costs. Direct capital costs are based on the proposed project scope, alignment information and relevant engineering information. The direct costs include material and labour costs for the transmission line and substation construction, including required clearing, grading and access road construction. The direct cost basis for the individual line components are as follows:

5.1.4.1 Clearing

Clearing costs assume that all existing vegetation is light brush or small trees, with no heavy timber. The majority of the length of the transmission line is assumed to require clearing, with the exception of the portions of the alignment within Whitehorse, Carcross and Fraser Customs, and a portion of the alignment starting 7 km from Skagway and stretching to the Canadian border, where tree growth is not significant. Clearing costs are based on a unit rate of $4,800 per hectare, which assumed 20% hand clearing and 80% machine clearing for the right-of-way. Right-of-way widths are provided previously in section 3.6.5 It is assumed that Route Option B (ATCO Right-of-Way from Carcross to Whitehorse) will only require clearing for the additional 4 m right-of-way width acquired to accommodate the new 138 kV conductors, while Route Option A (Highway) and Route Option B (Railway) will require clearing for their entire right-of-way widths.

5.1.4.2 Access Costs

Access costs are based on recent project experience. A unit cost of $1,000 per km was assumed for portions of the alignment within existing right-of-way. For portions of the alignment requiring access roads, a unit cost of $80,000 per km was assumed for rolling terrain requiring a compacted gravel surface, and $120,000 per km for rocky, mountainous terrain requiring a combination of a rock blasting with a compacted gravel surface. For portions of the transmission with very remote and steep terrain helicopter installation of steel Y-towers has been assumed in order to reduce access costs.

5.1.4.3 Structures

Structure material costs are based on available per pole costs for wood poles and components. For steel lattice structures, a unit cost of $5.00/kg was used, while a unit cost of $5.50/kg was used for foundation steel. A unit cost of $6.50/kg was used for steel pole structures. Structures are assumed to be direct-buried in gravel soil, or supported on concrete foundations with rock anchors for bedrock.

5.1.4.4 Overhead Conductors and OPGW

Conductor and optical ground wire (OPGW) material costs are based on available per kilometre costs for the conductor and OPGW sizes assumed in section 3.6.1. Conductor costs included allowances for armour rods and vibration dampers.

5.1.4.5 Submarine Cable

Submarine cable material costs are based on a per-kilometre cost for submerged cables plus a unit cost for the termination yards at either end of the crossing. A 1.2 long submarine cable is assumed for option C around Carcross. These costs are based on values for similar crossing sizes published in the Southeast Alaska Intertie Study Phase 1 Final Report by D. Hittle & Associates Inc., December 2003 and adjusted for inflation.

5.1.4.6 Substations

It is assumed that the transmission line will terminate in Whitehorse in the existing Yukon Energy Corporation's (YEC) Riverside substation. The Riverside substation currently has unused capacity for a new transmission line and is configured for 138 kV, so a high-voltage transformer is assumed to not be required. An estimate for the cost of upgrading to accommodate the new 138 kV transmission line was provided by the YEC; however, no breakdown of this cost was provided.

The new substation at the Skagway terminus of the line is assumed to be three to four acres in size and located near the intersection of Dyea Road and the Klondike Highway. The substation is estimated to require two 34.5 kV breakers, one 139 kV breaker and a step-up transformer rated 12/16/20 MVA. It is also projected to require a 12 MVAr Static VAR Compensator (SVC), which is a device that regulates voltage fluctuations in small, discrete steps in order to maintain a constant voltage. An SVC was assumed in lieu of switchable reactors in order to reduce the likelihood of switching surges and provide greater control over voltage fluctuations that can result from power transfer changes over the length of the transmission line. The cost estimate considers material and labour costs for clearing, grading (assuming a fairly flat site with gravel underlay), construction and equipment installation. The estimate is also based on the assumption that the cost of a new substation for the West Creek hydro generating facility will be included as a subcomponent of the cost of that facility.

5.1.4.7 Labour & Equipment

The averaged unfactored labour and equipment rate assumed for the work is $70.00 per worker-hour. The rate averages hourly wages across all trades and skill levels, and includes hourly equipment rates averaged across all workers. It assumes union labour rates. To this is applied a rate of 30% for contractor overhead and profit. The worker-hours required for construction tasks are based on published values from the National Electrical Contractor Association (NECA) Manual of Labour Units.

5.1.4.8 Productivity Allowances

A productivity factor was applied to labour rates. These rates are used to take into account craft skill and availability, climate, work week extension losses in productivity, travel time and local conditions. An allowance for 25% of the work occurring under winter conditions is assumed. The components of the productivity factor are summarized in Table 11 below. In addition to the base productivity factor, the estimate includes site specific productivity factors of 1.20 for work adjacent to the existing ATCO 34.5 kV line, 1.25 for work in steep mountainous terrain and 1.40 for work in swampy soils.

Table 11. Base Productivity Factor Components

Influence Factor Description	Productivity Loss
Craft Skill & Availability	25.0%
Climate / Winter Work	17.0%
Extended Work Week	7.5%
Union Influence	2.8%
Total Productivity Loss	52%
Base Productivity Factor	**2.10**

5.1.4.9 Indirect Costs

Indirect costs for the project include planning, property acquisition, permitting, survey and structure staking, engineering, project management, construction management, and owners' costs. Where more accurate data is not available these costs are based on historical values for similar transmission line projects in Yukon and southeast Alaska. Indirect costs are calculated as a percentage of the direct capital costs, and these are presented in Table 12 below.

Table 12. Indirect Costs as Percentage of Direct Costs

Indirect Cost	Percentage of Direct Costs
Planning	3%
Property Acquisition & Permitting	7%
Survey & Structure Staking	2%
Engineering	8%
Project Management	7%
Construction Management	5%
Owners' Costs	5%

5.1.4.10 Overhead, Interest and Contingency

The overhead and interest costs are based on historical values for similar transmission line projects in Yukon and southeast Alaska. They are taken to be 0.95% of the direct and indirect project costs.

A 15% contingency is applied to the direct and indirect project costs.

5.1.4.11 Exclusions

- Business development costs
- Financing costs
- Construction All Risk Insurance, liability insurance, or any other insurance types relevant to a construction project of this type
- Goods and services tax (GST), Provincial sales tax (PST), Alaska State and U.S. federal tax.
- Removal of hazardous materials
- Allowance for funds used during construction (AFUDC)
- Extraordinary site security & health and safety beyond normal construction security & safety.
- Ambulances and medical facilities
- Currency fluctuations beyond those specified in this Estimate
- Allowances for scope changes
- Event-driven risk
- Cost Escalations
- Escalation related to Owner's cost.

5.2 CAPITAL COST ESTIMATE

Cost estimates were prepared for the three alignment options outlined earlier in this report. For each alignment option, the cost of constructing the line with or without a fibre optic communication under-build was considered. Note that the estimate for the line construction without a fibre under-build does not include a provision for adding a future under-build; if the structures were designed to allow for future under-building the initial cost would approach that of the fully-installed fibre under-build case, minus the cost of stringing the fibre itself. The cost estimate summary is presented in the Table 13 and Table 14 below for the Alaskan and Canadian portions of the transmission line, respectively.

Table 13. Cost Estimate for Alaskan Portion of Transmission Line

Project Component	Cost No Fibre ($000 CAD)	Cost With Fibre ($000 CAD)
TRANSMISSION LINE		
Direct Cost		
Wood H-Frame Line Construction	1,285	1,408
Steel Tower Line Construction	7,793	8,678
Subtotal Direct Cost	***9,077***	***10,086***
Indirect Cost (% of Direct Costs)		
Planning (3%)	272	303
Property Acquisition & Permitting (7%)	635	706
Survey & Structure Staking (2%)	182	202
Engineering (8%)	726	807
Project Management (7%)	635	706
Construction Management (5%)	454	504
Owner's Costs (5%)	454	504
Subtotal Indirect Cost	***3,359***	***3,732***
Transmission Line Subtotal	**12,436**	**13,817**
SUBSTATION		
Direct Cost		
Skagway Substation	13,862	13,862
Subtotal Direct Cost	***13,862***	***13,862***
Indirect Cost		
Property Acquisition	70	70
Engineering	510	510
Project and Construction Management	418	418
Owner's Costs (5%)	693	693
Subtotal Indirect Cost	***1,691***	***1,691***
Substation Subtotal	**15,553**	**15,553**
TOTALS		
Transmission Line + Substation Subtotal	27,989	29,370
Overhead & Interest (0.95%)	266	279
Contingency (15%)	4,198	4,406
Total Cost	**32,453**	**34,055**

The cost estimate above does not include annual operating and maintenance (O&M) expenses.

