Appendix 5.7
Small Hydro Screening Assessment
(Knight Piesold 2016)

YUKON ENERGY CORPORATION
SMALL HYDROELECTRIC PROJECTS

SCREENING ASSESSMENT

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YUKON ENERGY CORPORATION
SMALL HYDROELECTRIC PROJECTS

SCREENING ASSESSMENT
VA103-556/2-2

Rev	Description	Date
0	Issued in Final	October 7, 2016

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EXECUTIVE SUMMARY

Yukon Energy Corporation (YEC) commissioned Knight Piésold Ltd. (KP) to conduct a desktop review of potential small hydroelectric projects in the Yukon and northern British Columbia. The objectives of the study were to compare technical and economic development criteria and to establish a ranking that provides YEC with the basis for further studies.

This study utilized a four stage screening process to identify the best development options from a list of forty five sites:

- Screen 1: Removal of Redundant Sites and Sites Located in Parks (44 reduced to 40 Sites)
- Screen 2: Removal of Sites with Excessive Transmission Lengths (40 reduced to 23 Sites)
- Screen 3: Unit Cost of Energy Screening (23 reduced to 5 Sites), and
- Screen 4: Focused Assessment of Preferred Options (Top 5 Sites).

The screening process yielded the following results:

- The most attractive (preferred) projects, based on a desktop level assessment of location, project layout, site characteristics, capacity, energy, and cost, are Drury Lake, Finlayson River, Anvil Creek, Tutshi – Windy Arm, and Wolf River.
- The Levelized Cost of Capacity (LCOC) for the preferred sites ranges from $700 to $1,200/kW-yr at the YEC real interest rate of 3.38 percent.
- The Levelized Cost of Energy (LCOE) for the preferred sites ranges from $0.13 to $0.21/kWh at the YEC real interest rate of 3.38 percent.
- Based on a stand-alone assessment of hydropower development and interconnection to the closest existing or proposed transmission line, the most attractive small hydro sites are the Finlayson River, Wolf River, and Tutshi – Windy Arm. Drury Lake and Anvil Creek appear to be more expensive on a cost of energy basis.
- The optimal installed capacities for the Finlayson River, Tutshi – Windy Arm, and Wolf River Projects are likely in the order of double those used in the present study. 20 MW was the upper bound cap for this study based on the purpose set out in the RFP (to evaluate sites of 20 MW or less).
- The Tutshi – Windy Arm Project has the additional benefit of increasing the winter generation at the Yukon Generating Station downstream.
- If the Moon Lake – Tutshi Lake pumped storage project is developed, it may have material synergies with development of the Tutshi – Windy Arm small hydro project.

The optimal small hydro site will depend on a number of factors, including capital costs, desired capacity, development of proposed transmission lines, environmental impacts, and social conditions. Further evaluation of the preferred sites is recommended to improve the understanding of engineering, economic, environmental, and social factors impacting project development. Should such assessment indicate that there are no technical or environmental showstoppers, further evaluation of the sites through pre-feasibility and feasibility studies should be pursued to prove economic viability.

The table below summarizes the key financial and technical attributes for the five preferred sites.

ATTRIBUTES	Drury Creek	Finlayson River	Anvil Creek	Tutshi - Windy Arm	Wolf River
TECHNICAL:					
Installed Capacity (MW)	8.1	17.6	9.8	7.2	20.0
Net Annual Generation (GWh)	31.7	138.9	41.3	56.6	95.6
Mean Annual Discharge (m^3/s)	4.9	16.5	4.1	16.1	40.3
Design Flow - Qd (m^3/s)	9.3	13.3	8.2	15.0	37.7
Gross Head (m)	99	150	135	54	60
Transmission Line Length (km)	1	5	11	1	23
FINANCIAL:					
Estimated Capital Cost	$ 97,250,000	$ 265,990,000	$ 109,210,000	$ 125,400,000	$ 220,170,000
O&M Costs - Fixed ($/yr)	$ 1,945,000	$ 5,320,000	$ 2,184,000	$ 2,508,000	$ 4,403,000
O&M Costs - Variable ($/yr)	$ 158,000	$ 695,000	$ 207,000	$ 283,000	$ 478,000
YEC Rate Scenario (3.38%)					
Levelized Cost of Energy ($/kWh)	$ 0.19	$ 0.12	$ 0.17	$ 0.14	$ 0.14
Levelized Cost of Capacity ($/kW-yr)	$ 700	$ 1,000	$ 700	$ 1,100	$ 700
IPP Rate Scenario (4.61%)					
Levelized Cost of Energy ($/kWh)	$ 0.23	$ 0.14	$ 0.20	$ 0.17	$ 0.17
Levelized Cost of Capacity ($/kW-yr)	$ 900	$ 1,100	$ 800	$ 1,300	$ 800
High Interest Rate Scenario (8.82%)					
Levelized Cost of Energy ($/kWh)	$ 0.24	$ 0.15	$ 0.21	$ 0.18	$ 0.18
Levelized Cost of Capacity ($/kW-yr)	$ 900	$ 1,200	$ 900	$ 1,400	$ 900

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ABBREVIATIONS

C	loaded capital cost
CFRD	Concrete Faced Rockfill Dam
DFO	Fisheries and Oceans Canada
EPCM	Engineering, Procurement and Construction Management
GWh	gigawatt hour
IFR	Instream Flow Requirement
km	kilometre
KP	Knight Piesold Ltd.
LC	levelized capital cost per year
LCOC	Levelized Cost of Capital
LCOE	Levelized Cost of Energy
m	metre
m^3	cubic metre
Mm^3	million cubic metre
m^3/s	cubic metre per second
MAD	Mean Annual Discharge
MAUD	Mean Annual Unit Discharge
MW	megawatt
MWh	megawatt hour
Q_d	design flow
WAF	Whitehorse – Aishihik – Faro (transmission grid)
WSC	Water Survey of Canada
YDC	Yukon Development Corporation
YEC	Yukon Energy Corporation
YECL	Yukon Electrical Company Ltd.
yr	year

1 – GENERAL

1.1 INTRODUCTION

Yukon Energy Corporation (YEC) commissioned Knight Piésold Ltd. (KP) to conduct a desktop review of potential small hydroelectric projects in the Yukon and northern British Columbia. The objectives of the study were to compare technical and economic development criteria and to establish a ranking that provides YEC with the basis to plan further studies on the more favorable sites.

1.2 SCOPE

This study was undertaken in response to a two part Request for Proposals (RFP) issued by YEC, to identify potential pumped-storage sites within a 25 km radius of existing or proposed transmission infrastructure and to review a number of previously identified small hydro resources with capacities of 20 MW or less. The intention was to compare the cost of energy and installed capacity with other potential fossil fuel and renewable options that may be available to YEC, including wind, diesel and natural gas-fired generation.

The requirements for the small hydro study, as stated in the RFP, were:

- Review existing information for the various sites
- Update existing cost estimates
- Update power generation profiles
- Evaluate size of reservoirs and inundation areas for small hydro sites with storage, and
- Evaluate potential hydro sites against financial and technical attributes.

This desktop assessment covered proposed sites and reports dating back more than fifty years. Previous studies have varied in scopes and objectives, and not all existing information was available to KP for this review. No new geotechnical or physical data has been collected, and the assessment does not weigh environmental and societal impacts or the regulatory permitting process, with the exception that projects located in parks have been eliminated due to perceived regulatory barriers. The assessment is high level in nature and relies upon data, mapping, and project information from various sources with variable quality.

1.3 METHODOLOGY

This study utilized a four stage screening process to determine the preferred run of river and storage hydroelectric projects within the scope of this study:

- Screen 1: Removal of Redundant Sites and Sites Located in Parks
- Screen 2: Removal of Sites with Excessive Transmission Lengths and Associated Costs
- Screen 3: Unit Cost of Energy Screening, and
- Screen 4: Focused Assessment of Preferred Options (Top 5 Sites).

Each screening stage is detailed in subsequent sections of this report. The process has been developed to eliminate sites that are indeterminate, fundamentally flawed, and comparatively expensive or technically unviable, with the overriding objective of providing a focus for future studies on the better development options.

1.4 OVERVIEW OF HYDROELEC POWER GENERATION

Conventional hydroelectric power stations utilize the water in a river and the elevation drop in its channel (often at rapids and waterfalls) to generate electrical energy, which is transmitted to domestic and/or industrial consumers using powerlines. Hydropower is a renewable source of energy with a low carbon footprint. It is a long standing, proven technology that is prevalent worldwide and particularly in regions with high annual precipitation and mountainous terrain.

Conventional hydroelectric power projects can be subdivided into two general types:

- Run of River Hydro

Run of river hydroelectric plants utilize the available flow in a river at any given time, with minimal upstream headpond/reservoir storage. Water is typically diverted at a weir into a water conveyance system (canal, tunnel, and/or penstock), to a powerhouse, and then back into the natural river channel. Very little alteration is made to the natural hydrograph downstream of a run of river project.

Electric output is a function of short term (hourly or daily) river discharge, varying daily and seasonally in parallel with the river discharge hydrograph. In the Yukon, run of river generating potential occurs predominantly from May until August, during spring freshet and summer glacial melt.

- Storage Hydro

Storage hydroelectric plants utilize an upstream lake or reservoir to store water and to control the outflow and energy output on a daily, monthly, or seasonal basis. This allows for load shaping and winter generation, a time at which run of river generation is very low.

Storage hydropower configurations vary, from lake/reservoir controlled run of river style projects (with configurations as described above), to large dams with built in generating units where all elevation head is derived from the dam itself, to a combination of both.

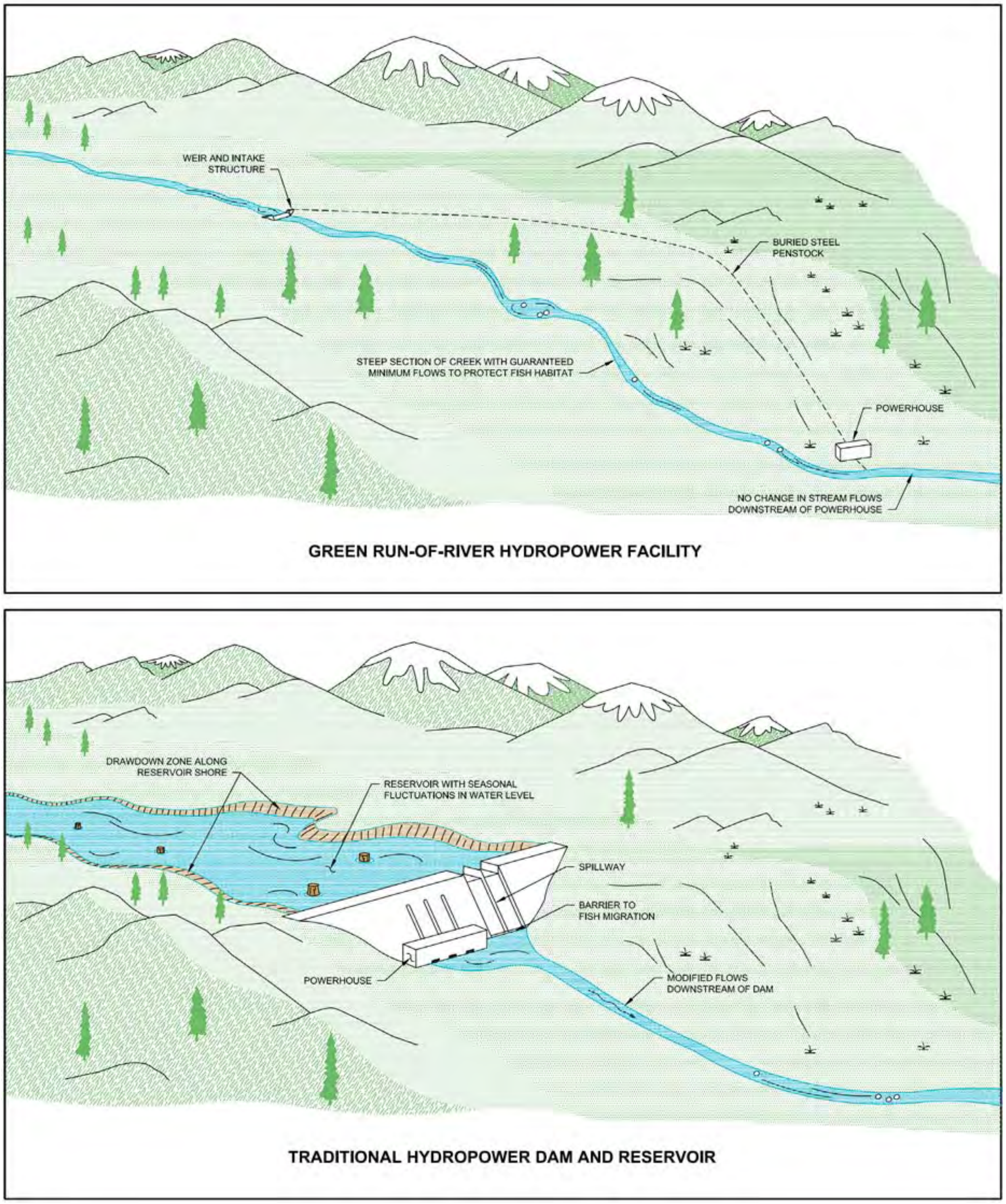


Figure 1.1 Conceptual Hydropower Project Layouts

1.5 YUKON'S ELECTRICITY SYSTEM

1.5.1 Current Capacity

YEC currently owns and operates approximately 131 MW of installed capacity, consisting of 92 MW of hydro, 0.8 MW of wind, and 37.8 MW of thermal (diesel and natural gas). Yukon Electrical Company Ltd. (YECL), owned by ATCO, supplies approximately 1.3 MW of hydroelectricity and 6.8 MW of diesel power.

YEC's hydroelectric generating capacity is comprised of:

- 37 MW Aishihik Generating Station, 150 km west of Whitehorse
- 15 MW Mayo Generating Station, 450 km north of Whitehorse
- 40 MW Whitehorse Generating Station, located on the Yukon River at Whitehorse, and
- 1.3 MW Fish Lake Generating Station (YECL).

1.5.2 Power Grid

The Yukon power grid is shown on Figure 1.2 and comprises the following major components:

- 138 kV Whitehorse / Aishihik / Faro (WAF) grid
- 69 kV Mayo / Dawson transmission line, and
- 138 kV Carmacks / Stewart transmission line, connecting the WAF grid and the Mayo / Dawson transmission line.

The Yukon electricity network is an isolated grid, with no connection to other jurisdictions (BC, Alaska or Northwest Territory). The Yukon grid currently services all Yukon communities except for Watson Lake, Burwash Landing/Destruction Bay, Beaver Creek, and Old Crow [YDC, 2015].