Table 14. Cost Estimate for Canadian Portion of Transmission Line

Project Component	Option A New ROW along Highway		Option B ATCO ROW		Option C New ROW along Railway	
	No Fibre ($000 CAD)	w/ Fibre ($000 CAD)	No Fibre ($000 CAD)	w/ Fibre ($000 CAD)	No Fibre ($000 CAD)	w/ Fibre ($000 CAD)
TRANSMISSION LINE						
Direct Cost						
Clearing	1,844	1,844	1,185	1,185	1,892	1,892
Access Construction	9,340	9,340	7,091	7,091	12,292	12,292
Line Construction	35,519	46,490	47,395	60,832	38,385	50,083
Subtotal Direct Costs	***46,703***	***57,674***	***55,671***	***69,108***	***52,569***	***64,267***
Indirect Cost (% of Direct Costs)						
Planning (3%)	1,401	1,730	1,670	2,073	1,577	1,928
Property Acquisition & Permitting (7%)	3,269	4,037	3,897	4,838	3,680	4,499
Survey & Structure Staking (2%)	934	1,153	1,113	1,382	1,051	1,285
Engineering (8%)	3,736	4,614	4,454	5,529	4,206	5,141
Project Management (7%)	3,269	4,037	3,897	4,838	3,680	4,499
Construction Management (5%)	2,335	2,884	2,784	3,455	2,628	3,213
Owner's Costs (5%)	2,335	2,884	2,784	3,455	2,628	3,213
Subtotal Indirect Costs	***17,280***	***21,339***	***20,598***	***25,570***	***19,451***	***23,779***
Transmission Line Subtotal	**63,983**	**79,013**	**76,269**	**94,678**	**72,020**	**88,046**
SUBSTATION						
Direct & Indirect Cost						
Riverside Substation Upgrade	1,700	1,700	1,700	1,700	1,700	1,700
Substation Subtotal	**1,700**	**1,700**	**1,700**	**1,700**	**1,700**	**1,700**
TOTALS						
Transmission Line + Substation Subtotal	65,683	80,713	77,969	96,378	73,720	89,746
Overhead & Interest (0.95%)	624	767	741	916	700	853
Contingency (15%)	9,852	12,107	11,695	14,457	11,058	13,462
Total Cost	**76,160**	**93,587**	**90,405**	**111,750**	**85,478**	**104,060**

Several observations can be made from the cost estimate:

- Option A (Highway) is the least expensive from the perspective of capital cost. Option B (ATCO Right-of-Way) is approximately 19% more expensive than Option A, and Option C (Railway) is approximately 13% more expensive than Option A.

- The line construction costs of Option B are approximately 33% greater than those of Option A. This is due to several factors:

  - Option B must support the additional loading of the existing 34.5 kV ATCO circuit as an under-build.

  - Option B will require live-line work and existing structure removal in order to accommodate the replacement and relocation of the existing ATCO circuit.

- The additional line construction costs of Option B are partially offset by its access road costs being approximately 24% less than those of Option A. This is primarily due to Option A diverting away from the highway and existing ATCO right-of-way for approximately 30 km between Carcross and Whitehorse, while Option B follows the existing right-of-way very closely.

- The cost of the transmission line without the fibre optic under-build is comparable to the cost of transmission lines of similar configuration throughout Yukon and southeast Alaska. By way of example, for the 19 km Alaskan portion of the line is estimated at $0.76 CAD million /km; whereas the 93km Swan-Tyee 138kV line constructed with similar methods is reported to have had an average cost of $0.97 CAD million /km. The 151 km of the Canadian portion of has an estimated cost of $0.49 CAD million/km (for Option A without fibre); this can be compared with the recent 138 kV Carmacks-Stewart line, constructed in relatively gentler terrain, which had a report cost of about $0.275CAD million/km.

- Adding the capacity for a fibre under-build (whether initial or future) has a substantial increase on the cost of the line. The reasons for this are two-fold:

  1. A transmission line with no third-party communication under-build can be constructed to Grade 2 standards for the majority of its length; however, any transmission line with a third-party communication under-build are required to be constructed to Grade 1 standards (CAN/CSA C22.3 No.1-10 Clause 6.3.4). This has a substantial effect on the cost of the line, because Grade 1 structures are required to resist much higher structural loads than Grade 2 structures, which results in stronger structures with shorter spans.

  2. A third-party communication line must be under-built on a transmission line to facilitate maintenance access for the communication line. Because of the ground clearance requirements of these under-built communication lines, the structure heights must be extended or spans reduced.

5.3 TRANSMISSION LINE CAPITAL COST SUMMARY

Table 15 provides a summary of the interconnection project capital costs.

Table 15. Southeast Alaska-Yukon Transmission Line Cost Summary (CAD, 2014$)

		Option A New ROW along Highway		**Option B ATCO ROW**		**Option C New ROW along railway**	
		No Fibre $000 CAD	**With Fibre** $000 CAD	**No Fibre** $000 CAD	**With Fibre** $000 CAD	**No Fibre** $000 CAD	**With Fibre** $000 CAD
Transmission Line							
Total	170 km						
Alaskan portion	19 km						
Canadian portion	151 km						
Alaskan portion		32,453	34,055	32,453	34,055	32,453	34,055
Transmission Line		*14,420*	*16,021*	*14,420*	*16,021*	*14,420*	*16,021*
Substation		*18,033*	*18,033*	*18,033*	*18,033*	*18,033*	*18,033*
Canadian portion		76,160	93,587	90,405	111,750	85,478	104,060
Transmission Line		*74,188*	*91,616*	*88,434*	*109,779*	*83,507*	*102,089*
Substation Upgrade		*1,971*	*1,971*	*1,971*	*1,971*	*1,971*	*1,971*
Total Transmission Line		**108,612**	**127,642**	**122,858**	**145,805**	**117,931**	**138,115**

Transmission line costs are estimated to be between $108.6 million and $145.8 million (CAD, 2014$) depending on the right of way (ROW) option selected and on whether fibre options are included or excluded.

As provided in Table 15 above, the fibre options add about $19-$23 million to the cost of transmission line. Based on information available from the Government of Yukon, the cost of installation of fibre between Skagway and Whitehorse (as currently planned without use of the transmission line) is estimated to be in the range of $9.5 million, which is much lower compared to fibre options added cost to the transmission lines noted in the above tables. Accordingly, the financial feasibility analysis of the interconnection Project does not consider further the fibre option.

Taking into account the above cost options, the lowest cost option (Option A) without fibre option is assumed for the financial feasibility analysis to be the most economically feasible option compared to the other options provided in Table D-1. Accordingly, the Project capital cost of $108.6 million for Option A (no fibre) is used for the Base Case feasibility analysis. In contrast, the most costly Project option without fibre (Option B) is approximately 13% higher cost than Option A.

5.4 OPERATING AND MAINTENANCE COSTS

Annual operating and maintenance (O&M) expenses were derived based on actual operating cost experience reported by Yukon and Alaska utilities for similar transmission lines. Because these are actually experienced costs, they likely represent the best estimate of operating and maintenance costs. Table 16 provides a summary of estimated O&M costs for the transmission line

For the Canadian portion of the transmission line, O&M costs are assumed to be $1,410/km based on costs reported by YEC in their 2012-2013 General rate application (response to CW-YEC-1-18 which shows $1,390/km in 2013; adjusted by inflation to 2014 dollars). This includes brushing & clearing. It is assumed that incrementally higher O&M costs in the White Pass area due to challenging weather will be offset by the lower brushing & clearing requirements of the alpine terrain.

For the 19km (12 miles) of the line in Alaska, an O&M cost of $2,050/km O&M [CAD, 2014$] was used based on costs provided by Southeast Alaska Power Agency (SEAPA) who operate the majority of the cross country transmission lines in southeast Alaska. To this, an additional cost of $3,110/km added for brushing and cleaning [CAD, 2014$] for the first 7 km only of the Alaskan portion of transmission line. This cost is on the lower end of the brushing/clearing cost range provided by SEAPA and was selected because this transmission line is further north (and in a harsher climate) leading to reduced vegetation growth than the other lines operated by SEAPA.

Table 16. Summary of Operating and Maintenance Costs

	Alaskan Portion	Canadian Portion
Distance (km)	19 (12 miles)	151
O&M Cost / km [CAD, 2014$]	$2,050 ($1,770 US$2014)	$720
Clearing & Brushing / km [CAD, 2014$]	$3,110 ($2,680, US$2014) (first 7km/4 miles only)	$690
Subtotal / km [CAD, 2014$]	$3,195 ($2,750 US$2014)	$1,410
Total $/yr	**$273,630**	

6 FINANCIAL VIABILITY

The financial feasibility analysis (including related sensitivity analysis) for the transmission interconnection between southeast Alaska and Yukon was prepared by InterGroup Consultants. The complete analysis is provided in Appendix F. The following section provides an abbreviated version of this analysis.

The objective of the Southeast Alaska and Yukon Economic Development Corridor viability assessment (the “Project”) is to determine the technical and financial conditions under which an electrical interconnection between Yukon and Southeast Alaska would be viable and to identify the most viable scenario that represents the greatest net benefit to both governments. Net benefit is the net positive impact after consideration of all incremental benefits less all incremental costs. The objective would be for the Project to be developed in the public interest to foster local economic development.

The purpose of a transmission line such as the Project is to send electricity from one location to another in order to supply electrical load requirements at the least cost. To be financially viable, the transmission line requires the following conditions:

1. A demand for power (a sufficient load) at one end; and
2. A supply of power at the other end that can meet that demand on a cost competitive basis.

In the context of the Project, electricity moved over the interconnection is assumed to be used to displace higher cost thermal (fossil fuel based) generation. There exists the potential for power to move in both directions depending on load requirements and power availability. The financial feasibility analysis considered the specific conditions (electrical loads, system reliability and other potential uses of the corridor such as a telecommunications link) that would need to be present to make development of such a corridor viable.

The financial feasibility analysis builds on the June 2014 workshop and background papers that defined the two development scenarios for the analysis (see Section 2 of this report). This includes the forecast loads and competitive electrical supply conditions/options available as of June 2014. This now includes the technical feasibility analysis and cost estimates that were subsequently developed. Assumptions and forecasts adopted for cruise ship loads (shore-side power loads) and Yukon grid loads remain unchanged from the June 2014 workshop and documented in Appendix B. Some of these key data sources and their associated references are:

- Skagway-Haines area integrated grid loads: See Background Paper #1 in Appendix B for detailed assessment. Data from Southeast Alaska Ingrated Resource Plan (Black & Veatch, 2012),

- Cruise ship loads: See Background Paper #1 in Appendix B for detailed assessment. Data from Initial Sales Model: Upper Lynn Canal Cruise Ship Port Electrification by Alaska Power & Telephone (2014). For the Base Case of both Scenarios it is assumed all four cruise ship berths would be electrified and there would be full utilization of the shore-side power resulting in a 30 GWh/yr demand.

- Yukon grid loads & surplus: See Background Paper #1 in Appendix B for detailed assessment. Data from Yukon Energy Corporation Application for an Energy Project Certificate and an Energy Operation Certificate Regarding the Proposed Whitehorse Diesel – Natural Gas Conversion Project (Yukon Energy Corporation, 2013)

- Power production estimate from West Creek: Updated power production estimated prepared for this project to maximize transmission line utilization (ie. winter energy production)—see Appendix E for details. Data is from the Haines Skagway Region – Feasibility Study - Volume 4 – Supplemental Investigations (R.W. Beck, 1983)

- West Creek cost estimate: No contemporary feasibility-level cost estimate were available at the time of this Study. The 1983 cost estimate prepared by R.W. Beck was utilized and inflated to 2014 dollars. A different cost estimate was provided in Municipality of Skagway's 2012 Renewable Energy Fund Round 6 Grant Application; however this was for a different scheme at West Creek which did not focus on winter energy generation. Since this scheme would not make use of the transmission interconnection, it was not considered in the current study. All further references to West Creek hydro in the current study are based on the R.W. Beck (1983) feasibility study.

The financial feasibility analysis assesses the viability of the interconnection Project under each of the two Development Scenarios under the Base Case assumptions (see Appendix F, Attachment E) as well as the following sensitivity analyses:

1. Impact of Changes in assumed Capital Costs;
2. Impact of Changes in assumed loads and power sales rates; and
3. Impact of Changes in assumed Average Cost of Capital (6.5% and 4.5%).

The financial feasibility analysis for each Development Scenario and sensitivity assesses the potential recovery of Project costs through charges for electricity transmitted over the interconnection. This becomes the Project "charge rates" (the rate per kWh the Project can charge to recover the Project costs. These rates are based on assumed market constraints as well as estimated Project costs. Each analysis also identifies the amount of government funding support required if the assumed Project charge rates are not able to fully recover the Project costs. For the purposes of this study, this additional funding support is expressed on an annual basis as will be described further herein.

The analysis assumes, for simplicity, constant annual costs and revenues over the assumed economic lives of the constituent projects (the transmission line and West Creek hydro). This simplification is appropriate based on the current level of Project information and potential energy load forecasts.

The financial feasibility analysis uses the following methodology and approach:

- **Present value (PV) costs for the Project and West Creek Hydro are stated as fixed annual costs:** PV costs for the interconnection Project and West Creek hydro are each presented in CAD, 2014$ including the capital development cost and the O&M costs over the relevant project lives. The project lives were assumed to be 55 years for the transmission line and 90 years for West Creek hydro. Annual PV costs are assumed constant [in CAD, 2014$] over the respective economic lives. The project costs are expressed as an annual PV of $4.65

million/year for the transmission line and $13.28 million/year for West Creek Hydro. This approach ignores normal utility rate recovery for such a project which requires higher annual costs at the outset that decline over the economic life.

- **Assume constant annual generation, electrical loads and sales rates:** For simplicity, financial feasibility assumes constant annual generation, electrical demand (loads) and sales rates (in real CAD, 2014$). This approach removes the complexities of varying annual forecasts over the respective economic lives of the Project and West Creek hydro. This assumption is conservative because of the potential for Yukon grid winter load growth over the life of the Project. The assumption is also valid because it is likely that any significant new electrical generation projects in the Yukon will be hydropower based which will continue to produce an energy surplus in summer months. If the Project proceeds, further analysis will be needed to confirm that assumed conditions over the economic life will continue to sustain Project feasibility.

- **Determine Lifecycle Cost of Energy (LCOE) in $/kW.h:** The incremental LCOE transferred over the interconnection (the Project) is determined by dividing the PV annual costs by the quantity of electricity (energy) transmitted over the interconnection.

  For West Creek hydro the LCOE is determined by dividing the PV annual costs of the hydro project by the total quantity of electricity (energy) used to displace electricity produced by thermal generation in Alaska (cruise ships) and Yukon. See Appendix F, Attachment E for specifics for Scenario 1 and Scenario 2.

- **Assumed West Creek hydro sales rates (Scenario 1 only):**

  - **Cruise Ship Sales:** $0.27/kW.h (based on assumed cruise ship purchase power rate).

  - **Yukon Grid Sales**: $0.139/kW.h (based on residual West Creek hydro PV annual costs after sales revenues to Cruise Ships divided by sale of 47 GW.h/year to Yukon).

- **Determination of interconnection use rates for electricity transmitted by the Project**: The Project's annual charges [CAD, 2014$] for electricity transmitted to recover the transmission line's costs are estimated as follows:

  - **Scenario 1: Development with West Creek hydro**

    - **Yukon Grid Sales to Cruise Ships:** $0.140/kW.h which is the assumed cruise ship purchase power rate of $0.27/kW.h *less* the assumed Yukon grid blended rate for summer sales of $0.13/kW.h (mix of surplus hydro generation and LNG-fired generation in Scenario 1).

    - **Electricity Purchased by Yukon from West Creek hydro:** two rates are estimated**:**

      - <u>Maximum Rate for the Interconnection Project:</u> $0.026/kW.h which is the maximum rate the Yukon would pay for winter power, from the Project. This is the difference between the cost of LNG-based generation ($0.165/kW.h for Scenario 1) and the West Creek hydro sales rate to Yukon ($0.139/kW.h as defined previously under "Yukon Grid Sales" for West Creek hydro).

- Residual Rate to recover LCOE: lesser of the Maximum Rate *or* the rate needed to recover annual Project PV costs less revenues from Yukon sales to cruise ships.

- **Scenario 2: Development for Supply of Yukon Hydro to Cruise Ships**

  - **Yukon Grid Sales to Cruise Ships:** two rates are estimated:

    - Maximum Rate for the Project: $0.180/kW.h which the assumed sales rate to Cruise Ships of $0.27/kW.h, less the assumed Yukon cost of electricity for summer sales of $0.09/kW.h (a mix of surplus hydro generation and LNG-fired generation in Scenario 2).

    - Residual Rate to recover LCOE: lesser of the Maximum Rate *or* the incremental LCOE for electricity transferred over the interconnection ($0.155/kW.h for Scenario 2).

6.1 Scenario 1 Assessment - Development with West Creek Hydro Generation

Development Scenario 1 focuses on development of the transmission line corridor to supply power from the proposed West Creek hydro project to Whitehorse to displace growing thermal generation required on the Yukon grid in winter months. West Creek also provides hydro power to cruise ship loads in Skagway during summer months. Under this scenario the construction of the transmission line would be timed such that it is available when the West Creek hydro project is commissioned (i.e., the scenario in effect assumes the transmission line project is viable only with a West Creek hydro project).

6.1.1 Development Scenario 1: Base Case Financial Feasibility Analysis

The Base Case financial feasibility analysis for Development Scenario 1 assumes that 47 GW.h/yr of West Creek hydro sales are transmitted to the Yukon grid during winter months. An additional 5 GW.h/yr of Yukon surplus hydro and backup LNG generation sales are transmitted to Alaska cruise ships during early summer months. Development Scenario 1 assumes Project in-service no sooner than 2025, and reflects forecast loads for 2030. This assumes no new mines connected to the Yukon grid. The connection of new mine loads would improve the interconnection Project's use, assuming there is no completing new renewable generation supply on the Yukon grid.