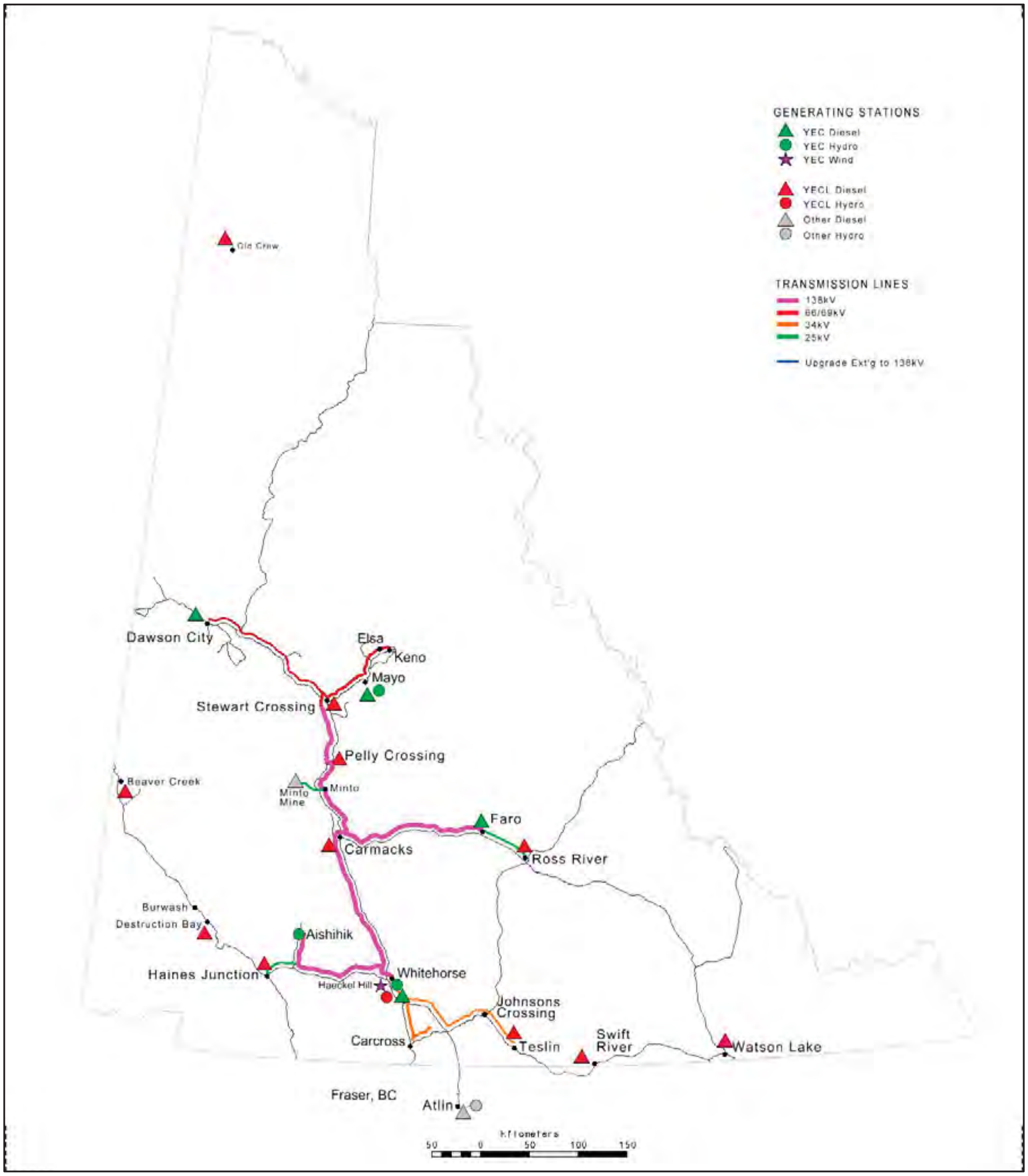


Figure 1.2 Yukon Electricity Network (YEC, 2016)

1.5.3 Proposed Transmission Lines

The following major transmission line extensions have also been considered by YEC:

- Aishihik to Destruction Bay
- Skagway (AK) to Whitehorse
- Atlin (BC) to Whitehorse, and
- Faro to Watson Lake, to connect Watson Lake to the Yukon grid.

1.6 INITIAL SITE LIST

In the RFP, forty nine projects were listed for review under the scope of the small hydro study. Upon project award, YEC requested that five sites be removed from the list. Table 1.1 provides a full listing of the forty four projects included in this study, along with their previously considered installed capacities and annual energy outputs as provided by YEC.

1.7 SMALL HYDRO SITE LOCATIONS

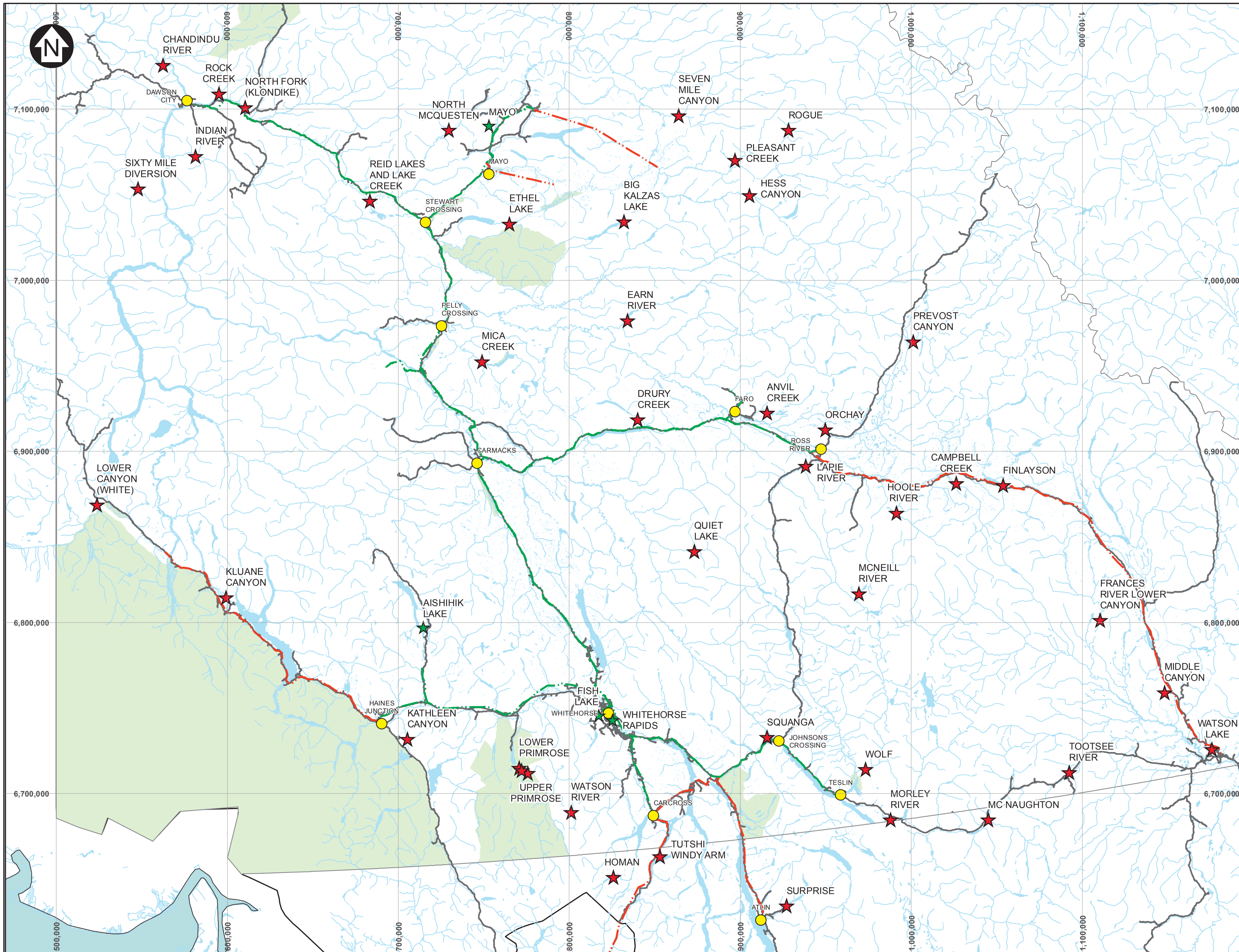
Figure 1.3 shows the location of the forty five sites, as well as existing and proposed transmission lines, communities, and existing hydropower plants.

Table 1.1 Initial Site List

Site #	Project	Type	Capacity [MW]	Energy [GWh]
1	Anvil Creek	Hydro with Storage	10.7	74
2	Big Kalzas Lake	Hydro with Storage	17	89.4
3	Campbell Creek	Hydro with Storage	20	105.1
4	Chandindu River	Run-of- River	3	15.9
5	Drury	Hydro with Storage	2.4	19.8
6	Earn	Hydro with Storage	7	36.8
7	Ethel Lake	Hydro with Storage	2	13.5
8	Finlayson	Hydro with Storage	17	128.9
9	Frances River (Lower Canyon)	Hydro with Storage	12.7	66.7
10	Hess Canyon	Hydro with Storage	18	94.6
11	Homan Lake	Hydro with Storage	4.2	26
12	Hoole River	Hydro with Storage	15	
13	Indian	Hydro with Storage	6	47.3
14	Kathleen Canyon	Run-of- River	2	
15	Kluane Canyon	Hydro with Storage	17	74.5
16	Kluane Canyon	Hydro with Storage	12	63.1
17	Lapie	Run-of-River	2	11.2
18	Lower Canyon on the White River	Hydro with Storage	16	84.1
20	McNaughton Cr.	Hydro with Storage	9.5	76
21	McNeil	Hydro with Storage	10	52.6
22	Mica Creek	Hydro with Storage	10	52.6
23	Middle Canyon (Small)	Hydro with Storage	14	
24	Morley River	Run-of- River	4	22.1
25	North Fork Klondike River	Run-of-River	2	12.3
26	North McQuesten	Hydro with Storage	5	26.3
27	Orchay	Hydro with Storage	4	35
28	Pleasant Creek	Hydro with Storage	5	26.3
29	Pleasant Creek with Rogue Diversion	Hydro with Storage	7	
30	Prevost Canyon	Hydro with Storage	11	60
31	Quiet Lake and Rose River Diversions	Hydro with Storage	15	78.8
32	Quiet Lake Diversion	Hydro with Storage	7	
33	Reid Lakes and Lake Creek	Hydro with Storage	4	22.1
34	Rock Creek	Run of River	1	5.1
35	Rogue	Hydro with Storage	12	63.1
36	Rose Lake to Kusawa Lake	Hydro with Storage	17	
37	Seven Mile Canyon	Hydro with Storage	10	52.6
38	Sixty Mile River Diversion	Hydro with Storage	18	94.6
39	Squanga Creek	Run of River	1.75	8.3
41	Tootsee River	Hydro with Storage	4	23
43	Tutshi-Windy Arm	Hydro with Storage	5.9	39.4
44	Upper and Lower Primrose	Hydro with Storage	16.1	92
47	Watson Lake & McDonald	Hydro with Storage	1	6
48	Watson River	Hydro with Storage	3	
49	Wolf River	Run of River	4.8	41.7

NOTES:

1. Site # is shown per YEC's description; initial list includes a total of 44 sites.



LEGEND:

- PROPOSED HYDROELECTRIC FACILITY
- EXISTING HYDROELECTRIC FACILITY
- CITY/TOWN
- EXISTING ROAD
- RIVER/CREEK
- LAKE
- OCEAN
- PROTECTED AREA

TRANSMISSION LINE

- EXISTING TRANSMISSION LINE
- PROPOSED TRANSMISSION LINE (YEC)

NOTES:

1. BASE MAP: GOVERNMENT OF YUKON MAPPING (GEOYUKON) NATIONAL GEOGRAPHIC MAPPING.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 7N.
3. PROPOSED TRANSMISSION ALIGNMENTS PROVIDED BY YUKON ENERGY CORP.
4. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:2,250,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

25 12.5 0 25 50 75 100 125 km

YUKON ENERGY CORPORATION

SMALL HYDRO ASSESSMENT

SITE LOCATIONS OVERVIEW MAP

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P/A NO.	REF NO.
VA103-00556/02	2
FIGURE 1.3	REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	06OCT'16	ISSUED WITH REPORT	SDR	CAC	KLA

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2 – INFORMATION REVIEW AND PRELIMINARY SCREENING

2.1 RECONCILIATION OF EXISTING INFORMATION

Many hydro studies have been completed for YEC, Yukon Electrical Company Ltd. (YECL), Yukon Development Corporation (YDC), and other entities in the Yukon, dating back over fifty years. The initial phase of this study was to review these reports and to compile project information.

The level of detail and quality in the available information was highly variable, with some sites having been studied numerous times, and others only having been identified as potential resources. Studies have varied, from desktop studies and high level reconnaissance to site investigations and feasibility designs.

A complete listing of the reports that were reviewed for the small hydro study, either having been provided to KP directly by YEC or found online through public sources, is provided in Section 6. It should be noted that this information was not comprehensive, and a number of historic reports were missing or otherwise unavailable for this study.

2.2 PRELIMINARY EVALUATION – SCREEN 1

The first screen targeted the removal of redundant projects and sites located in national or territorial parks. This level of screening resulted in the elimination of five sites.

2.2.1 Redundant Sites

From the information review, it appears that the site list included the following redundancies:

- Sites 15 and 16: Kluane Canyon – Although recorded with a different installed capacity, both sites are in the same location and represent only one resource potential (regardless, Kluane Canyon is located in a national park and is eliminated in Section 2.2.2).
- Site 23: Middle Canyon (Small) – Documentation revealed that the Lower Canyon on the Frances River (Site 9) is also known as Middle Canyon, and mapping investigations confirmed these sites to be interchangeable.

2.2.2 Sites Located in Parks

A review of project locations identified the following sites to be located in national or territorial parks:

- Sites 15 and 16: Kluane Canyon
- Site 36: Rose Lake to Kusawa Lake, and
- Site 44: Upper and Lower Primrose.

2.2.3 Sites Passing Screen 1

Table 2.1 provides the site list after Screen 1. Thirty nine sites were successful in progressing to the Screen 2 evaluation.