Table 17 provides the Base Case financial feasibility assessment of Scenario 1. This includes assumed West Creek hydro costs and revenues. Highlights include the following:

- The incremental LCOE for power transmitted over the interconnection, or Project "sales," is $0.089/kW.h [CAD, 2014$], assuming 52 GW.h/year are transmitted over the Project which has an annual PV costs of $4.65 million.

- Estimated annual Project revenues are $1.92 million [CAD, 2014$] based on $0.7 million recovered for transmission of 5 GW.h for Yukon summer sales to cruise ships and $1.22 million recovered for transmission of 47 GW.h of West Creek hydroelectricity to the Yukon in the winter.
    - Project revenues are limited by the assumed cost for West Creek power. i.e. even after annual revenue of $6.75 million for summer sales to cruise ships, a rate of $0.139/kW.h is required to recover the balance of West Creek hydro costs from winter sales to the Yukon grid.
    - With the assumed Yukon grid maximum rate of $0.165/kW.h for power purchases (assuming LNG generation displacement), only $0.026/kW.h remains to cover the cost the transmission project under this scenario. $0.026/kW.h is the difference between the maximum rate in Yukon of $0.165/kW.h and the cost of energy from West Creek at $0.139/kW.h
- The overall result is that transmission interconnection Project viability for Scenario 1 requires approximately 59% external funding support, or in terms of PV annual costs, an external funding support of $2.72 million/year[8].

[8] Approximates $2.35 million in US$2014 based on US-CAN dollar conversion at $1 US=$1.16 CAD.

Table 17. Development Scenario 1 Financial Feasibility

	Scenario 1 Base Case	
	Intertie Project	**West Creek Hydro**
Economic Life (years)	55	90
Cost of Capital (%/year)	5.45%	5.45%
Real Discount Rate (2%/yr inflation)	3.38%	3.38%
PV Costs (CAD, 2014$million)		
Capital	108.612	327.036
O&M over economic life	6.783	45.923
Total	115.395	372.959
Annual Costs each year (CAD, 2014$million)	$4.649	$13.280
Thermal Loads Displaced each year (GW.h/yr)		
Cruise Ships	5.0	25.0
Yukon Grid	47.0	47.0
LCOE for sales (CAS, 2014$/kW.h)	$0.089	$0.184
Sales Rate (CAD, 2014$/kW.h)		
Cruise Ships purchase rate (displace diesel)	0.27	0.27
Yukon av summer sale rate (w losses, LNG backup)	0.13	
Yukon max winter purchase rate (displace LNG)	0.165	
West Creek Hydro rate for winter sales to Yukon	-	0.139
Intertie Use Rates [CAD, 2014$/kW.h])		
Summer Sales to Alaska Cruise Ships		
Assumed Rate ($/kW.h)	0.140	0.27
Winter Sales to Yukon Grid		
Residual Rate to recover LCOE ($/kW.h)	0.026	
Maximum Rate for Project ($/kW.h)	*0.026*	
Annual Revenues (CAD, 2014$million)		
Alaska Cruise Ships thermal displacement	0.700	6.750
Yukon Grid thermal displacement (Residual Rate)	1.225	6.530
Total Annual Revenues (Residual Rate)	1.925	13.280
Total Annual Revenues (Maximum Rate)	*1.925*	
Unrecovered Annual Cost (CAD, 2014$million/yr)	2.724	0.000
Percent of Annual Cost (%)	*59%*	*0%*
Funding Support Needed (CAD, 2014$million/yr)	2.724	
PV Annual Surplus at Max Rates (CAD, 2014$million/yr)	0.000	
Percent of Annual Cost (%)	*0%*	

6.1.2 Scenario 1: Financial Feasibility Sensitivity Analysis

Table 18 provides financial feasibility sensitivity analysis for Scenario 1. Highlights include the following:

- **Project Capital Costs:** +/-15% variance has modest impact

- **West Creek Hydro Capital Costs**: as there are no contemporary cost estimates for this project, it is subject to a wide range of possible costs. Should costs be lower than assumed in this analysis, it could have material impacts on financial viability.

    - A reduction of 10% from the Base Case cost reduces Project revenues shortfall to $1.40 million/yr (PV annual costs). An adjustment of the capital cost using US GDP deflator rather than US CPI would also reduce the Base Case costs more than 10% [i.e., 15%] and revenue shortfalls would be approximate $0.77 million/yr in PV annual cost terms.

    - A cost reduction of the West Creek hydro by 21% from the Base Case cost assumptions results in Project revenues adequate to recover the present value of annualized Project costs.

- **Cost of Capital:** changes in cost of capital can have material impacts on financial feasibility:

    - Increase of the nominal cost of capital to 6.5% [versus 5.45% in the Base Case] increases Project revenue shortfall (unrecovered PV annual costs) to $6.72 million/yr;

    - Reduction of the nominal cost of capital to 4.5% yields a PV Annual Surplus at Maximum Rates of $0.64 million.

- **Power Sales Volumes:** changes in power sales volumes can have material impacts on financial feasibility:

  The ability to displace 60 GW.h of Yukon thermal generation (versus 49 GW.h assumed in the Base Case) reduces Project revenue shortfall (unrecovered PV annual costs) to $0.58 million/yr;

    - In contrast, reductions in assumed loads sent to Yukon to 40 GW.h sales increases Project revenue shortfall (unrecovered PV annual costs) to $3.88 million/yr;

    - Removal of cruise ship loads for West Creek hydro and Yukon sales increases Project revenue shortfall (unrecovered PV annual costs) to $9.18 million.

- **Power Sales Rates:** changes in power sales rates [CAD, 2014$] can have material impacts on financial feasibility:

    - Increase of the Yukon maximum rate for power purchase (reflects thermal fuel and O&M costs displaced) to $0.20/kW.h [versus $0.165/kW.h in the Base Case] reduces unrecovered PV annual costs to $1.08 million; reduction of this maximum rate to $0.14/kW.h increases unrecovered PV annual costs to $3.90 million.

    - Increase of the cruise ship rate for power purchase to $0.30/kW.h [versus $0.27/kW.h in the Base Case] reduces unrecovered PV annual costs to $1.82 million; reduction of this maximum rate to $0.24/kW.h increases unrecovered PV annual costs to $3.62 million.

Combined changes in several of the identified factors could increase or offset the sensitivities assessed. For example, at the assumed power sales rates and capital costs, Scenario 1 would recover the transmission line Project costs if West Creek hydro costs were 15% lower (at $278 million) and Yukon thermal generation displacement higher by 5 GW.h/year to 52 GW.h/year.

Table 18. Development Scenario 1Sensitivity Analysis

Scenario 1 - Sensitivity Analysis	Unrecovered PV Annual Costs [CAD, 2014$ million/year]	PV Annual Surplus at Maximum Rates [CAD, 2014$ million/year]
Base Case Financial Feasibility	2.724	0.000
Project Capital Cost Variance:		
Project Capital Cost +15% [$125 M]	3.381	0.000
Project Capital Cost -15% [$92 M]	2.068	0.000
West Creek Hydro Capital Cost Variance:		
West Creek Capital Cost +25% [$409 M]	6.044	0.000
West Creek Capital Cost -10% [$294 M]	1.396	0.000
West Creek Capital Cost -21% [$258 M]	0.000	0.065
West Creek Capital Cost -25% [$245 M]	0.000	0.596
West Creek Capital Cost -50% [$163 M]	0.000	3.916
Cost of Capital		
Nominal cost of capital at 6.5% (real 4.41%)	6.717	0.000
Nominal cost of capital at 4.5% (real 2.45%)	0.000	0.642
Power Sales Volumes		
WC sales ships 25 GW.h, Yukon 81 GW.h	0.000	2.886
WC sales ships 25 GW.h, Yukon 65 GW.h	0.000	0.246
WC sales ships 25 GW.h, Yukon 60 GW.h	0.579	0.000
WC sales ships 25 GW.h, Yukon 55 GW.h	1.404	0.000
WC sales ships 25 GW.h, Yukon 40 GW.h	3.879	0.000
WC sales ships 20 GW.h, Yukon 53 GW.h	2.384	0.000
WC sales Yukon 53 GW.h (No Cruise Ships)	9.184	0.000
Power Sales Rates		
Yukon grid max purchase rate $0.20/kW.h	1.079	0.000
Yukon grid max purchase rate $0.18/kW.h	2.019	0.000
Yukon grid max purchase rate $0.14/kW.h	3.899	0.000
Cruise Ship purchase rate 0.30/kW.h	1.824	0.000
Cruise Ship purchase rate 0.24/kW.h	3.624	0.000
Yukon grid summer sales rate $.165/kW.h	2.899	0.000
Yukon grid summer sales rate $.10/kW.h	2.574	0.000

6.2 SCENARIO 2 ASSESSMENT - DEVELOPMENT WITH YUKON SUMMER HYDRO SURPLUS AND SKAGWAY CRUISE SHIP LOADS

Development Scenario 2 focuses on development of the Project transmission corridor independently of any new hydropower developments in the upper Lynn Canal area (such as West Creek hydro project). The transmission corridor would be developed initially to transmit surplus summer power from Whitehorse to Skagway to displace summer cruise ship diesel generation loads as soon as port electrification is completed in Skagway.

6.2.1 Development Scenario 2: Base Case Financial Feasibility Analysis

The Base Case financial feasibility analysis for Development Scenario 2 assumes that 30 GW.h/year of Yukon surplus hydro and backup LNG generation sales are transmitted to Alaska cruise ships during summer months. Development Scenario 2 assumes the transmission line Project in-service no sooner than 2020, and reflects forecast loads for the 2020 to 2030 time period assuming no new mines connected to the Yukon grid. Connection of new mines could reduce surplus hydro supply and thereby reduce Project viability, unless offsetting new renewable generation supply occurred on the Yukon grid.

Table 19 provides the Scenario 2 Base Case financial feasibility analysis. Highlights include the following:

- The incremental LCOE for power transmitted over the interconnection, or Project "sales," is $0.155/kW.h [CAD, 2014$]. This assumes 30 GW.h/year are transmitted over the Project which has annual PV costs of $4.649 million.

- Estimated annual Project revenues are sufficient to recover fully the transmission line Project's costs. The key factor affecting this recovery of the costs is the margin between the estimated cost of summer power production in the Yukon of ($0.09/kW.h) and the assumed cruise ships purchase power rate ($0.27/kW.h). Under the Base Case assumptions, this margin is $0.18/kW.h, and thus exceeds the threshold for the minimum Project "sales" rate of $0.155/kW.h.[9]

- Table 19 shows two rate revenues: "Residual rates" are limited to project cost recovery, i.e., $0.155/kW.h; "Maximum rates" equal the full margin over grid rates ($0.18/kW.h).

- The overall result is the Project financially viability under Scenario 2 and Base Case assumptions does not require additional government funding support. The estimated annual surplus revenue at maximum rates is 16% ($0.751 million per year.[10]) of the annualized present value of the project costs.

[9] This feasibility analysis does not address how the " revenue in excess of costs" (e.g., $0.025/kW.h in the Base Case for Scenario 2) is allocated. For example, this could be used to reduce the rate to cruise ships or increased Yukon grid rates for summer sales.

[10] Approximates $0.65 million in US$2014

Table 19. Development Scenario 2 Financial Feasibility

	Base Case Intertie Project
Economic Life (years)	55
Cost of Capital (%/year)	5.45%
Real Discount Rate (2%/yr inflation)	3.38%
PV Costs (CAD, 2014$million)	
Capital	108.612
O&M	6.783
Total	115.395
Annual Costs (CAD, 2014$million)	$4.649
Thermal Loads Displaced (GW.h/yr)	
Cruise Ships	30.0
LCOE for sales (CAD, 2014$/kW.h)	$0.155
Sales Rate (CAD, 2014$/kW.h)	
Cruise Ships purchase rate (displace diesel)	0.27
Yukon av summer sale rate (w losses, LNG backup)	0.09
Intertie Use Rates [CAD, 2014$/kW.h])	
Summer Sales to Alaska Cruise Ships	
Residual Rate to recover LCOE ($/kW.h)	0.155
Maximum Rate for Project ($/kW.h)	*0.180*
Annual Revenues (CAD, 2014$million)	
Residual Rate revenues to recover LCOE	4.649
Maximum Rate revenues	*5.400*
Unrecovered Annual Cost (CAD, 2014$million/yr)	0.000
Percent of Annual Cost (%)	*0%*
Funding Support Needed (CAD, 2014$million/yr)	0.000
PV Annual Surplus at Max Rates (CAD, 2014$million/yr)	0.751
Percent of Annual Cost (%)	*16%*

6.2.2 Scenario 2: Financial Feasibility Sensitivity Analysis

Table 20 provides financial feasibility sensitivity analysis for Scenario 2. Highlights include the following:

- **Project Capital Costs:** +/-15% variance has modest impact (surplus revenue is reduced, but is still positive with a 15% increase in transmission line Project capital costs).
- **Cost of Capital:** changes in cost of capital can have material impacts on financial feasibility**:**
  - Increase of the nominal cost of capital to 6.5% [versus 5.45% in the Base Case] results in a revenue shortfall (unrecovered PV annual costs) of $0.16 million/year;
  - Reduction of the nominal cost of capital to 4.5% increases surplus revenues to $1.51 million (in terms of PV annual surplus revenue).
- **Power Sales Volumes:** reductions in power sales volumes below the 30 GW.h/yr (which was assumed in the Base Case) can have material impacts of financial feasibility:
  - Reduction to 25 GW.h/yr results in a revenue shortfall (in unrecovered PV annual costs) of $0.15 million (3% of PV annual costs).
  - Reduction to 20 GW.h/yr results in a revenue shortfall of $1.05 million.
  - Each 5 GW.h/yr reduction in power sales volume reduces revenue (PV annual cost recovery) by $0.9 million or 19% of PV annual costs.
- **Power Sales Rates:** changes in power sales rates can have material impacts of financial feasibility:
  - An increase of the average rate for Yukon summer sales (reflects mix of surplus hydro and LNG based generation) to $0.15/kW.h (versus $0.09/kW.h in the Base Case) results in a revenue shortfall (unrecovered PV annual capital costs) of $1.05 million. Each $0.03/kW.h increase in the average Yukon summer sales rate reduces transmission Project's annual cost recoveries by $0.9 million (assuming 30 GW.h/yr sales).
  - Increase of the cruise ship rate for power purchase to $0.30/kW.h (versus $0.27/kW.h in the Base Case) increases revenues (PV annual surplus) to $1.65 million. Reduction of this maximum rate to $0.24/kW.h results in a revenue shortfall (unrecovered PV annual costs) of $0.15 million.

Table 20. Development Scenario 2 Sensitivity Analysis

Scenario 2 - Sensitivity Analysis	Unrecovered PV Annual Costs [CAD, 2014$ million/year]	PV Annual Surplus at Maximum Rates [CAD, 2014$ million/year]
Base Case Financial Feasibility	**0.000**	**0.751**
Project Capital Cost Variance:		
Project Capital Cost +15% [$125 M]	**0.000**	**0.094**
Project Capital Cost -15% [$92 M]	**0.000**	**1.407**
Cost of Capital		
Nominal cost of capital at 6.5% (real 4.41%)	**0.157**	**0.000**
Nominal cost of capital at 4.5% (real 2.45%)	**0.000**	**1.510**
Power Sales Volumes		
Summer sales to Cruise Ships 25 GW.h	**0.149**	**0.000**
Summer sales to Cruise Ships 20 GW.h	**1.049**	**0.000**
Summer sales to Cruise Ships 15 GW.h	**1.949**	**0.000**
Power Sales Rates		
Yukon grid summer sales rate $0.15/kW.h	**1.049**	**0.000**
Yukon grid summer sales rate $0.12/kW.h	**0.149**	**0.000**
Yukon grid summer sales rate $0.06/kW.h	**0.000**	**1.651**
Cruise Ship purchase rate at 0.30/kW.h	**0.000**	**1.651**
Cruise Ship purchase rate at 0.24/kW.h	**0.149**	**0.000**

The above analysis highlights the sensitivity of the Project financial feasibility analysis for Development Scenario 2 to changes in specific Base Case assumptions. Combined changes in several of the above factors could increase or offset the sensitivities noted. For example, at the assumed capital costs the impact of two possible combined changes in sales volumes and rates is shown below:

- Reduced sales to cruise ships of 25 GW.h/year at a rate of $0.25/kW.h and assuming Yukon cost of generation of $0.12/kW.h results in a revenue shortfall (unrecovered PV annual cost) of $1.4 million (or 30% of PV annual cost).

- Reduced sales to cruise ships of 20 GW.h/year at a rate of $0.25/kW.h and assuming Yukon cost of generation of $0.08/kW.h results in a revenue shortfall (unrecovered PV annual cost) of $1.25 million (or 27% of PV annual cost).

6.3 FINANCIAL FEASIBILITY DISCUSSION AND SUMMARY

The financial feasibility assessment has determined the following for each of the Development Scenarios considered:

- **Project viability for Development Scenario 1:** Under Base Case parameters Scenario 1 is not viable without external funding support equal to 59%, or $2.72 million/year,[11] of the present value (PV) annual costs. The estimated Project revenues are constrained by the assumed cost for power from West Creek hydro and the maximum rate that Yukon can pay for winter energy.