Table 2.1 Sites Passing Screen 1

Site #	Project	Site #	Project
1	Anvil Creek	25	North Fork Klondike River
2	Big Kalzas Lake	26	North McQuesten
3	Campbell Creek	27	Orchay
4	Chandindu River	28	Pleasant Creek
5	Drury	29	Pleasant Cr with Rogue
6	Earn	30	Prevost Canyon
7	Ethel Lake	31	Quiet Lake and Rose River Diversions
8	Finlayson	32	Quiet Lake Diversion
9	Frances River (Lower Canyon)	33	Reid Lakes and Lake Creek
10	Hess Canyon	34	Rock Creek
11	Homan Lake	35	Rogue
12	Hoole River	37	Seven Mile Canyon
13	Indian	38	Sixty Mile River Diversion
14	Kathleen Canyon	39	Squanga Creek
17	Lapie	41	Tootsee River
18	Lower Canyon White	43	Tutshi-Windy Arm
20	McNaughton Cr.	47	Watson Lake & McDonald
21	McNeil	48	Watson River
22	Mica Creek	49	Wolf River
24	Morley River		

NOTES:
1. Site # is shown per YEC's description; initial list included a total of 44 sites.

2.3 TRANSMISSION LINE LENGTH – SCREEN 2

Transmission line length and the associated costs of interconnection, along with access road lengths and costs, are significant factors impacting the viability of hydroelectric project development. With transmission costs estimated in the order of $500,000/km to $1,000,000/km, the economics of small hydro projects can be substantially eroded as transmission distance increases.

For this assessment, transmission lengths exceeding 25 km to an existing or proposed future transmission line were considered to be too great, and these projects were eliminated from further consideration at this time. Future grid expansions may warrant further consideration of sites outside of the 25 km buffer used in this study.

Project clustering may significantly improve the economics of more distant project groupings if they are developed concurrently, and this may render some of the more distant projects viable. However, it is outside the scope of this study to consider project clusters.

2.3.1 Distance to Existing and Proposed Transmission Lines

Table 2.2 provides a summary of the estimated shortest linear length to interconnect to existing and proposed future transmission lines. This table only includes the thirty nine sites passing Screen 1.

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Table 2.2 Distance (km) to Existing and Proposed Transmission Lines

Site #	Project	Distance to Existing Transmission	Distance to Proposed Transmission
1	Anvil Creek	6.7	
2	Big Kalzas Lake	83.9	37.3
3	Campbell Creek	77	0.5
4	Chandindu River	29.2	
5	Drury	0.5	
6	Earn	62.9	
7	Ethel Lake	32.5	28.1
8	Finlayson	155.3	5.1
9	Frances River (Lower Canyon)	193.2	23.6
10	Hess Canyon	113.9	56.1
11	Homan Lake	43.3	15.3
12	Hoole River	46.8	15.0
13	Indian	29.2	
14	Kathleen Canyon	6.1	
17	Lapie	7.3	6.1
18	Lower Canyon on the White River	186.4	47.7
20	McNaughton Cr.	132.3	88.9
21	McNeil	93	72.3
22	Mica Creek	7.2	
24	Morley River	81.1	33.9
25	North Fork Klondike River	1.3	
26	North McQuesten	25.0	
27	Orchay	13.1	
28	Pleasant Creek	89.8	10.3
29	Pleasant Creek with Rogue Diversion	89.8	10.3
30	Prevost Canyon	81.6	78.5
31	Quiet Lake and Rose River Diversions	81.1	
32	Quiet Lake Diversion	81.1	
33	Reid Lakes and Lake Creek	4.6	
34	Rock Creek	3.9	
35	Rogue	149	79.5
37	Seven Mile Canyon	84.5	31.5
38	Sixty Mile River Diversion	58.4	
39	Squanga Creek	2.8	
41	Tootsee River	172.4	73.9
43	Tutshi-Windy Arm	24.8	0.5
47	Watson Lake & McDonald	254.7	1.9
48	Watson River	1.8	
49	Wolf	55.1	22.1

NOTES:

1. Site # is shown per YEC's description; initial list includes a total of 44 sites.

2.3.2 Sites Passing Screen 2

Table 2.3 provides the site list for projects within 25 km of existing or proposed transmission lines, along with the installed capacity and energy output values provided by YEC. Twenty two sites met the criteria and progressed to Screen 3.

Table 2.3 Sites Passing Screen 2

Site #	Project	Type	Capacity [MW]	Energy [GWh]
1	Anvil Creek	Hydro with Storage	10.7	74
3	Campbell Creek	Hydro with Storage	20	105.1
5	Drury	Hydro with Storage	2.4	19.8
8	Finlayson	Hydro with Storage	17	128.9
9	Frances River (Lower Canyon)	Hydro with Storage	12.7	66.7
11	Homan Lake	Hydro with Storage	4.2	26
12	Hoole River	Hydro with Storage	15	
14	Kathleen Canyon	Run-of- River	2	
17	Lapie	Run-of-River	2	11.2
22	Mica Creek	Hydro with Storage	10	52.6
25	North Fork Klondike River	Run-of-River	2	12.3
26	North McQuesten	Hydro with Storage	5	26.3
27	Orchay	Hydro with Storage	4	35
28	Pleasant Creek	Hydro with Storage	5	26.3
29	Pleasant Creek with Rogue Diversion	Hydro with Storage	7	
33	Reid Lakes and Lake Creek	Hydro with Storage	4	22.1
34	Rock Creek	Run-of- River	1	5.1
39	Squanga Creek	Run-of- River	1.75	8.3
43	Tutshi-Windy Arm	Hydro with Storage	5.9	39.4
47	Watson Lake & McDonald	Hydro with Storage	1	6
48	Watson River	Hydro with Storage	3	
49	Wolf River	Hydro with Storage	4.8	41.7

NOTES:

1. Site # is shown per YEC's description; initial list included a total of 44 sites.

3 – COST TO BENEFIT ASSESSMENT - SCREEN 3

3.1 GENERAL

The Screen 3 evaluation was based on consideration of capital costs, capacity, and the energy potential of each site. Six run of river and sixteen small hydro with storage sites underwent the following sequence of tasks:

- Hydrology review and assessment
- Review of project layouts
- Energy Modelling
- Indicative cost estimating, and
- Cost to benefit analyses (Unit Cost of Energy, Unit Cost of Capacity).

3.2 HYDROLOGY

A hydrology review was conducted on all sites passing Screen 2. The purpose of this review was to determine the suitability of hydrological values previously developed for various projects, and to develop hydrological estimates for those sites where no historically reported information could be obtained.

3.2.1 Regional Hydrology

Data from a total of forty six Water Survey of Canada (WSC) gauges with catchment areas between 10 km^2 and 7,000 km^2 were reviewed to develop an understanding of regional trends in measured runoff for catchments of varying sizes and regions. The data were used to develop estimates of Mean Annual Discharge (MAD) and Mean Annual Unit Discharge (MAUD) at all project sites that passed Screen 2. The data were also used to produce typical hydrographs to estimate the distribution of flow throughout the year.

3.2.2 Discharge

Table 3.1 provides the estimated MAUD and MAD values for all sites passing Screen 2. Where no previous hydrology information could be obtained, KP developed estimates on the basis of the MAUD values from the WSC gauges in the region. These gauges are dispersed across the majority of the Yukon and provide a reasonable means of assessing hydrologic patterns throughout the region. Some of the basic trends evident in the data are as follows:

- MAUD appears to decrease in a south-westerly direction along the border between the Yukon and the Northwest Territories, with lower unit discharge values evident in the dry, lower relief interior zones versus the mountainous terrain along the eastern provincial border.
- In the south-western corner of the Yukon, MAUD appears to be relatively high due to the onshore movement of moist maritime air from the Pacific Coast. The effects of this moisture influx extends slightly beyond the Coastal Mountain Range, and then drops off markedly due to a ‘precipitation shadow’ effect that results in a progressive reduction in MAUD moving east.

MAUD values were selected for the project sites on the basis of proximity and similarity of catchment size to the WSC stations. Commonly, there are two to three local gauge stations that provide a basis for estimating unit discharge. Where applicable, consideration was also given to the MAUD values reported for various project sites.

Additional regional considerations when determining a site's MAUD included:

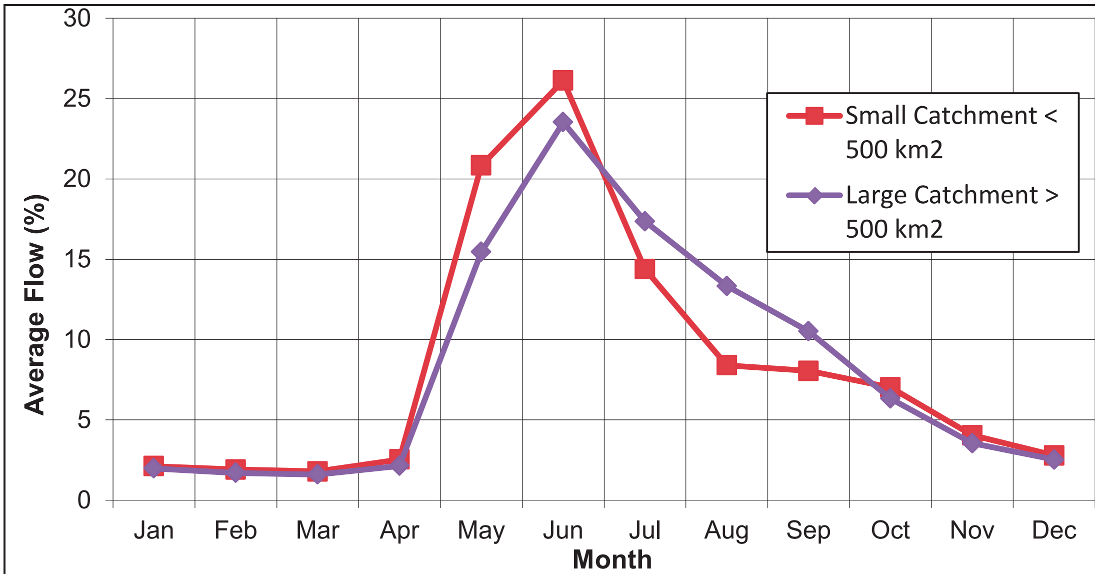
- Glaciers in a watershed, which generally increase MAUD due to melt during the warm summer months
- Lakes in a watershed, which generally decrease MAUD due to greater evaporation, and
- The local relief, with higher elevation watersheds generally having higher precipitation and correspondingly higher MAUD.

Table 3.1 Unit Runoff and Discharge

Site #	Project	Catchment Area (km^2)	MAUD, Reported ($L/s/km^2$)	MAUD, KP Estimate ($L/s/km^2$)	MAD (m^3/s)
1	Anvil Creek	513		8.0	4.1
3	Campbell Creek	611		9.0	5.5
5	Drury	550	9.0		4.9
8	Finlayson	1,542	10.7		16.5
9	Frances River (Lower Canyon)	12,969		7.5	97.3
11	Homan Lake	150		12.0	1.8
12	Hoole River	738		9.0	6.6
14	Kathleen Canyon	904		15.5	14.0
17	Lapie	1,293	10.1		13.1
22	Mica Creek	543		4.5	2.4
25	North Fork Klondike River	1,100	12.6		13.9
26	North McQuesten	2,010		7.5	15.1
27	Orchay	390	7.5		2.9
28	Pleasant Creek	843		9.0	7.6
29	Pleasant Cr with Rogue	3,272		9.0	29.4
33	Reid Lakes and Lake Creek	1,024	5.4		5.5
34	Rock Creek	424	12.6		5.3
39	Squanga Creek	838	3.6		3.0
43	Tutshi-Windy Arm	992	16.2		16.1
47	Watson Lake & McDonald	330	3.4		1.1
48	Watson River	97		9.0	0.9
49	Wolf River	3,500		11.5	40.3

3.2.3 Hydrographs

Using the available WSC gauge data, hydrographs were generated and grouped according to watershed size in an effort to determine if any consistent and pronounced differences in annual hydrograph shape could be related to catchment size in the Yukon. The catchment sizes of the forty six WSC gauges that were considered range from 10 km^2 to 7,000 km^2. A variety of size groupings were plotted for comparison purposes and it appeared that there are two basic groups of hydrographs of similar shape: those for areas less than 500 km^2 and those for areas greater than 500 km^2. There does not appear to be sufficient variation in hydrograph shape to merit further division by basin size. The two basic hydrograph shapes, which were delineated according to the average monthly values for the indicated basin sizes, are shown on Figure 3.1.



NOTES:
1. BASED ON AN EVALUATION OF MONTHLY AVERAGE FLOWS AT 46 WATER SURVEY OF CANADA (WSC) GAUGES IN YUKON.

Figure 3.1 Typical Hydrograph

For relatively small basins, the peak freshet flow period is more pronounced but of shorter duration than for large basins, which tend to sustain flows at higher levels through the summer months. This pattern is consistent with the tighter elevation range characteristic of smaller basins (with snowmelt occurring more rapidly and more consistently throughout the basin) and the higher likelihood of glacier content in the large basins (which supply late summer flows through melting).

3.2.4 Dependable Capacity (Flow)

Dependable Capacity is defined by BC Hydro to be the maximum capacity that a generating station can reliably produce when required, with an 85 percent level of confidence and assuming that all generating units are in service (BC Hydro, 2005). In the context of hydropower plants, capacity synonymous with availabile flow and storage upstream of the intake.

In line with the 85 percent confidence level described above, Dependable Flow is herein defined to be the monthly flow that will be available for a given month in 85 percent of calendar years (P85). P85 values will vary between different drainages and river systems based on site specific climate and hydrology conditions.

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The hydrological estimates described in Sections 3.2.1 – 3.2.3 screening level assessments based on regional climatic and hydrographic trends. The WSC gauge data that was reviewed represents average flow data (P50 conditions). Long term site specific data was not available and ‘true’ site specific percentile values, such as P85, were not determined. However to support YEC’s assessment of potential small hydro resources relative other generation technologies, KP assessed select regional data to provide indicative P85 values for each project as follows.

Based on the assumption that annual discharge follows a normal distribution (example shown on Figure 3.2), the P85 Dependable Flow will occur approximately one standard deviation below the P50 level (-1σ). The size of the standard deviation is dependent on the spread of the data for any particular river system, which is influenced by catchment area, elevation, and regional climatic trends.