- **Project viability for Development Scenario 2:** Under Base Case parameters Scenario 2 is viable without government funding support. The interconnection "revenue" (present value (PV) annual surplus revenue) is 16% of PV annual costs, or $0.751 million per year[12]. The key factors affecting the recovery of costs is the assumed volume of summer sales (30 GW.h/year) and the assumed spread between the estimated cost of summer power production in Yukon and the assumed cruise ships' power purchase rate.

The transmission line Project on its own as per Scenario 2 under Base Case conditions appears to be financially feasible provided there is sufficient summer surplus hydro power and low cost thermal generation backup (e.g., LNG) available in Yukon. Scenario 2 requires cruise ship loads of about 30 GW.h/year to be supplied with shore power in summer months at the Base Case power purchase rates. However, the Project is not currently financially viable with Scenario 1 Base Case conditions due to the relatively high assumed cost of power delivered by West Creek hydro.

Sensitivity analysis undertaken for each Development Scenario indicates that changes in power sales volumes, power sales rates and the cost of capital can have a material impact on financial feasibility. Changes in capital cost for the Project have only a modest impact. For Scenario 1, financial feasibility of the Project is very sensitive to the development costs for West Creek hydro.

The financial feasibility has assumed a cost of capital based on recent Yukon Energy Corporation experience, as well as Project rates that are levelized over the Project economic life. Confirmation of specific ownership, financing and rate arrangements for the Project would be required in order to confirm the Project's financial feasibility.

Project viability under Scenario 2 is based upon a long-term opportunity to transmit surplus power during the summer months from the Yukon grid to cruise ships in Skagway. Sensitivity analysis confirms that financial feasibility of the Project with the Scenario 2 Development Scenario is reasonably robust. This assumes that cruise ships purchase an adequate amount of energy and power purchase rates are confirmed prior to actual development. With respect to the likely sustainability of Yukon summer surplus renewable energy generation and LNG backup generating capacity:

[11] Approximates $2.35 million in US$2014 based on US-CAN dollar conversion at $1 US=$1.16 CAD.
[12] Approximates $0.65 million in US$2014 based on US-CAN dollar conversion at $1 US=$1.16 CAD.

- The Yukon's hydropower-based energy system tends to have surplus renewable generation in summer months due to low average loads and excess renewable hydro generation. This is not expected to change in the foreseeable future.

- It is reasonable to expect future development of new renewable generation (to meet winter demands) with ongoing load growth.

- Access to summer sales in Alaska as assumed under Development Scenario 2 will enhance the viability of new renewable generation on the Yukon grid (for example a Next Generation Hydro project) This is because the sale of power to Alaska enhances the utilization of the new renewable generation.

- Development of the transmission interconnection Project under Scenario 2 would also create specific new opportunities for future hydro development in southeast Alaska and northwest BC, for example, Moon Lake.

- Backup LNG-fired generating capacity on the Yukon grid is also likely to increase in future in step with ongoing planned retirement of existing diesel generation units plus the need to increase backup capacity due to ongoing increases in the winter peak load.

In conclusion, Development Scenario 2 offers conditions where the interconnection Project between Yukon and Southeast Alaska would be financially viable and make sense to pursue in the near term.

This project remains challenging for any single entity to pursue, given the multiple jurisdictions and participants. The next steps to proceed with Development Scenario 2 for the earliest potential in-service of the interconnection Project (e.g., 2020) would likely require a joint Alaska-Yukon initiative to confirm if the relevant conditions to proceed can be established, including the following:

1. Confirmation of financial feasibility conditions, including:

    a) arrangements as needed for adequate cruise ship purchase power volumes and rates to be secured and supplied through shore-power by 2020 and for a reasonable period thereafter;

    b) arrangements as needed to define basic provisions for securing Yukon Energy surplus summer hydro and backup LNG generation. The future capacity of such generation to supply the potential cruise ship loads (taking into account capacity related requirements for multiple concurrent cruise ship loads) needs to be determined; and

    c) arrangements as needed to define basic provisions for the Project regarding ownership, financing, basis for rate charges for interconnection use (and how these may change as conditions change), and extent if any of government funding to support.

2. Confirmation of permitting and development requirements and timelines for the Project, preparation of the required assessment and regulatory submissions. This would also require the preparation of engineering designs and feasibility-level cost estimates for the Project to support such submissions.

7 SOCIAL-ECONOMIC & ENVIRONMENTAL BENEFITS & IMPACTS

7.1 ASSOCIATED ECONOMIC DEVELOPMENT OPPORTUNITIES

The financial feasibility presented previously establishes the primary economic opportunity of the transmission line. This represents the core "business case" or financial justification for the transmission line. In addition to these direct benefits the development of the transmission line could also facilitate future local economic opportunities. Potential users of the transmission line are both customers and generators of energy. However, at this time, there are no additional proposed projects or users of the transmission line that provide quantifiable projects that materially affect the financial viability of the interconnection at this time.

A key benefactor of a transmission interconnection is the cruise ship based economy in Skagway Alaska. The cruise ship industry is the major economic activity in Skagway. Not only does it create the majority of the seasonal employment to the community, but it is also a major source of municipal revenue. As noted previously, provision of shore-side power to the cruise ships is fundamental to the viability of the transmission line. Providing the cruise ships with shore side power can potentially represent additional benefit or competitive advantage as a destination port. To be attractive, the power would likely need to be provided to the cruise ships at a rate that represents cost saving over on-board electrical generation with fossil fuels.

The following is a qualitative identification of known possible future economic opportunities that may benefit from the transmission line in absence of other specific proposed projects or developments whose benefit from the interconnection can be monetized at this time. Generally these opportunities consist of:

1. potential new customers (residential, commercial or industrial); and
2. new electrical supply sources, namely hydropower projects.

7.1.1 New Residential & Commercial Customers

With respect to customers, there are currently no significant un-serviced commercial or residential customers or communities between Skagway and Carcross as the region is essentially unpopulated. The highway camp and customs station at Fraser is already served by a mini-hydro development. Provision of power to individual customers from the 138kV transmission line would likely be cost prohibitive due the requirement of a substation to transform the power to distribution voltages.

The community of Carcross is already served by ATCO Electrical Yukon's 34.5kV line from Whitehorse. A new 138 kV transmission line from Whitehorse to Skagway could potentially reinforce the existing service to Carcross, however this would require a new substation in Carcross. This additional substation would raise the cost of the transmission line by several million dollars and therefore does not fundamentally improve the economic viability of the interconnection which is the focus of the current Study. The service benefit of reinforcing the electrical transmission system to Carcross should be assessed further if it is decided to proceed with the development of the southeast Alaska-Yukon interconnection.

7.1.2 Industrial Customers

Industrial customers are primarily mines. Unfortunately the mineral potential between Skagway and Carcross is limited and there are no operating mines in this region or any new mines proposed or in development. The nearest operating mine is Coeur Alaska, Inc.'s Kensington Mine which is an underground gold mine located 75 km south of Skagway. The mine opened in summer 2010 and has stated mine life of 10 years. The project uses on-site diesel electric generation with approximately 6 MW of generating capacity installed on-site.

An inventory of known mineral deposits in the vicinity of the Southeast Alaska and Yukon Economic Development Corridor can be used as an indicator of potential projects in the long-term in absence of any current industrial projects in development. However these deposits can give a general indication of the long-term potential opportunities in the region. A mineral deposit is an explored mineral occurrence with a defined ore-body with a published tonnage and grade. Known mineral deposits were extracted from the Yukon and BC's MINFILEs and the Alaska Resource Data Files (ARDF) for the region near the economic development corridor. Table 21 lists the known deposits, their tonnage and estimated power requirements based on deposit size[13]. The location of these deposits is shown on Figure 10.

As can be seen in Table 21 the mineral development potential in the region is relatively low. Other than the Kensington Mine, there are no other major industrial customers proposed in the region or under development. There are few mineral deposits in the region and most are very small or highly unlikely to be developed. The most advanced of these is the Palmer deposit 60 km northwest of Haines, Alaska.

[13] Power and energy requirement are estimated from the Society of Mining Engineers' Handbook (Hartman 1992) using deposit size. For a further discussion, see the report entitled "Research Services for Yukon Mineral Industry Power Demand", Gartner Lee Limited 1997 prepared for Government of Yukon Department of Economic Development.

Table 21. Known mineral deposits near the SE Alaska-Yukon Economic Development Corridor

Deposit Name (MINFILE / ARDF #)	Location	Commodity & comments	Reported Tonnage (million tonnes)	Dist. from T-Line (km)	Peak Power Demand (MW)*	Energy Demand (GWh/yr)*
Mt Skukum (105D 158)	Wheaton River Valley	Underground Gold. Past producing mine in 1980's	0.1	65	1.4	7
Skukum Creek (105D 022)	Wheaton River Valley	Underground Gold	0.5	65	2.7	14
Venus (105D 005)	Montana Mountain	Silver, lead & Zinc. Historic mine. Majority of Montana Mountain is Carcross-Tagish FN Settlement Lands	0.1	0	1.4	7
Bighorn (104M 006)	South of Fantail Lake	Historic silver, lead & zinc veins	0.07	35-45 km	1.2	6
Klukwan & Klukwan Fan (SK030 & SK031)	25 km NW of Haines along the Haines Road	Iron – site was withdrawn from development until recently and there is no current exploration or development activities associated with the deposit.	500	55 km from Skagway	34	277
Palmer (SK066)	60 km NW of Haines AK	Polymetallic volcanogenic massive sulfide deposit under active exploration by Constantine Metal Resources Ltd.	4.75	90 km from Skagway	6	38

Notes:

* Power and energy requirement are estimated from the Society of Mining Engineers' Handbook (Hartman 1992) using deposit size.