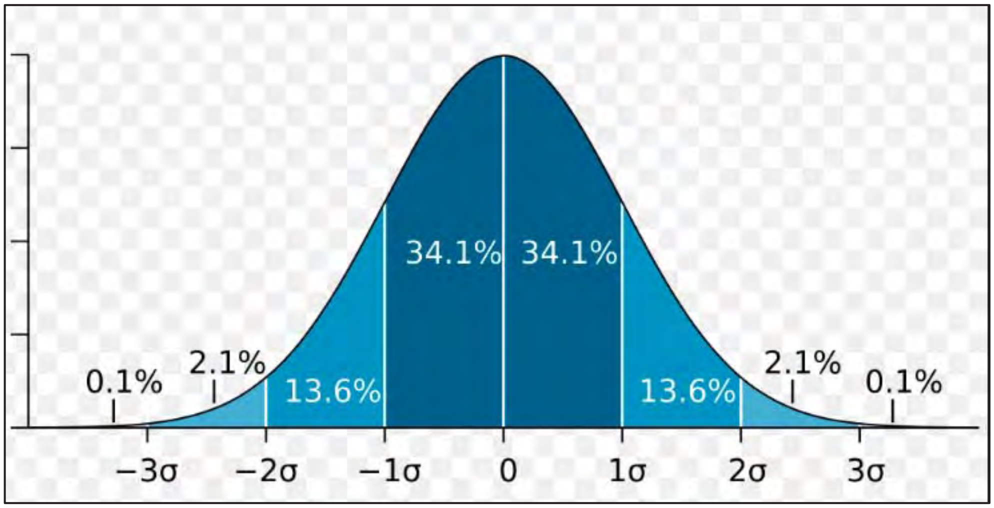


Figure 3.2 Normal Distribution

In order to provide YEC with a rough approximation of the dependable capacity for the small hydro sites, KP has reviewed the standard deviation and coefficient of variation observed in a small sample of long term WSC gauge data. This review indicates that the coefficient of variation is higher during the freshet and summer period than it is during the shoulder seasons and winter months. It also indicates that the coefficient of variation for smaller catchment areas is higher than that for larger catchments. Both of these observations align with expectation.

For the small hydro sites, and especially for sites that operate on a run of river basis, the Dependable Capacity will vary significantly from month to month, and during winter, dependable capacity is close to zero in some cases. The estimated indicative monthly dependable capacity and energy output values are included in Appendix A.

3.3 RUN OF RIVER PROJECTS

3.3.1 Design Basis

Run of river hydroelectric plants utilize the available flow in a river at any given time, with minimal headpond/reservoir storage, and electric output is a function of short term (hourly or daily) yield. The optimal installed capacity depends on numerous factors, including constructability, environmental requirements, and the need for and ability to sell seasonal power.

As illustrated in Figure 3.1, the majority of the electric generating potential for run of river projects in the Yukon occurs between May and August, from the onset of the spring freshet through summer as snow and glacial melt feed the river systems. Winter flows tend to be very low, as surface water is frozen and rivers are fed predominantly from lakes and groundwater sources. As such, run of river projects do not offer good base load and are more beneficial for peak energy production in the spring and summer seasons.

Assuming that all energy output can be utilized, the optimal design flow for a run of river plant tends to be in the order of 2 times the Mean Annual Discharge (MAD). If peak power during the spring and summer is not desired and base load is more highly valued, a lower design flow and a correspondingly higher capacity factor should be targeted, such as 0.5 times MAD.

For the purpose of assessing and fairly comparing the run of river projects, it is assumed that all energy output can be utilized and, accordingly, design flow has been set at 2 times MAD. The exception is Site 49 – Wolf River, which is considered with a lower design flow to not exceed the 20 MW upper limit for this small hydro assessment. It appears that a much higher design flow for this site is an optimization worth considering in a future study.

3.3.2 Energy Models

Energy models were developed for the six run of river hydro sites evaluated in Screen 3. The energy models used the monthly hydrology data developed for this study and a number of assumptions:

- Instream Flow Requirements (IFR) equal to 5 percent of MAD.
- 10 percent head losses through intake and conveyance to the turbine, at maximum design flow, and a linear decrease in head loss with decreasing flow.
- Average efficiency of 90 percent from turbine to the point of sale, to account for turbine – generator losses, transformer losses, transmission losses, station usage, and outages.
- Turbine types auto selected for optimal performance according to design flow and head.

3.3.3 Indicative Costs

Basic indicative cost estimates were developed for each project using KP's in-house experience and cost estimating database for projects with comparable characteristics. Where the level of detail in the existing design was insufficient to permit an accurate assessment of site specific conditions, facility layouts, sizes, and costs were scaled according to head, flow, installed capacity, and other key project costing metrics. Cost estimates included the following major components:

- Task 100: Mobilization, Demobilization, Insurance, Bonds, Overheads, and Contractor's Profits
- Task 200: Access and Site Preparation
- Task 300: Intake, Forebay, Headrace, and Tailrace
- Task 400: Water Conveyance System
- Task 500: Powerhouse and Ancillary Services
- Task 600: Power Generation Equipment (Water to Wire)
- Task 700: Switchyard, Transmission, and Interconnection
- Task 800: Dam(s) and Reservoir(s)
- Engineering, Procurement, and Construction Management (EPCM): 8 %, and
- Contingency: 30 %.

3.3.4 Cost to Benefit Analysis

The fair evaluation of alternative hydropower development options requires an assessment of project costs and benefits. The Screen 3 assessment was based on the comparative values for two financial metrics, the Unit Cost of Capacity and the Unit Cost of Energy:

- ***Unit Cost of Capacity = Net Present Cost at Commissioning ($) / Installed Capacity (MW)***
  This unit of measurement can be useful for gauging project costs in relation to other proposed or existing power projects. For instance, YEC's Mayo B Hydroelectric Project was constructed for a cost of roughly $120 million, and added 10 MW of power to the Yukon's energy system (YEC, 2016), equating to a unit capacity cost of roughly $12 million/MW. The unit capacity cost of the better options in this study are in this order of magnitude, providing some confidence in the underlying quantities and unit rates that have been assumed.
  While unit capacity cost does have its usefulness, it is not a good measure of the overall project value since capacity is not directly correlated to energy production and revenues.
- ***Unit Cost of Energy = Net Present Cost at Commissioning ($) / Average Annual Energy Production (GWh/yr)*****.**
  Unit energy cost is a useful financial metric for the determination of a project's value and relative ranking of sites with different installed capacities and hydrology characteristics. Provided that all energy can be sold, unit energy cost is directly correlated with revenue. The Screen 3 assessment and selection of preferred sites was based on the unit cost of energy.
  Unit energy costs in the order of $2.5 million/GWh/yr or less are considered to be favorable development costs and projects with this value may warrant further consideration.

Table 3.2 provides a summary of the major design outputs for the run of river projects, along with the estimated (indicative) costs and cost to benefit metrics. The values presented are based on a net present cost at commissioning that assumes a construction duration of 3 years and a real interest cost of 4.61 percent (IPP development rate provided by YEC).

Table 3.2 Run of River Screen 3 Summary Table

Site #	Name	Design Flow	Gross Head	Installed Capacity	Net Avg. Energy	Net Present Cost	Unit Capacity Cost	Unit Energy Cost
		m³/s	m	MW	GWh/yr		$/MW	$/GWh/yr
14	Kathleen	28.0	15.0	3.7	12.6	$ 61,323,000	$ 16,537,000	$ 4,857,000
17	Lapie	26.2	36.0	8.3	29.6	$ 92,078,000	$ 11,057,000	$ 3,116,000
25	North Fork Klondike	27.8	69.0	16.9	60.0	$ 180,170,000	$ 10,638,000	$ 3,004,000
34	Rock Creek	10.6	40.0	3.7	12.6	$ 97,531,000	$ 26,053,000	$ 7,722,000
39	Squanga Creek	6.0	54.0	2.9	10.2	$ 30,248,000	$ 10,574,000	$ 2,980,000
49	Wolf River	28.3	80.0	20.0	104.9	$ 271,023,000	$ 13,559,000	$ 2,584,000

NOTES:
1. Net Average Energy is based on P50 hydrology estimates as described in Section 3.2.
2. Estimated monthly energy output values are provided in Appendix A.
3. Net Present Cost assumes a three year construction period and an interest rate of 4.61 percent.

3.4 SMALL HYDRO WITH STORAGE PROJECTS

3.4.1 Design Basis

Storage hydroelectric plants utilize an upstream lake or reservoir to store water and to control the outflow and energy output on a daily, monthly, or seasonal basis. This allows for load shaping and winter generation, provided the reservoir has sufficient storage in relation to MAD and the design flow of the plant. Storage capacity is of particular value during the low flow fall, winter, and early spring months, when run of river output is low and reliance on costly diesel power generation is high.

The available storage in an upstream reservoir is a significant factor to be considered in the sizing of storage hydro plants. While this study does not specifically address environmental considerations, lake level changes may impact the environment and private land, and technical constraints may further hinder the construction of high dams for large lake raises. The design basis for the storage hydro plants considered in this assessment was discussed with YEC during this study and was agreed as follows:

- For sites where storage is possible on a natural lake or lakes, lake level increases have been limited to 5 m.
- Where no upstream lake is available and/or where minimal viable elevation drop has been identified, a dam sized to store 20 m of water has been provided for both water storage and head (Site 9 – Frances River, Site 12 – Hoole River, Site 26 – North McQuesten River).

The selection of the optimal design flow and the corresponding installed capacity is a function of the reservoir storage capacity and MAD. The general approach used for the selection of design flow is:

- Where the available lake storage capacity exceeds the annual yield of a river system, reservoir size was reduced to roughly the volume of annual average yield, and the annualized flow through the plant was adjusted to match the man annual yield (flow approaches MAD, less IFR releases).
- Where the available lake storage capacity is substantially less than the annual yield of a river system, the design flow was set at 2 times MAD and the plant was assumed to operate as a run of river style project when the reservoir is near full, with the added benefit of an improved capacity factor due to reservoir draw down in the low flow months.

3.4.2 Reservoir Flooded Areas

Table 3.3 provides a summary of the reservoir storage characteristics for all of the small hydro with storage sites evaluated in Screen 3. These reservoir characteristics coupled with the hydrology conditions (Section 3.2) are the basis for the Screen 3 energy and cost estimating for the small hydro with storage sites.

For each of the options listed in Table 3.3, the area upstream of the dam that will be inundated when the dam is filled has been estimated using the available topography and a standard depth – area interpolation. Flooded areas are calculated as the estimated new lake area minus the natural lake area. These are best guess values based on the coarse mapping interval that was available.

Table 3.3 Storage Hydro Reservoir Characteristics

Site #	Project	Natural Lake Area (km^2)	Lake Level Increase (m)	New Lake Area (km^2)	Estimated Available Storage (m^3)
1	Anvil Creek	5.3	5.0	5.9	27,875,000
3	Campbell Creek	2.5	5.0	3.2	14,250,000
5	Drury Lake	26.0	5.0	27.9	134,750,000
8	Finlayson (Wolverine Lake)	8.2	5.0	10.6	47,000,000
8	Finlayson (Finlayson Lake)	20.0	5.0	23.0	107,500,000
9	Frances River (Lower Canyon)	2.8	20.0	15.5	70,625,000
11	Homan Lake	5.2	5.0	7.1	30,625,000
12	Hoole River	0.0	20.0	2.3	10,063,000
22	Mica Creek	32.6	2.0	35.0	71,400,000
26	North McQuesten	0.0	20.0	9.0	38,375,000
27	Orchay (Lake B)	0.7	5.0	0.9	3,875,000
27	Orchay (Orchay Lake)	5.5	5.0	6.3	29,375,000
28, 29	Pleasant Creek	10.0	5.0	13.5	58,750,000
33	Reid Lakes and Lake Creek	20.3	5.0	31.7	129,875,000
43	Tutshi Lake	51.9	5.0	55.0	267,125,000
47	Watson Lake	13.9	2.5	14.5	35,438,000
48	Watson River	0.2	5.0	0.6	2,000,000

3.4.3 Cost to Benefit Analysis

Energy models were developed for each small hydro with storage site, using the design basis described in Section 3.4.1 and the energy model assumptions described in Section 3.3.2. Indicative cost estimates were developed as described in Section 3.3.3.

Table 3.4 provides a summary of the major design outputs for the small hydro with storage projects, along with the estimated (indicative) costs and cost to benefit metrics. The values presented are based on a net present cost at commissioning, assuming a construction duration of 3 years and a real interest cost of capital of 4.61 percent (IPP development rate provided by YEC).

Table 3.4 Small Hydro with Storage Screen 3 Summary Table

Site #	Name	Design Flow	Gross Head	Installed Capacity	Net Avg. Energy	Net Present Cost	Unit Capacity Cost	Unit Energy Cost
		m^3/s	m	MW	GWh/yr		$/MW	$/GWh/yr
1	Anvil	8.2	135.0	9.8	41.3	$ 120,502,000	$ 12,329,000	$ 2,918,000
3	Campbell	11.0	77.0	7.5	29.0	$ 145,101,000	$ 19,403,000	$ 5,010,000
5	Drury	9.3	99.0	8.1	31.7	$ 84,993,000	$ 10,484,000	$ 2,682,000
8	Finlayson	13.3	150.0	17.6	138.9	$ 280,698,000	$ 15,932,000	$ 2,021,000
9	Frances	129.5	17.5	20.0	88.7	$ 281,896,000	$ 14,089,000	$ 3,178,000
11	Homan	3.6	77.0	2.4	13.5	$ 84,507,000	$ 34,529,000	$ 6,277,000
12	Hoole	13.2	17.5	2.0	7.7	$ 145,368,000	$ 71,276,000	$ 18,982,000
22	Mica	4.6	35.0	1.4	5.6	$ 123,257,000	$ 86,654,000	$ 22,165,000
26	North McQuesten	30.2	17.5	4.7	18.0	$ 156,324,000	$ 33,502,000	$ 8,675,000
27	Orchay	2.7	132.0	3.1	24.6	$ 89,740,000	$ 28,798,000	$ 3,653,000
28	Pleasant	5.4	40.0	1.9	14.9	$ 154,622,000	$ 81,554,000	$ 10,344,000
29	Pleasant & Rogue	56.7	40.0	20.0	77.9	$ 536,734,000	$ 26,804,000	$ 6,889,000
33	Reid Lakes & Lake Creek	5.2	90.0	4.1	32.4	$ 163,807,000	$ 39,830,000	$ 5,052,000
43	Tutshi - Windy Arm	15.0	51.0	6.8	53.4	$ 136,411,000	$ 20,141,000	$ 2,555,000
47	Watson Lake & McDonald	2.1	60.0	1.1	4.4	$ 56,326,000	$ 49,947,000	$ 12,776,000
48	Watson River	1.8	50.0	0.8	2.9	$ 28,593,000	$ 35,984,000	$ 10,009,000

NOTES:

1. Net Average Energy is based on P50 hydrology estimates as described in Section 3.2.
2. Additional capacity and energy values are provided in Appendix A; average capacity and average energy, and dependable capacity and firm energy.
3. Net Present Cost assumes a three year construction period and an interest rate of 4.61 percent.

3.5 SHORTLIST OF PREFERRED SITES

The five preferred sites were selected based on the lowest unit energy costs presented in Tables 3.2 and 3.4. Table 3.5 presents a summary of the shortlisted sites; which include one (1) run of river project (Wolf River) and four (4) small hydro with storage projects.