7.1.3 Hydropower Development Opportunities

In additional to energy customers there are potential energy development projects that could benefit from a transmission line between the upper Lynn Canal and Whitehorse. These projects could be developed by either the public electrical utilities or potentially by independent power producers.

Table 22 identifies the known hydropower sites in the vicinity of the Southeast Alaska-Yukon Economic Development Corridor. The location of these sites is shown on Figure 10.

Table 22. Known hydropower opportunities near the SE Alaska-Yukon Economic Development Corridor

Hydropower Site	Location (Distance to T-line)	Estimated Capacity (MW)	Estimated Energy (GWh/yr)	Comments
Tutshi Lake	Tutshi Lake to Windy Arm (<1km)	6	35	Transmission line to Carcross estimated to be 18% of original project cost.
Moon Lake	East side of Tutshi Lake (1 to 5 km)	5.8	30	Potential high-head site in northern BC. Transmission line to Carcross estimated to be 25% of original project cost.
Homan Lake	West of Bennett (15 km)	4.2	23	Reconnaissance study only
Fraser	Existing mini-hydro site at Fraser customs & highways maintenance station	0.25 currently installed capacity	unknown	Site has potential for expansion. Owner declined to indicate scale of expansion potential.
West Creek	West of Dyea (9km)	20-25	106	See Section 4 of this report
Burro Creek	West side of Lynn Canal across from Skagway (3 km)	3.4-7.3	12-20	From Burro Creek Hydroelectric Feasibility Study, 2011
Connelly Lake	25 km NW of Haines, AK (40 km from Skagway)	6-12	35 - 44	Information from 2012 AP&T FERC application
Schubee Lake	East side Lynn Canal south of Skagway, (11 km)	4.9	37	Reconnaissance study conducted in 2013 by AP&T. Limited winter energy.
Walker Lake	5 km west of Klukwan (65km from Skagway)	1-2	3	From SE Alaska Integrated Resource Plan

Figure 10. Economic Development Opportunities near the SE Alaska – Yukon Economic Development Corridor

7.2 ENVIRONMENTAL AND SOCIAL BENEFITS AND IMPACTS

Development of an electrical interconnection between Whitehorse Yukon and Skagway Alaska would have environmental and social benefits and impacts beyond that monetized in the financial analysis completed as part of this study. There are potential other economic benefits as discussed in the previous section.

Environmental and social impacts (and to a lesser degree benefits) are assessed as part of the regulatory processes.

A few of the more significant and key environmental and social impacts are identified as follows. Note that this list is not intended to be comprehensive or definitive, but rather highlights some of the more substantive benefits and impacts that should be considered. These additional benefits and impacts have not been factored into the financial viability assessment conducted in this current study but should be considered in decision making and future work.

7.2.1 Environmental Benefits & Impacts

Greenhouse Gas Emission Reductions

Development Scenario 1 greenhouse gas emission (GHG) reductions are achieved by displacing fossil fuel usage for power generation by the cruise ships in Skagway primarily with renewable energy from West Creek hydro. Additional GHG reductions are achieved by displacement of fossil-fuel based electrical generation in the Yukon during winter months. This is offset by increased fossil fuel electrical generation (assumed to be LNG based) in Yukon to meet spring-shortfall to meet cruise ship demand. Total GHG reductions are estimated at 44,500 tonnes CO_2e / yr as follows:

- Cruise ship GHG reductions: 25,300 tonnes CO_2 / yr (based on 30 GWh/yr delivered)[14]
- Winter fossil-fuel based electrical generation GHG reductions in Yukon: 20,400 tonnes CO_2e/yr (based on 47 GWh/yr delivered)[15]
- GHG emission from Yukon fossil-fuel based electrical generation for cruise ships: +1,300 tonnes CO_2e / yr (60% of the 5 GWh/yr delivered being produced by LNG generation)

[14] The efficiency of electrical generation with Marine Fuel Oil is assumed to be 3.7kWh/L. Greenhouse gas emission factor of 3.124 kg/L has been used based on Environment Canada's National Inventory Report for heavy fuel oil ships.

[15] This assumes displacement of LNG based electrical generation with an emission factor of 0.435 t/MWh of CO_2e as reported in YEC's Yukon Utilities Board Application for Energy Certificate and Energy Operation Certificate Regarding the Proposed Whitehorse Diesel – Natural Gas Conversion Project: http://yukonutilitiesboard.yk.ca/proceedings/yec-lng-project-proceeding/

Development Scenario 2 greenhouse gas emission (GHG) reductions are achieved by displacing fossil fuel usage for power generation by the cruise ships in Skagway with energy from Yukon. This is offset by increased fossil fuel electrical generation (assumed to be LNG based) in Yukon to meet spring-shortfall to meet cruise ship demand. Total GHG reductions are estimated at 21,400 tonnes CO_2e/yr as follows:

- Cruise ship GHG reductions: 25,300 tonnes CO_2 / yr (based on 30 GWh/yr delivered)
- GHG emission from Yukon-based fossil fuel based electrical generation for cruise ships: +3,900 tonnes CO_2e / yr (30% of the 30 GWh/yr delivered being produced by LNG-fired generation)

Air Quality Improvement

Emissions from cruise ships in the Port of Skagway are causing local degradation of air quality. The emissions result in a notable haze in viewsheds and odors throughout Skagway. This negative impact from the cruise ships on the community, the local environment and degradation to visitor experience has been a significant concern for the Municipality of Skagway. This issue is the major incentive for commissioning of this transmission interconnection study. Studies conducted by National Park Services (Schirokauer et al., 2014) have determined measurable impacts to local vegetation associated with emissions; however the significance of this impact was not stated. The study also noted that given the proximity of the community to the emission source(s) that there is potential concern to human health related to fine particulates, polycyclic aromatic hydrocarbon (PAH) compounds and metals.

Photo 12. Heavy haze from cruise ships at dock in Skagway, July 2014

A 2008 study by US Forest Services determined that cruise ships are responsible for 73% of nitrogen oxide (NOx) emissions and 99% of sulfur dioxide (SO_2) emissions in Skagway. No estimates were presented for fine particulate emissions. It is reasonable to assume that a significant improvement in air quality would be achieved if cruise ships utilizing shore-side power when in port. Using NOx and SO_2 as general air quality indicators, the benefit of the project would be it could result in up to a 73% reduction in local NOx emissions and up to a 99% reduction of SO_2 emissions.

Facilitate Future Renewable Energy Project Development

The development of the Southeast Alaska and Yukon transmission interconnection could facilitate the development of future renewable energy projects and hydropower project in particular. Development of additional hydropower resources in the region would result in the environmental benefit of reduced future fossil fuel requirements to meet the region's growing electrical needs. The list of potential hydropower sites in the region is provided in Table 22. In particular, two sites along the transmission line, Moon Lake and Tutshi Lake, would benefit from the transmission line because it would reduce the estimated energy costs from these projects by 25% and 18% respectively.

Project Footprint

The most direct environmental impact from the project would be the vegetation clearing and land surface disturbance from the transmission line's right of way. Total new right-of-way footprint of the three alignment options is:

- Options A (New right of way along South Klondike Highway): 410 ha
- Option B (Rebuild on ATCO's right of way): 270 ha
- Options C (New right-of-way along WP&YR): 410 ha

Option B has a significantly lower project footprint because it requires only widening the existing right-of-way by 4 m as opposed to a new 23 m right of way from Carcross to Whitehorse.

7.2.2 Social Benefits & Impacts

Many of the economic benefits (e.g. role of the cruise ship industry in the economy of Skagway) are inextricably linked to social benefits. Therefore social benefits and impacts should be considered jointly as socioeconomic benefits and impacts. A few of the additional social benefits and impacts that should be considered in association with the transmission interconnection include:

Air Quality in Skagway

Air quality improvement was discussed previously as an environmental benefit. This also has several social benefits:

- As noted in the 2014 air quality study, there are likely health benefits to Skagway residents from improved air quality.
- Overall aesthetic and visual improvement to the valley for Skagway residents.
- Overall more attractive visitor experience to Skagway as a pristine northern destination not marred by emission haze and smog.