Table 3.5 Shortlist of Preferred Sites

Site #	Name	Design Flow	Gross Head	Installed Capacity	Net Avg. Energy	Net Present Cost	Unit Capacity Cost	Unit Energy Cost
		m^3/s	m	MW	GWh/yr	$	$/MW	$/GWh/yr
1	Anvil	8.2	135.0	9.8	41.3	$ 120,502,000	$ 12,329,000	$ 2,918,000
5	Drury	9.3	99.0	8.1	31.7	$ 84,993,000	$ 10,484,000	$ 2,682,000
8	Finlayson	13.3	150.0	17.6	138.9	$ 280,698,000	$ 15,932,000	$ 2,021,000
43	Tutshi - Windy Arm	15.0	51.0	6.8	53.4	$ 136,411,000	$ 20,141,000	$ 2,555,000
49	Wolf River	28.3	80.0	20.0	104.9	$ 271,023,000	$ 13,559,000	$ 2,584,000

It should be noted that, while the costs and costing metrics were assessed in an unbiased manner, a significant variable is accuracy of project reference information and quality of data for each sites; which induces inaccuracy into the assessment model. With more comprehensive site specific data (i.e. hydrology, topography and foundation conditions) the economics of preferred projects could deteriorate while other sites could improve, and therefore the comparative rankings would change.

Four (4) additional sites ranked closely to the five preferred sites and may warrant further consideration when site specific is available, including:

- Squanga Creek $M 2.980/GWh/yr
- North Fork Klondike River: $M 3.004/GWh/yr
- Lapie River $M 3.116/GWh/yr, and
- Frances River $M 3.178/GWh/yr/.

4 – EVALUATION OF PREFERRED SITES

4.1 PROJECT LAYOUTS

For the preferred sites, reference information and project layouts were reviewed in finer detail than was possible for the full list of sites evaluated in Screen 3. This involved detailed reconnaissance of historic reports, old and current mapping, and other pertinent site specific considerations.

4.1.1 Drury Lake

Reference Reports: *1989, 1990, 1991 Hydro Investigations* [S. Demers], *Assessment of Potential Hydro Sites* [KGS Group, 2008]

The Drury Lake Project is located on Drury Creek between Drury Lake and Little Salmon Lake, in the Yukon River watershed. The site is approximately 170 km north of Whitehorse and is situated within 1 km of the Robert Campbell Highway and the existing WAF transmission line.

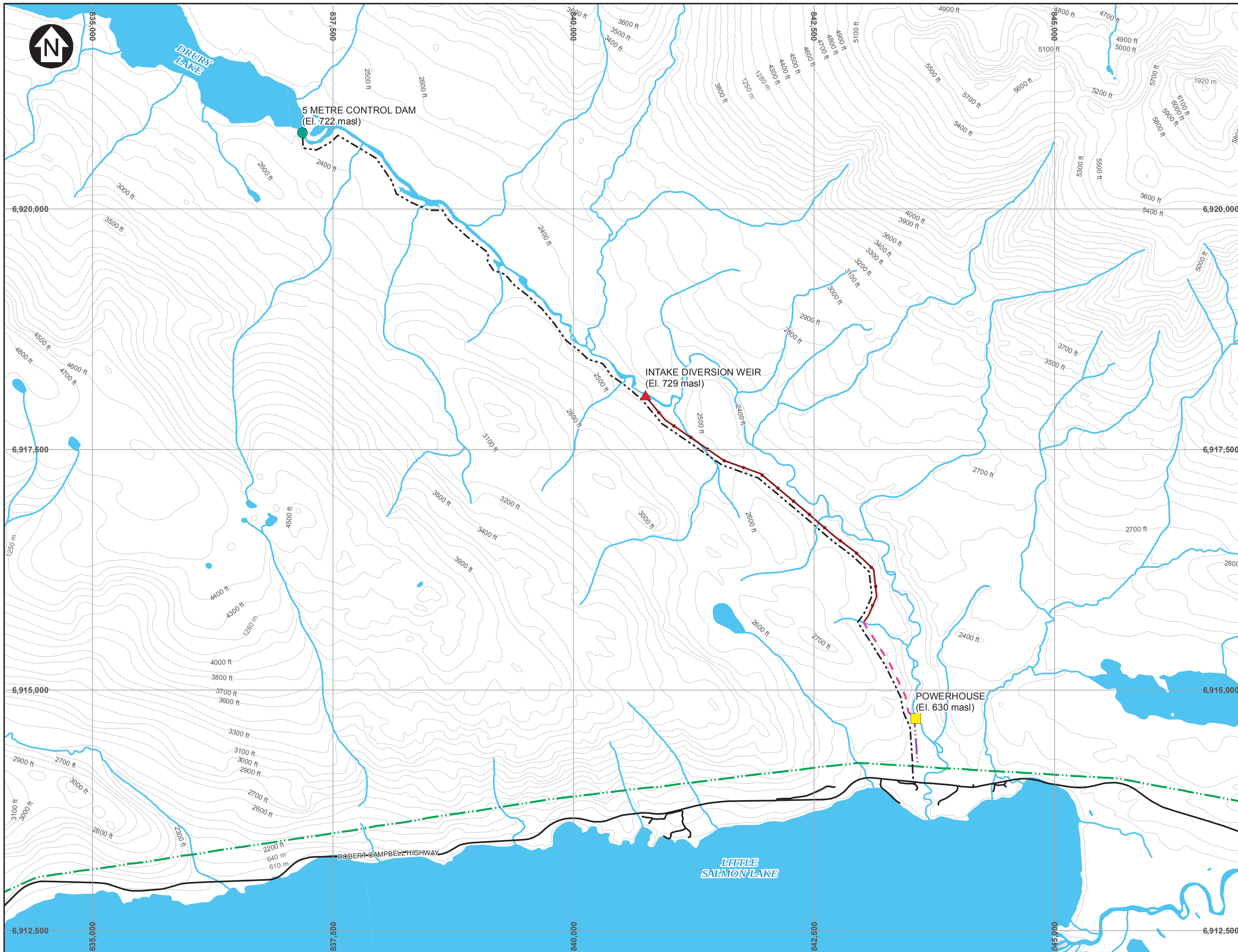
A variety of studies have previously been commissioned, including high level reconnaissance, geotechnical investigations, and design studies, and these have resulted in a number of alternative design concepts. The most recent study was completed by KGS in 2008 and provides basic site layouts, design and geotechnical considerations, and cost estimates for different options.

While earlier studies considered a low gradient canal and a short penstock, geotechnical risk and the presence of permafrost were noted by KGS. At this desktop level, the conveyance alignment and specific constructability concerns cannot be addressed in any detail beyond that reported by KGS, and so the selection of a buried low pressure penstock instead of a canal has been adopted by KP.

A preliminary general arrangement of the project layout is shown on Figure 4.1. Key project parameters and characteristics for this layout are as follows:

- Q_d = 9.3 m^3/s.
- Gross Head = 99 m.
- Installed Capacity = 8.1 MW.
- 5.3 km of access roads from the Robert Campbell Highway to the powerhouse, along the water conveyance, and upstream to the outlet of Drury Lake.
- Concrete Faced Rockfill Dam (CFRD) or earthfill control dam at the outlet of Drury Lake to provide 5 m of storage (operating storage of 135 Mm^3). The dam would be constructed with an IFR discharge system and a spillway to Drury Creek for flood water management.
- Intake weir across Drury Creek, approximately 4 km downstream of the lake outlet (El. 729 masl)
- 4.8 km penstock located on the south side of Drury Creek (alignment as previously indicated by KGS), comprising 3.6 km of low pressure pipe (LPP) and 1.2 km of high pressure pipe (HPP).
- Powerhouse (El. 630 masl) and substation at the edge of Drury Creek, upstream of the Robert Campbell Highway and the river mouth at Little Salmon Lake.
- 0.5 km transmission line, with t-tap interconnection to the existing WAF grid.

There does not appear to be much value in increasing the capacity of the Drury Lake Project. As designed, all available water (after IFR) on an average annual basis would be used for six months of reservoir filling and six months of generation; such that an increased capacity would only decrease the generating period.



LEGEND:

- CITY/TOWN
- CONTOUR (100 ft)
- EXISTING ROAD
- EXISTING TRANSMISSION LINE
- RIVER/CREEK
- LAKE

PROPOSED PROJECT FACILITIES

- DAM
- INTAKE / DIVERSION WEIR
- POWERHOUSE
- PENSTOCK
- LOW PRESSURE PIPE
- INTERCONNECTION TRANSMISSION
- ROAD

NOTES:

1. BASE MAP: GOVERNMENT OF YUKON TOPOGRAPHY; NATIONAL GEOGRAPHIC MAPPING.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 7N.
3. CONTOUR INTERVALS IN FEET.
4. PROPOSED TRANSMISSION ALIGNMENTS PROVIDED BY YUKON ENERGY CORP.
5. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:40,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

0.5 0.25 0 0.5 1 1.5 2 km

YUKON ENERGY CORPORATION

SMALL HYDRO ASSESSMENT

DRURY CREEK
GENERAL ARRANGEMENT

Knight Piésold CONSULTING

P/A NO.	REF NO.
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FIGURE 4.1	REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
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4.1.2 Finlayson River

Reference Reports: *1990 Hydro Investigations* [S. Demers, 1990]

The Finlayson River is a major tributary to Frances Lake and the Frances River, in the Liard River watershed. The Finlayson River Project is located adjacent to the Robert Campbell Highway and just upstream of Frances Lake, approximately 300 km to the northeast of Whitehorse.

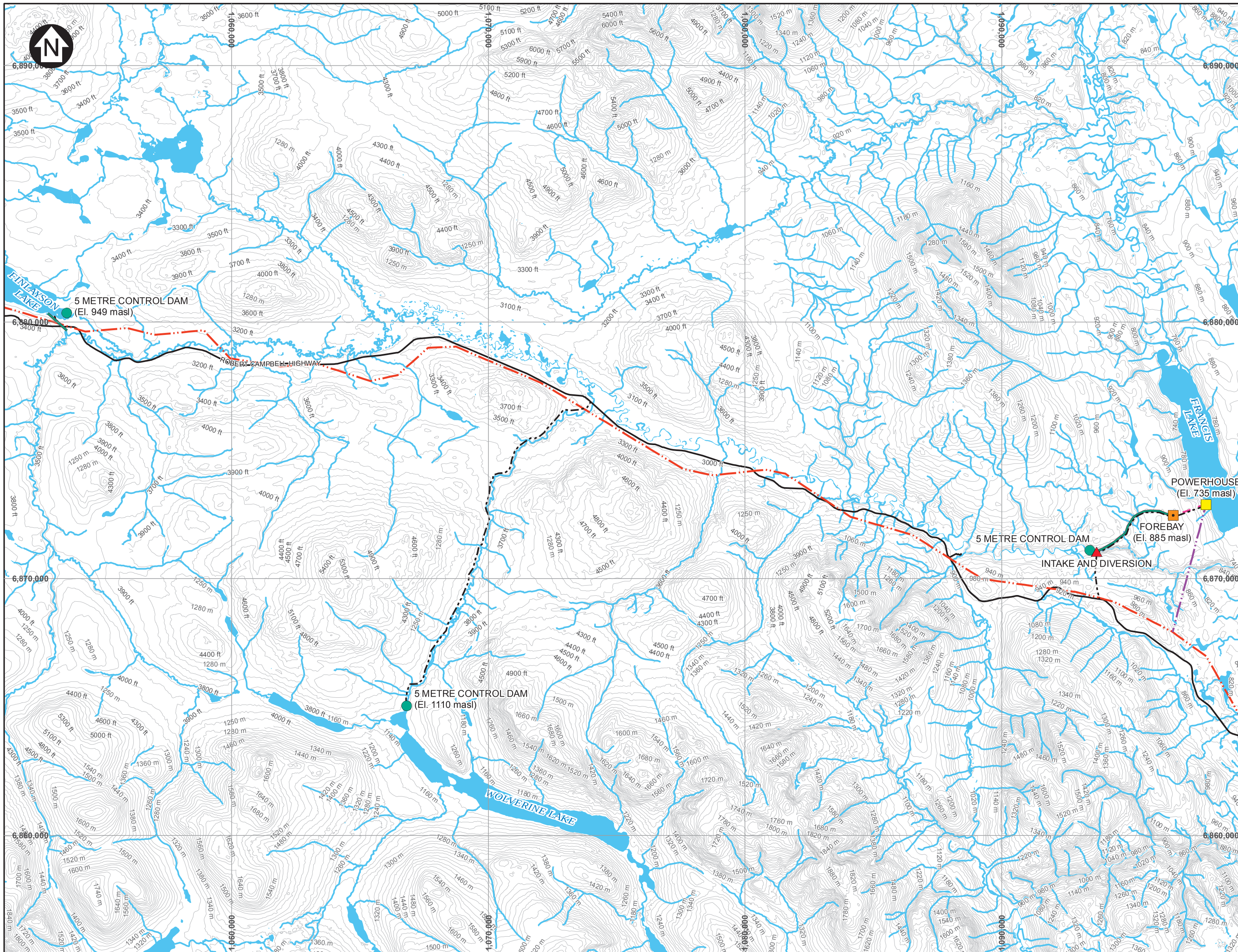
The only available study for this project was the 1990 Hydro Investigations by S. Demers. This study is outdated and high level in nature, and little is known of site specific geotechnical conditions. However, it is assumed that the locations of the intake dam, canal, penstock, and powerhouse are the most suitable and have therefore been used for this desktop level study.

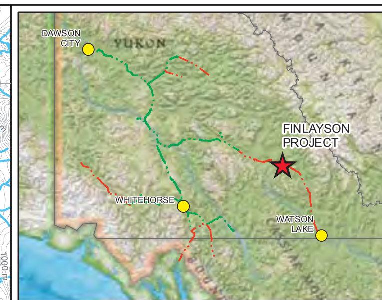
The design concept involves lake storage and flow regulation on Finlayson Lake and Wolverine Lake, and an intake diversion dam on Finlayson River downstream of the Wolverine River confluence. In its previously envisioned configuration, the intake dam on Finlayson River would be 66 m high at the head of a canyon, and reservoir flooding would require rerouting approximately 3 km of the Robert Campbell Highway. The highway is gravel, and the anticipated costs and technicalities of rerouting this highway are not anticipated to be difficult. However, should rerouting of the highway be impractical for permitting or other reasons, it is likely that a smaller dam and a modified water conveyance alignment could be found.

A basic general arrangement for the proposed project layout is shown on Figure 4.2.Key project parameters for this layout are as follows:

- Q_d = 13.3 m^3/s.
- Gross Head = 150 m.
- Installed Capacity = 17.6 MW.
- 17 km of access roads, to reach the outlets of Wolverine and Finlayson Lakes, the intake diversion dam, water conveyance and powerhouse.
- Relocation of 3 km of the Robert Campbell Highway (due to dam flooding).
- Control dams at the outlets of Wolverine and Finlayson Lakes to provide 5 m of lake storage (combined operating storage of 155 Mm^3). The dams would be constructed with IFR release systems and spillways for flood water management.
- 66 m high CFRD or structured earthfill intake diversion dam located at the head of a canyon on the Finlayson River, upstream of Frances Lake.
- Spillway at the south abutment to route flood flows safely downstream to Finlayson River.
- Water conveyance canal at the north abutment, extending 4.7 km to a forebay (El. 885 masl).
- 1.35 km penstock.
- Powerhouse and substation, located at the shore of Frances Lake (El. 735 masl).
- 5.1 km transmission line, with t-tap interconnection to the proposed Ross River – Watson Lake transmission line paralleling the Robert Campbell Highway.

In its present configuration, the Finlayson River Project is sized for firm power of 17.6 MW, operating at a 100 percent capacity factor all year. It is anticipated that the optimal project in terms of a cost to benefit assessment would be much larger, perhaps in the order of 40 to 45 MW. Site investigations and a more detailed review of site specific data would be required to confirm project viability.





LEGEND:

- CITY/TOWN
- CONTOUR (10 m/100 ft)
- EXISTING ROAD
- PROPOSED TRANSMISSION LINE (YEC)
- RIVER/CREEK
- LAKE

PROPOSED PROJECT FACILITIES

- DAM
- INTAKE / DIVERSION WEIR
- POWERHOUSE
- FOREBAY
- PENSTOCK
- CANAL / TAILRACE CANAL
- INTERCONNECTION TRANSMISSION
- ROAD

NOTES:

1. BASE MAP: GOVERNMENT OF YUKON TOPOGRAPHY; NATIONAL GEOGRAPHIC MAPPING.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 7N.
3. CONTOUR INTERVALS IN BOTH FEET AND METRES.
4. PROPOSED TRANSMISSION ALIGNMENTS PROVIDED BY YUKON ENERGY CORP.
5. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:150,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

2 1 0 2 4 6 8 km

YUKON ENERGY CORPORATION

SMALL HYDRO ASSESSMENT

FINLAYSON RIVER
GENERAL ARRANGEMENT

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA103-00556/02	2
FIGURE 4.2	REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	06OCT'16	ISSUED WITH REPORT	SDR	CAC	KLA

4.1.3 Anvil Creek

Reference Reports: *Nil*.

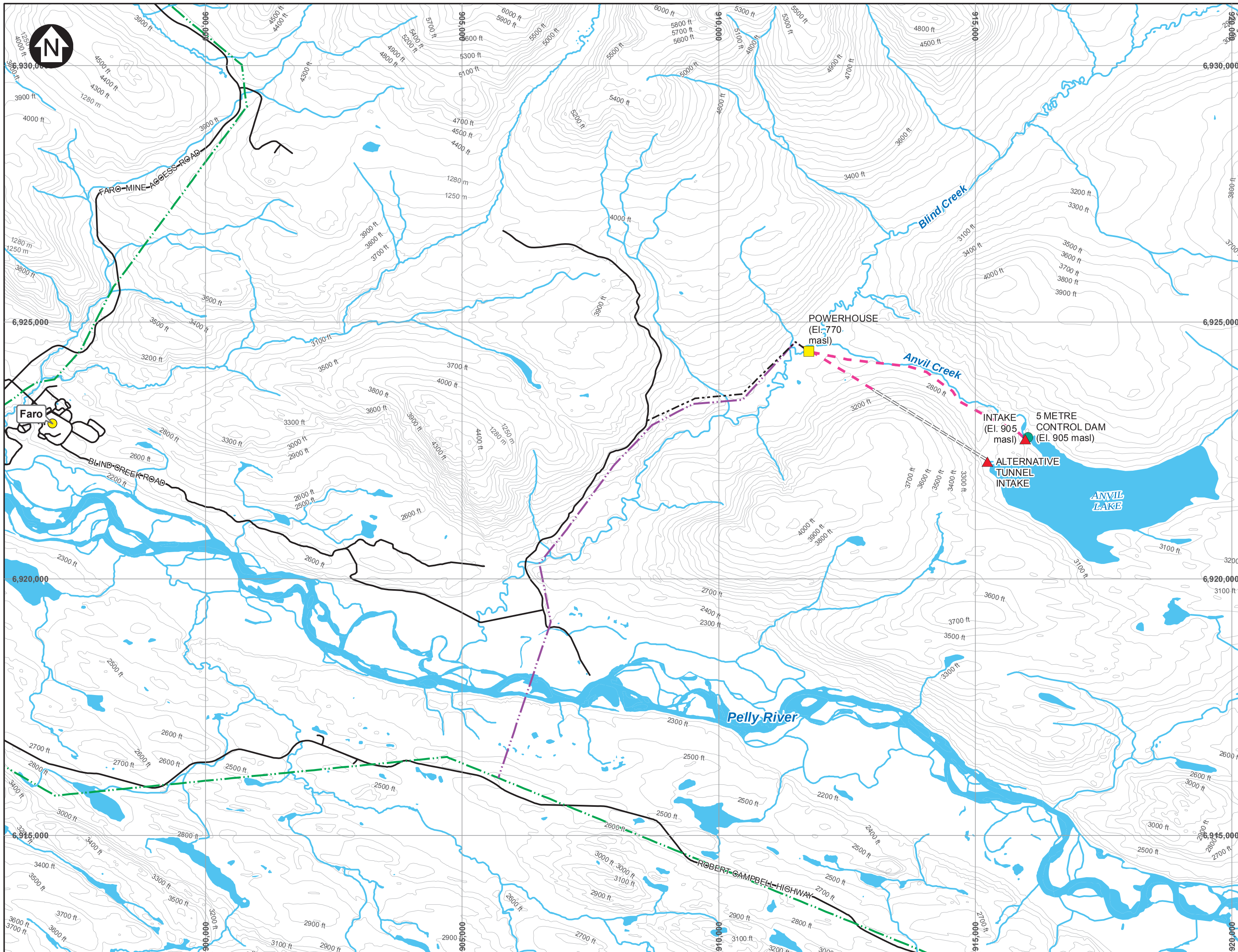
The Anvil Creek Project is located on Anvil Creek, approximately 205 km northeast of Whitehorse and 16 km east of Faro. The project is located in the Pelly River watershed, a tributary to the Yukon River. Very little previous information could be obtained for the data review of this site.

The KP concept involves lake storage and flow regulation on Anvil Lake and a buried penstock following the Anvil Creek valley to a powerhouse location upstream of the Anvil Creek – Blind Creek confluence. An alternative configuration involves a tunnel and penstock combination that offers a shorter overall water conveyance length. This option is envisioned to be more costly than the full penstock option, however should surficial conditions prove difficult in the Anvil Creek valley, it may become a viable alternative.

A basic general arrangement for the proposed project layout is shown on Figure 4.3, including both water conveyance options. Key project parameters for this layout are assumed as follows:

- Q_d = 8.2 m^3/s.
- Gross Head = 135 m.
- Installed Capacity = 9.8 MW.
- 3.5 km of new access road to access the powerhouse site from the Blind Creek Road. An allowance of 5 km of existing road upgrades for the Blind Creek access road have been allotted.
- 11 km of transmission line service access roads.
- Concrete Faced Rockfill Dam (CFRD) or earthfill control dam at the outlet of Anvil Lake to provide 5 m of storage (operating storage of 27.9 Mm^3). The dam would be constructed with an IFR discharge system and a spillway to Anvil Creek for flood water management.
- Intake weir at the dam and lake outlet (El. 905 masl)
- 4.7 km penstock located adjacent to Anvil Creek.
- Powerhouse (El. 770 masl) and substation at the edge of Anvil Creek.
- 11 km transmission line crossing the Pelly River and interconnecting to the WAF grid at the Robert Campbell Highway (Highway 16).

Very limited reference information was available for the Anvil Creek hydropower site. The project layout was developed using Google Earth and publicly available mapping on the Yukon Government website (GeoYukon). Site characterisation of terrain hazards, bedrock and surficial geology, access, and technical viability of the project should be determined through site visits and acquisition of topographic data and aerial photos.



LEGEND:

- CITY/TOWN
- CONTOUR (10 m/100 ft)
- EXISTING ROAD
- EXISTING TRANSMISSION LINE
- RIVER/CREEK
- LAKE

PROPOSED PROJECT FACILITIES

- DAM
- INTAKE / DIVERSION WEIR
- POWERHOUSE
- PENSTOCK
- TUNNEL
- INTERCONNECTION TRANSMISSION
- ROAD

NOTES:

1. BASE MAP: GOVERNMENT OF YUKON TOPOGRAPHY; NATIONAL GEOGRAPHIC MAPPING.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 7N.
3. CONTOUR INTERVALS IN BOTH FEET AND METRES.
4. PROPOSED TRANSMISSION ALIGNMENTS PROVIDED BY YUKON ENERGY CORP.
5. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:75,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

1 0.5 0 1 2 3 km

YUKON ENERGY CORPORATION

SMALL HYDRO ASSESSMENT

ANVIL CREEK
GENERAL ARRANGEMENT

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA103-00556/02	2

FIGURE 4.3	REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	06OCT'16	ISSUED WITH REPORT	SDR	KK	KLA

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4.1.4 Tutshi – Windy Arm

Reference Reports: *1990, 1991 Hydro Investigations* [S. Demers, 1990, 1991], *Assessment of Potential Hydro Sites* [KGS Group, 2008].

The Tutshi – Windy Arm Project is a proposed storage hydropower development located between Tutshi Lake and Windy Arm of Tagish Lake in northern British Columbia. Tutshi and Tagish Lakes are tributaries to the Yukon River. The project site is approximately 45 km to the south of Carcross, Yukon, and the proposed powerhouse location is within 1 km to the east of the Klondike Highway.

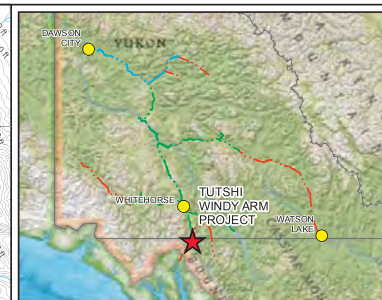
A number of studies have previously been completed for this site, including geotechnical investigations, design, and cost estimates, resulting in a number of alternative design concepts. This desktop study is based on the most current concepts, presented in the 2008 KGS report.

A basic arrangement for the proposed project layout is shown on Figure 4.4. Key project parameters for this layout are as follows:

- Q_d = 15.0 m^3/s.
- Gross Head = 54 m.
- Installed Capacity = 7.2 MW.
- 23.5 km of access roads, to reach the powerhouse, surface conveyance, tunnel intake, and outlet control dam on Tutshi Lake.
- Tutshi Lake outlet control dam to provide 5 m of lake storage (operating storage of 267 Mm^3), equipped with IFR release system and spillway for flood water management.
- Tunnel intake and 1.7 km tunnel through the hill separating the north end of Tutshi Lake from Windy Arm of Tagish Lake (Intake El. 707 masl).
- 2.7 km long penstock.
- Powerhouse on the south shore of Windy Arm, Tagish Lake (El. 656 masl).
- Substation and 0.5 km long transmission line, with t-tap interconnection to the proposed transmission line alongside the Klondike Highway.

In its present configuration, the Tutshi – Windy Arm Project is sized for firm power of 7.2 MW, operating at a 100 percent capacity factor all year. It is anticipated that the optimal project in terms of a cost to benefit assessment would be larger, perhaps in the order of 15 MW. At this larger installed capacity and higher design flow (Q_d = 30 – 32 m^3/s), the project would utilize more of the annual inflow to Tutshi Lake that would be spilled for a smaller project.

Site investigations and a more detailed review of site specific data would be required to confirm project viability and the optimal project size.



LEGEND:

- CITY/TOWN
- CONTOUR (10 m/100 ft)
- EXISTING ROAD
- PROPOSED TRANSMISSION LINE (YEC)
- RIVER/CREEK
- LAKE

PROPOSED PROJECT FACILITIES

- DAM
- INTAKE
- POWERHOUSE
- PENSTOCK
- TUNNEL
- LOW PRESSURE PIPE
- INTERCONNECTION TRANSMISSION
- ROAD

NOTES:

1. BASE MAP: GOVERNMENT OF YUKON TOPOGRAPHY; NATIONAL GEOGRAPHIC MAPPING.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 7N.
3. CONTOUR INTERVALS IN FEET.
4. PROPOSED TRANSMISSION ALIGNMENTS PROVIDED BY YUKON ENERGY CORP.
5. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:75,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

1 0.5 0 1 2 3 4 km

YUKON ENERGY CORPORATION

SMALL HYDRO ASSESSMENT

TUTSHI LAKE - WINDY ARM
GENERAL ARRANGEMENT

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA103-00556/02	2
FIGURE 4.4	REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	06OCT'16	ISSUED WITH REPORT	SDR	KK	KLA

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4.1.5 Wolf River

Reference Reports: *1990, 19911 Hydro Investigations* [S. Demers, 1990, 1991].

The Wolf River is a tributary of the Nisutlin River upstream of Teslin Lake, in the headwaters of the Yukon River. The Wolf River Project site is located near the river mouth and approximately 22 km to the northeast of the community of Teslin and the Alaska Highway.

The only available studies for this project were the 1990 and 1991 Hydro Investigations by S. Demers. Little is known of site specific geotechnical conditions and cannot be confirmed at the desktop level. It is assumed for the purpose of this study that the location of the powerhouse, penstock, and conveyance alignment was the most suitable based on the site visit by S. Demers.