Yukon-Alaska Community Development

Development of a transmission interconnection between Yukon and Southeast Alaska will help build the social and cultural connection between the two communities. The sharing of resources (in this instance, renewable energy) and mutually supporting and enhancing trade between the communities builds societal connections. Quantifying the value of strengthening community relations is beyond the scope of this current study; however, it is known stronger social connections between communities builds community resilience and overall wellbeing of the citizens.

Electrical Grid Reinforcement

An additional benefit of a new transmission line could be improved electrical grid resilience for the Carcross valley. The benefit of this was not assessed in the current study because it did not positively affect the basic financial viability of the transmission interconnection between Whitehorse and Skagway. Supplying Carcross from the transmission line would require an additional substation in Carcross. The additional cost of the substation does not enhance the basic business case of the transmission line; however, there are additional benefits that should not be overlooked. From a social perspective, if Carcross was also supplied from the new transmission line there could be reduced outages (or reduced extent/duration of outages) in the Carcross area. An additional benefit of Option B (rebuild on ATCO's right-of-way) would be the replacement of ATCO's aging distribution line in the Carcross valley.

Traffic Disruption During Construction

During construction traffic along the South Klondike Highway south of Carcross will likely be disrupted by construction activities. These disruptions would likely result in minor delays occurring over the span of a single construction period.

Visual Impacts

The construction of the line will result in visual impacts to the viewshed along the South Klondike Highway. This will be most significant south of Carcross where the line will either be in close proximity to the roadway due to topography, or in areas of little vegetation cover such as the White Pass. The alignment chosen for most of the route is on the upslope (west) side of the highway to help minimize the view from the highway. In the vicinity of White Pass two alternative alignments are shown that may help mitigate viewshed impacts.

8 CONCLUSIONS & RECOMMENDATIONS

8.1 CONCLUSIONS

Based on the Development Scenarios prepared for this study, it is concluded that:

Technical Feasibility

1. A 138kV transmission line between Skagway and Whitehorse is required to deliver the power required at either end of the Project (ie. up to 20MW).
2. The northern terminus of the transmission line is most logically the Riverside Substation at Yukon Energy's Whitehorse Rapid Generating Station.
3. Construction and operation of a transmission line over the rugged White Pass is technically feasible using existing and proven transmission line designs from Yukon and Alaska.
4. Capital cost for a new transmission line, without a fibre optic underbuild, is estimated at between $109 million and $123 million [CAD, 2014$] ($94 to $106 million US$2014[16]) depending on the alignment selected.
5. Combining the fibre optic link with the transmission project is more costly than burying the fibre optic cable separately from the transmission line. As there appears to be no economic benefit to combining the projects, this indicates that both projects can proceed independently of each other without raising concerns about missed opportunities.

West Creek Hydro

1. A high-level review of the West Creek hydroelectric site was conducted and it appears to be a reasonably attractive hydropower site. It was studied extensively in the early 1980's but has received little further study until recently by the Municipality of Skagway. The current review of the site was carried out a component of the Development Scenarios to better understand the availability of public power from the West Creek site.
2. There are multiple configurations that could be developed for West Creek hydro resulting in a range of project costs and capacities. For the purposes of the current study, a power generation arrangement for the West Creek hydro was selected that maximized winter power production in order to maximize utilization of the transmission interconnection in Scenario 1. Under this generation scheme West Creek supplies the majority of the cruise ship's shore-side power needs and supplies 47 GWh/yr to Yukon in winter months.
3. There has been no contemporary feasibility-level assessment of the capital cost for West Creek hydro development. For the purposes of the current study, the 1983 cost estimate for a 20MW project was inflated to 2014 dollars using the US Consumer Price Index (a sensitivity analysis was also conducted using the US GDP deflator as an alternative).

[16] Based on US-CAN dollar conversion at $1 US=$1.16 CAD as of January 2, 2015.

Financial Feasibility

1. Supply of cruise ship port electrification power, or "shore-side power," is fundamental to the viability of a southeast Alaska-Yukon electrical transmission interconnection under all reasonably foreseeable development scenarios. It is estimated that the cruise ships could consume up to 30 GWh/yr (during May to September) if all cruise ships utilized shore-side power.
2. Development of the transmission interconnection is financially viable in the near-future, without external financial support (subsidy) under Scenario 2. This is based on supply of the cruise ships with 30 GWh/yr of electricity during summer months primarily from surplus Yukon hydroelectricity. Loads of less than 30GWh/yr would likely require external financial support.
3. Development Scenario 1, which consists of co-development of West Creek hydro for supply of summer energy to cruise ships and winter energy to the Yukon, requires external support (subsidy) on the order of 59% of the transmission interconnection's capital and operating costs.

Economic, Social and Environmental Benefits

There are substantive local economic development, social and environmental benefits from a transmission interconnection project beyond that which was monetized in this current study. Some of the key additional local benefits include:

1. This study identifies that there is a reasonable, currently available and potentially financially viable energy supply option with the transmission line for the electrification of the Skagway cruise ship port.
2. There are no significant new additional customers (or loads) in the reasonably foreseeable future in the vicinity of the transmission line. Specifically there is relatively limited potential for new industrial customers, such as mines, near the economic development corridor.
3. Development of the transmission line could facilitate the development of additional hydropower projects in the region. There are at least 280 GWh/yr of known hydropower schemes (including West Creek) in the region that could utilize the transmission line. For some projects, such as Moon Lake hydro in northern BC, pre-development of the transmission line could reduce the previously estimated levelized cost of energy for the project by up to 25%.
4. Development of the transmission line could also provide additional benefits to the Yukon electrical grid such as redundancy and/or refurbishment of transmission lines in the Southern Lakes regions. The value of these benefits have not been assessed in this current study.
5. Significant greenhouse gas emission reductions could be realized by the development of the electrical interconnection. These reductions could be on the order of 44,500 and 21,400 tonnes of CO_2e / year for Scenario 1 and 2 respectively.
6. Significant improvement in Skagway summer air quality could be achieved by full electrification of the Skagway cruise ship port. If all cruise ships took advantage of shore-side power, almost a 73% reduction in NOx and 99% reduction in SO_2 emissions could be achieved.

8.2 RECOMMENDATIONS

It is recommended that:

1. Continued work on the assessment and development of the electrical transmission interconnection component of the Southeast Alaska and Yukon Economic Development Corridor is pursued. Given the international benefits of this project and multi-jurisdictional consideration, leadership from the governments of Yukon and Alaska is warranted to advance the Project. This includes:

   - Confirmation of the parties needed to move the Project forward such as the utilities, Municipality of Skagway and potentially other private entities.

   - Determine funding sources for the next phase of work. Work with the parties to establish a framework and next steps of confirming project feasibility.

   - A goal could be a MOU within the 2015 fiscal year to confirm the key parties and specific work plans to move the project forward.

2. A business case for the electrification of the Skagway cruise ship port be prepared to confirm the business case for the transmission project under Scenario 2. This business case should include, but not be limited to:

   a) Engineering and costs estimates for shore-side power infrastructure;

   b) Arrangements as needed for adequate cruise ship purchase power volumes and rates to supply shore power by 2020 and for a reasonable period thereafter.

   c) Determine phase-in of cruise ship loads, electric rates to be paid and long-term market stability.

   d) Confirm rates for power delivered to Skagway from Yukon and associated transmission and distribution costs.

   e) Benefits of working collaboratively in the near future to keep project momentum.

3. Other financial feasibility conditions for the Project assuming Scenario 2 be confirmed, including:
   a) Arrangements as needed to define basic provisions for securing Yukon surplus summer hydro and backup fossil-fuel (in particular LNG) based generation. The future capacity of such generation to supply the potential cruise ship loads (taking into account capacity related requirements for multiple concurrent cruise ship loads) needs to be determined; and
   b) Arrangements as needed to define basic provisions for the Project regarding ownership, financing, basis for rate charges for interconnection use (and how these may change as conditions change), and extent if any of external (government) funding to support.

4. Permitting and development requirements and timelines for the Project be confirmed for preparation of the required assessment and regulatory submissions. This would also require the preparation of engineering designs and feasibility-level cost estimates for the Project to support such submissions.

5. Future engineering work should also include further assessment of additional equipment required for the relatively low-capacity and exposed transmission system. This is to ensure the system reliability is acceptable, economies are realized, and operational coordination is achieved.

6. Future work on the transmission line assessment should include potential synergies with other power development opportunities (ie. Moon Lake) and system benefits such as grid redundancy and/or reinforcement in the Southern Lakes region. Future assessment should also consider a phased approach to development of the transmission line.

7. A contemporary feasibility-level cost estimate is prepared for West Creek hydro in order to re-evaluate the assumptions utilized in this current analysis.

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APPENDIX A:
Transmission Line Concept Route Maps

APPENDIX B:
Development Scenarios Workshop Report

APPENDIX C:
Skagway-Whitehorse Interconnection System Analysis

APPENDIX D:
Transmission Line Design Criteria

APPENDIX E:
West Creek Hydro Technical Review

APPENDIX F:
Southeast Alaska & Yukon Economic Development Corridor: Financial Feasibility Analysis