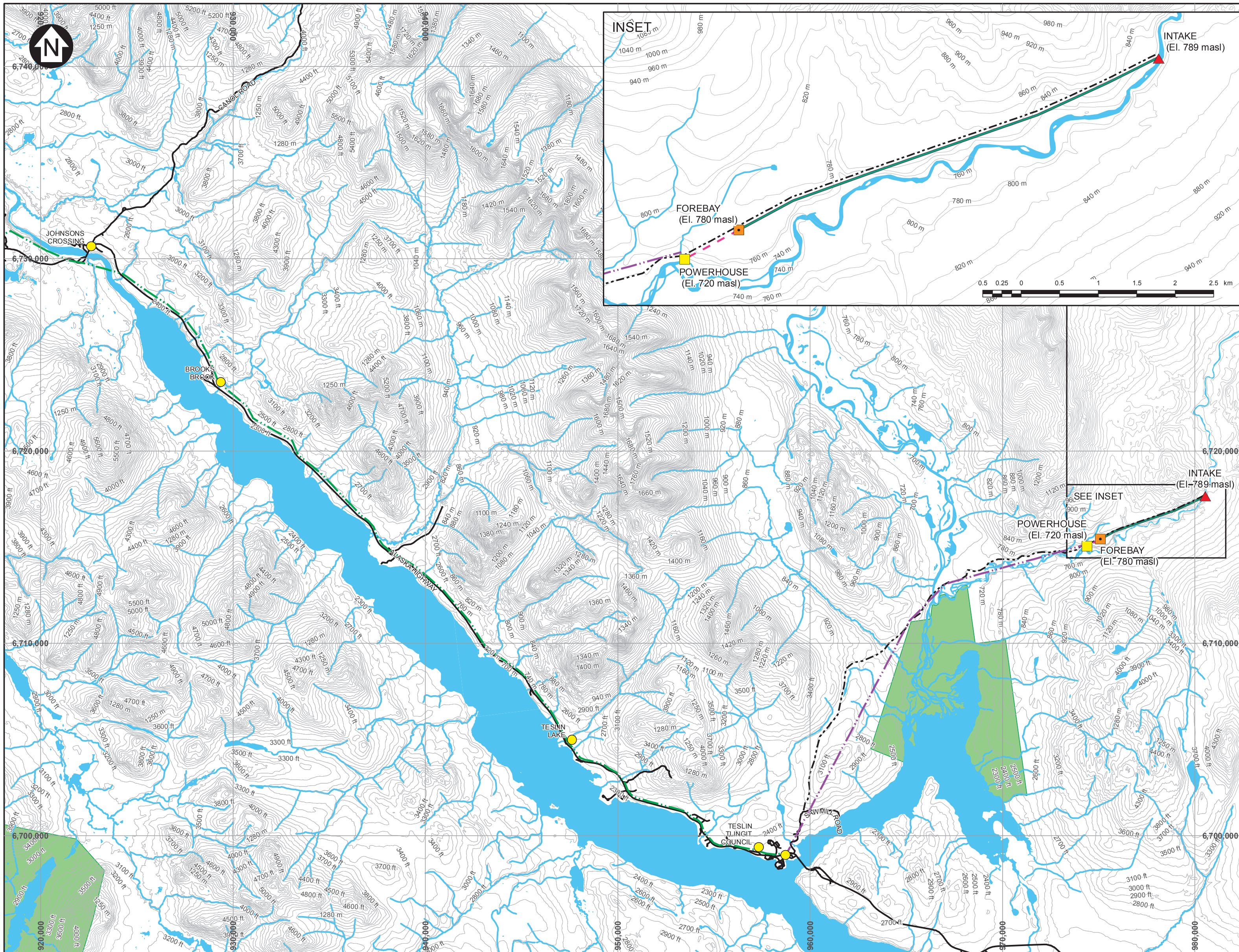
The project was envisioned to comprise a water conveyance approximately 11 kilometres in length. A review of Google Earth and regional mapping have led to a decision to move the intake further downstream, shortening the conveyance without a significant reduction in head. However, actual head will need to be confirmed with more accurate mapping.

A basic general arrangement for the proposed project layout is shown on Figure 4.5. Key project parameters for this layout are as follows:

- Q_d = 37.7 m^3/s.
- Gross Head = 60 m.
- Installed Capacity = 20 MW.
- 23 km of access roads to reach the project facilities.
- An intake diversion weir across Wolf River, diverting water to a 5.9 km long canal on the north side of the river (Intake El. 789 masl).
- Forebay (El. 780 masl) and 800 m long penstock.
- Powerhouse (El. 720 masl) and short tailrace channel to Wolf River.
- Substation and 23 km transmission line to Teslin, with a t-tap interconnection to the YEC proposed upgraded transmission line to Teslin.

This project has good power generating potential, and there may be an opportunity to target a higher installed capacity, in the order of 40 to 45 MW, for optimal project economics. However, for this study, an upper bound capacity of 20 MW was set as a cap for small hydro, in line with the scope described in the RFP.

The 1991 study also noted the potential opportunity for storage in Wolf Lake, which could improve winter generation and the plant capacity factor. This has not been considered in this study but may be a worthwhile design consideration in the future.



LEGEND:

- CITY/TOWN
- CONTOUR (10 m/100 ft)
- EXISTING ROAD
- EXISTING TRANSMISSION LINE
- RIVER/CREEK
- LAKE
- PROTECTED AREA

PROPOSED PROJECT FACILITIES

- INTAKE / DIVERSION WEIR
- POWERHOUSE
- FOREBAY
- PENSTOCK
- CANAL / TAILRACE CANAL
- INTERCONNECTION TRANSMISSION
- ROAD

NOTES:

1. BASE MAP: GOVERNMENT OF YUKON TOPOGRAPHY; NATIONAL GEOGRAPHIC MAPPING.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 7N.
3. CONTOUR INTERVALS IN BOTH FEET AND METRES.
4. PROPOSED TRANSMISSION ALIGNMENTS PROVIDED BY YUKON ENERGY CORP.
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SMALL HYDRO ASSESSMENT

WOLF RIVER
GENERAL ARRANGEMENT

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA103-00556/02	2

FIGURE 4.5 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
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4.2 TURBINE SELECTION

The selection of the optimal turbine and major equipment type and configuration is a function of design flows, installed capacities, and operating criteria. Conceptual turbine selections for the preferred sites described in this section generally conform to the typical equipment operating ranges illustrated on Figure 4.6. The preliminary turbine selections for the preferred sites are:

- Drury Creek: Francis
- Finlayson River: Pelton
- Anvil Creek: Pelton
- Tutshi-Windy Arm: Francis, and
- Wolf River: Francis.

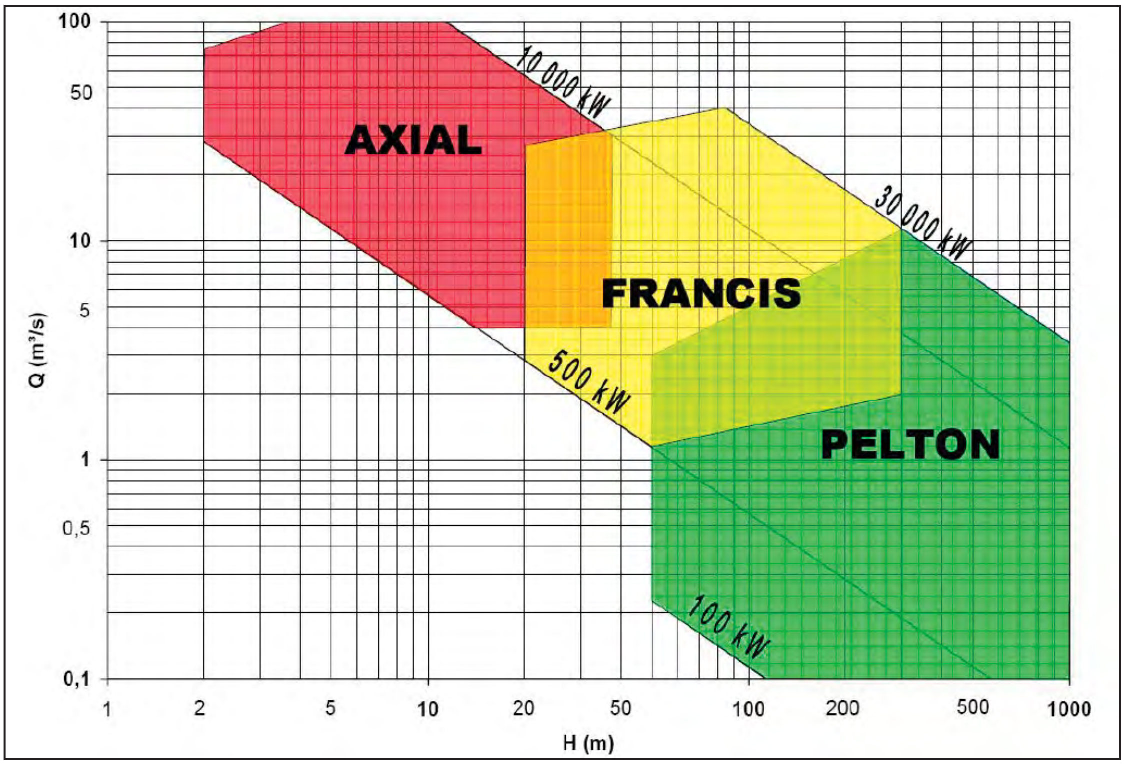

Figure 4.6 Turbine Selection Guideline

4.3 CAPITAL COST EVALUATION

Capital cost estimates have been developed based on the project configurations outlined in Section 4.1. Site specific data were used to establish project size, quantities and constructability. These attributes were used to estimate approximate material volumes for excavation, backfill, embankment material and reinforced concrete. Electrical and mechanical equipment requirements were estimated based on empirical data from KP's prior projects and published in industry technical reports.

The capital cost estimate includes an allowance for the Contractor's preliminary and general costs (overheads, insurance, bonus and profit etc.), an allowance for EPCM costs, and contingency.

Unit rates for material production, equipment procurement and installation costs relied on KP's internal costing database including recent, relevant experience with similar sized hydroelectric projects in Western Canada and the Yukon. KP's hydro project cost database also offered an order of magnitude check of total estimated costs for individual facility components and complete facilities, based on projects with comparable characteristics such as design flow, penstock pipe characteristics (length, diameter, pressure rating), gross head, generating capacity, powerhouse area, excavation quantities, reinforced concrete volumes, backfill quantities, switchyard capacity and transmission line capacity and length. Where a project interconnection is via "Tee-Tap" type interconnection it is assumed the transmission line interconnects to the closest possible point along an existing or future proposed transmission line; requiring expensive substation and/or switching station infrastructure. There may be sites where a cheaper option exists to extend the transmission line slightly further to interconnect at an existing substation. In this case the avoided costs of building a new substation or switching station could outweigh the cost of extending the transmission line. This was not considered in this study, but should be in the next level of study. An indicative interconnection arrangement is depicted in Figure 4.7 below:

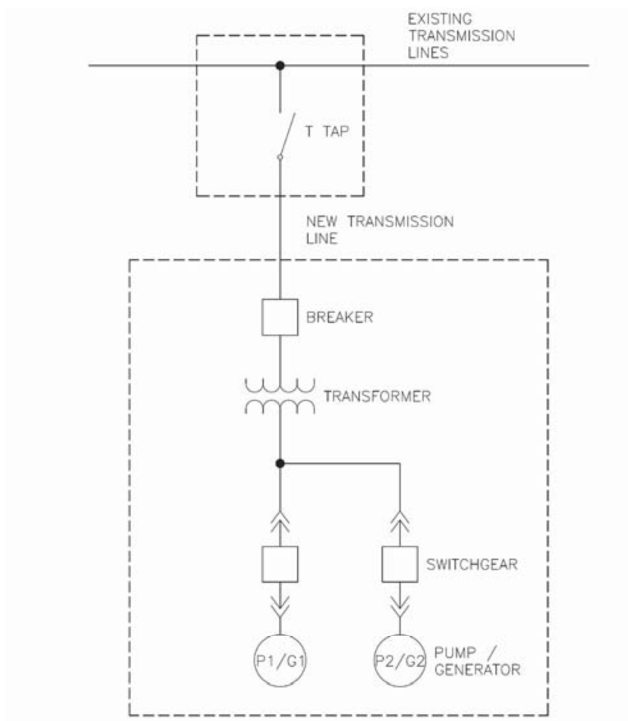

Figure 4.7 Indicative T-tap Interconnection Arrangement

Generating equipment costs were based on installed capacity, head and flow, while switchyard costs were estimated based on installed capacity. Adjustments to reflect the higher construction costs in the Yukon were included where appropriate. All dollars are shown in 2015 Canadian Dollars (CAD).

Capital costs were considered at a screening level, and costs will vary as more site specific assessments are undertaken and project designs are refined. The estimates have been prepared with sufficient detail for a preliminary AACE Class 5 estimate (±50%). These costs should be used as comparison of sites rather than as a reliable indication of the actual construction costs for any single project.

The overall estimated costs for the preferred sites are shown in Table 4.1.

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TABLE 4.1

YUKON ENERGY CORPORATION
SMALL HYDRO ASSESSMENT

CAPITAL COST ESTIMATE
PREFERRED SITES

10/6/2016 19:22

ITEM	DESCRIPTION	Drury Creek	Finlayson River	Anvil Creek	Tutshi - Windy Arm	Wolf River
100	MOB, DEMOB, INSURANCE, BONDS, OVERHEADS, CONTRACTOR'S PROFIT	$ 16,263,000	$ 44,480,000	$ 18,263,000	$ 20,970,000	$ 36,818,000
200	ACCESS AND SITE PREPARATION	$ 3,548,000	$ 8,650,000	$ 6,636,000	$ 7,216,000	$ 8,934,000
300	INTAKE, FOREBAY, HEADRACE AND TAILRACE	$ 2,318,000	$ 4,224,000	$ 2,036,000	$ 4,509,000	$ 11,137,000
400	WATER CONVEYANCE SYSTEM	$ 30,790,000	$ 27,253,000	$ 20,732,000	$ 39,901,000	$ 49,115,000
500	POWERHOUSE AND ANCILLARY SERVICES	$ 5,328,000	$ 11,236,000	$ 6,274,000	$ 5,057,000	$ 13,868,000
600	POWER GENERATION EQUIPMENT (WATER TO WIRE)	$ 5,675,000	$ 12,333,000	$ 6,842,000	$ 5,022,000	$ 13,980,000
700	SWITCHYARD, TRANSMISSION AND INTERCONNECTION	$ 3,161,000	$ 7,332,000	$ 8,677,000	$ 3,067,000	$ 20,097,120
800	DAM(S) AND RESERVOIR(S)	$ 3,391,000	$ 77,239,000	$ 9,680,000	$ 5,128,000	$ 5,595,000
	SUB-TOTAL (CONSTRUCTION COSTS)	**$ 70,474,000**	**$ 192,747,000**	**$ 79,140,000**	**$ 90,870,000**	**$ 159,544,120**
	EPCM ENGINEERING COST (8% of CONSTRUCTION COST)	$ 5,638,000	$ 15,420,000	$ 6,331,000	$ 7,270,000	$ 12,764,000
	CONTINGENCY (30 % of CONSTRUCTION COST)	$ 21,142,000	$ 57,824,000	$ 23,742,000	$ 27,261,000	$ 47,863,000
	TOTAL ESTIMATED CAPITAL COST	**$ 97,250,000**	**$ 265,990,000**	**$ 109,210,000**	**$ 125,400,000**	**$ 220,170,000**

M:\1\03\00556\02\A\Report\2 - Small Hydro\Rev 0\Tables\[Preferred Sites Rev0.xlsx]Table 4.1

NOTES:

1. DOES NOT INCLUDE UPFRONT ENVIRONMENTAL, PERMITTING AND OWNERS COSTS.
2. DOES NOT INCLUDE APPLICABLE SALES TAXES.
3. EPCM COSTS INCLUDE DETAILED ENGINEERING, TENDERING OF CIVIL AND WATER-TO-WIRE CONTRACTS, SITE SUPERVISION, OVERALL PROJECT MANAGEMENT AND ENVIRONMENTAL MONITORING.
4. COSTS ARE PRELIMINARY AND ARE CONSIDERED EQUIVALENT TO AN AACE CLASS 5 ESTIMATE.

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REV	DATE	DESCRIPTION	PREP'D	CHK'D

4.4 FINANCIAL EVALUATION

KP has developed a financial model to assess the Levelized Cost of Energy (LCOE) and Levelized Cost of Capacity (LCOC) for the five preferred sites. The basic parameters used in the financial model include:

- Capital Cost Estimate — Varies by alternative
- Fixed Operating Costs — 2.0% of initial capital cost per year
- Variable Operating Costs — $0.005/kWh for power generation
- Net Annual Generation — Varies by option
- Construction Period — 3 years, and
- Project Life — 65 years.

No escalation/inflation is included in the financial evaluation. Interest rates are assumed for the real cost of capital as provided by YEC:

- YEC resource options — 3.38%
- IPP resource options — 4.61%, and
- High interest scenario — 8.82%.

The loaded capital cost, or net present cost at Commercial Operation Date (COD) is accounts interest accrued during construction, using the following formula:

$$C = \sum_{\mathrm{yr}=0}^{\mathrm{n}} \mathrm{c}(1+i)^{\mathrm{n}-\mathrm{yr}}$$

Where:

$$C = loaded\ capital\ cost$$
$$c = construction\ cost\ in\ given\ year\ of\ interest$$
$$yr = construction\ year\ of\ interest$$
$$n = total\ number\ of\ years\ of\ construction\ (4)$$
$$i = interest\ rate$$

Next, the levelized capital cost per year is calculated using the capital recovery factor formula:

$$LC = \frac{iC(1+i)^N}{(1+i)^N - 1}$$

Where:

$$LC = levelized\ capital\ cost\ per\ year$$
$$N = total\ project\ life$$

A summary of the project financial attributes for the preferred sites is included in Table 4.2. The summary provides levelized cost results for the YEC development real cost of capital rate, IPP rate, and high interest scenario rates provided by YEC.

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TABLE 4.2

YUKON ENERGY CORPORATION
SMALL HYDRO ASSESSMENT

PROJECT FINANCIAL ATTRIBUTES - PREFERRED SITES

10/6/2016 19:25

ITEM	Site # / Rate	5 Drury Creek	8 Finlayson River	40 Anvil Creek	43 Tutshi - Windy Arm	49 Wolf River
Project Life (Yrs)	65					
Real Cost of Capital (YEC)	3.38%					
Real Cost of Capital (IPP)	4.61%					
Real Cost of Capital - High Rate Scenario	8.82%					
Installed Capacity (MW)		8.1	17.6	9.8	7.2	20.0
Net Annual Generation (GWh)		31.7	138.9	41.3	56.6	95.6
Overnight Capital Cost ($)		**$97,250,000**	**$265,990,000**	**$109,210,000**	**$125,400,000**	**$220,170,000**
Construction Cost, Yr. 1	20%	$19,450,000	$53,198,000	$21,842,000	$25,080,000	$44,034,000
Construction Cost, Yr. 2	40%	$38,900,000	$106,396,000	$43,684,000	$50,160,000	$88,068,000
Construction Cost, Yr. 3	40%	$38,900,000	$106,396,000	$43,684,000	$50,160,000	$88,068,000
Fixed O&M Costs (% of Capital)	2.0%	$1,945,000	$5,320,000	$2,184,000	$2,508,000	$4,403,000
Variable Costs, Generation	0.5c/kWh	$158,000	$695,000	$207,000	$283,000	$478,000
YEC Rate Scenario						
Interest During Construction	3.38%	$6,030,000	$16,490,000	$6,770,000	$7,800,000	$13,650,000
Loaded Capital Cost, at End of Construction Period ($)		**$103,280,000**	**$282,480,000**	**$115,980,000**	**$133,200,000**	**$233,820,000**
Levelized Capital Cost		$3,946,000	$10,792,000	$4,431,000	$5,089,000	$8,933,000
Levelized Annual Cost		$6,049,000	$16,807,000	$6,822,000	$7,880,000	$13,814,000
Capital Cost of Energy Output	$/MWh	$3,300	$2,000	$2,800	$2,400	$2,400
Capital Cost of Capacity	$/kW-yr	$12,700	$16,000	$11,900	$18,600	$11,700
Levelized Cost of Energy	**$/kWh**	**$0.19**	**$0.12**	**$0.17**	**$0.14**	**$0.14**
Levelized Cost of Capacity	**$/kW-yr**	**$700**	**$1,000**	**$700**	**$1,100**	**$700**
IPP Rate Scenario						
Interest During Construction	4.61%	$8,280,000	$22,640,000	$9,300,000	$10,670,000	$18,740,000
Loaded Capital Cost, at End of Construction Period ($)		**$105,530,000**	**$288,630,000**	**$118,510,000**	**$136,070,000**	**$238,910,000**
Levelized Capital Cost		$5,140,000	$14,057,000	$5,772,000	$6,627,000	$11,635,000
Levelized Annual Cost		$7,243,000	$20,072,000	$8,163,000	$9,418,000	$16,516,000
Capital Cost of Energy Storage	$/MWh	$3,300	$2,100	$2,900	$2,400	$2,500
Capital Cost of Capacity	$/kW-yr	$13,000	$16,400	$12,100	$19,000	$12,000
Levelized Cost of Energy	**$/kWh**	**$0.23**	**$0.14**	**$0.20**	**$0.17**	**$0.17**
Levelized Cost of Capacity	**$/kW-yr**	**$900**	**$1,100**	**$800**	**$1,300**	**$800**
High Interest Rate Scenario						
Interest During Construction	8.82%	$16,210,000	$44,330,000	$18,200,000	$20,900,000	$36,700,000
Loaded Capital Cost, at End of Construction Period ($)		**$113,460,000**	**$310,320,000**	**$127,410,000**	**$146,300,000**	**$256,870,000**
Levelized Capital Cost		$5,526,000	$15,113,000	$6,205,000	$7,125,000	$12,510,000
Levelized Annual Cost		$7,629,000	$21,128,000	$8,596,000	$9,916,000	$17,391,000
Capital Cost of Energy Storage	$/MWh	$3,600	$2,200	$3,100	$2,600	$2,700
Capital Cost of Capacity	$/kW-yr	$14,000	$17,600	$13,000	$20,400	$12,900
Levelized Cost of Energy	**$/kWh**	**$0.24**	**$0.15**	**$0.21**	**$0.18**	**$0.18**
Levelized Cost of Capacity	**$/kW-yr**	**$900**	**$1,200**	**$900**	**$1,400**	**$900**

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NOTES:
1. DISCOUNT RATES ARE REAL COST OF CAPITAL AS PROVIDED BY YEC. NOMINAL RATES HAVE NOT BEEN INCLUDED.
2. TIME VALUE OF MONEY HAS NOTE BEEN ASSESSED.

0	6OCT'16	ISSUED WITH REPORT VA103-556/2-2	SDR	KLA
REV	DATE	DESCRIPTION	PREP'D	CHK'D

4.5 OTHER CONSIDERATIONS

The cost estimates and financial attributes described in Section 4.2 and 4.3 are appropriate for a stand-alone approach to project evaluation. Two additional potential synergies have been identified: benefits to downstream generation at other hydroelectric facilities, and benefits from potential pumped-storage developments. These benefits are described below.

4.5.1 Benefits to Downstream Generation

In the KGS 2008 study, it was noted that the Tutshi – Windy Arm Project would offer potential increases in winter generation at the Whitehorse Generating Station, due to the increased available winter flows in the Yukon River that will result from attenuation of the Tutshi Lake outflows. In the KGS study, the estimated magnitude of the increase was 6 GWh/yr.

This is an advantage that should improve the economics and relative merit of developing the Tutshi – Windy Arm Project. No other preferred site will improve the winter generation of the Whitehorse Generating Station or the three other existing hydropower facilities in the Yukon.

4.5.2 Benefits from Pumped-Storage Development

In parallel with this study, KP also completed an assessment of potential pumped-storage hydropower sites that could provide winter power to the Yukon. The study (KP Reference VA103-556/2-1) investigated a number of sites, many of which are located within the same watersheds as the small hydro sites considered in this report.

Of particular note, the best pumped-storage site for all scenarios assessed is located between Moon Lake and Tutshi Lake. Development of both the pumped-storage scheme and the Tutshi – Windy Arm small hydro project could have significant advantages, including shared cost of access to the Tutshi Lake outlet control dam, and additional flow control on Tutshi Lake, with the potential for compounded increases in winter generation. Additionally, it may provide significant logistical and construction related advantages if both sites were to be developed concurrently or in sequence.

The optimal project configuration for the combined Moon Lake – Tutshi Lake pumped-storage project and Tutshi – Windy Arm small hydro project would require a more detailed study encompassing both of these projects.

4.6 DEVELOPMENT SCHEDULE

A high level development schedule has been created to illustrate the relative timelines for completing critical tasks associated with developing small hydro projects in the Yukon. The relative timelines for completing the major development tasks is similar for each option described above, and this schedule should be considered as generic and indicative only. The major development tasks and timelines are listed below.

1. Feasibility Study – 1 year
   - Will require detailed mapping and site specific hydrology data for a minimum of one year of data collection
2. Environmental Assessment (Permitting and Baseline Studies) – 2 years (will start concurrent with Feasibility Study)
   - Will include fisheries, hydrological and wildlife/terrestrial studies that will be inputs to the Environmental Assessment for each project
   - First Nations and stakeholder consultation will also be included in this stage
3. EPC Tendering Process – 1 year
   - EPC tender design can start immediately after Feasibility Study
4. Construction – 3 years
   - Will commence once Environmental Assessment Certificate is received and EPC contractor is selected
5. Commissioning – 4-6 months
   - Commences after Construction
6. Operations – 65 years

The best case scenario for duration of project development is 5.5 years; from the start of the Feasibility Studies through to the end of Commissioning. Actual project development schedules are site specific and may be influenced environmental baselines studies, consultation with first nations and broader public opposition to development of the project.

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FIGURE 4.6

YUKON ENERGY CORPORATION
SMALL HYDROELECTRIC PROJECTS
DEVELOPMENT SCHEDULE - MAJOR TASKS

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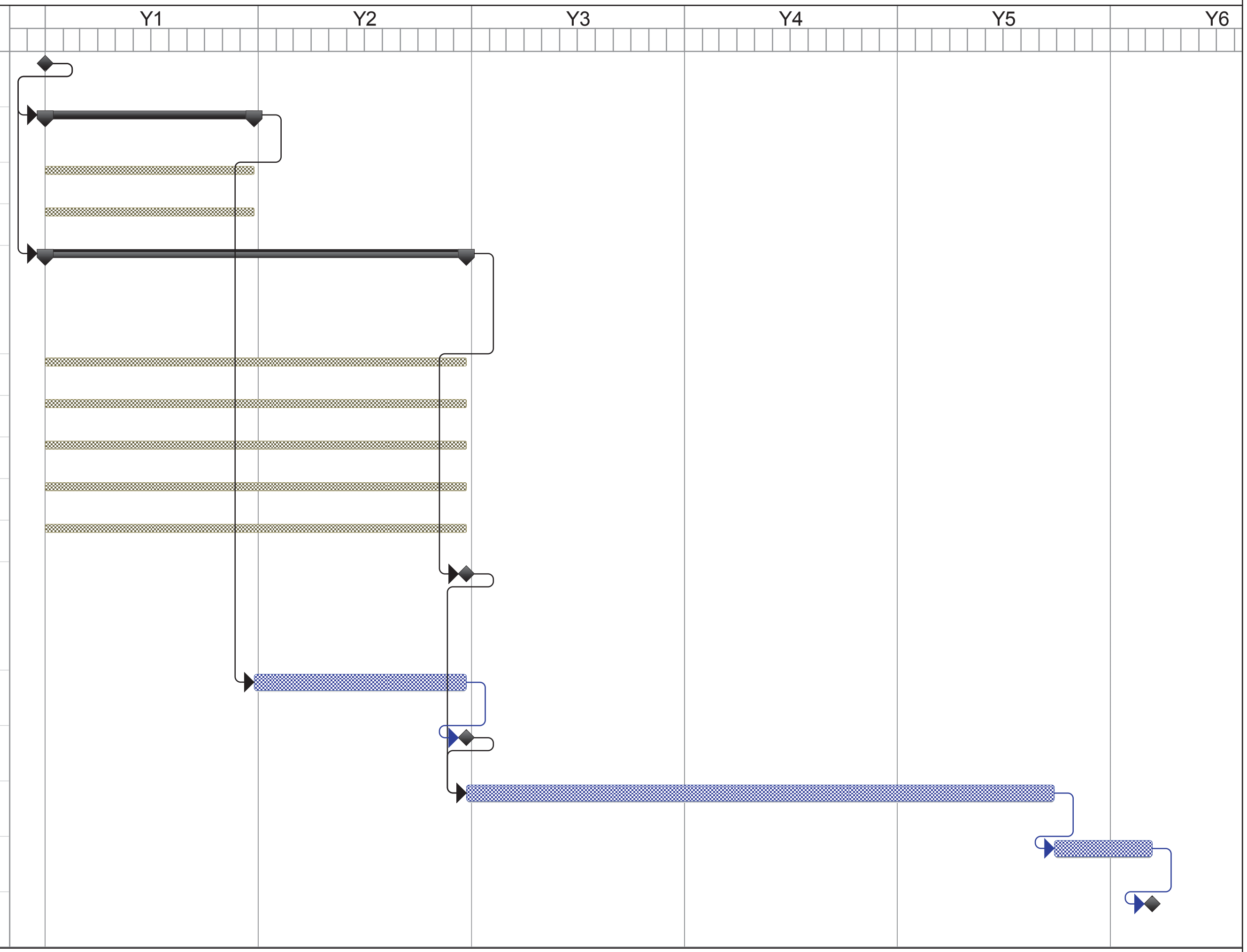
ID	WBS	Task Name
1	1	Notice to Proceed
2	2	Feasibility Study
3	2.1	Prefeasiility Engineering
4	2.2	Hydrology Assessment
5	3	Environmental Assessment
6	3.1	Fisheries Studies
7	3.2	Hydrology Studies
8	3.3	Wildlife & Terrestrial
9	3.4	First Nations Consultation
10	3.5	Stakeholder Consultation
11	4	Environmental Certificate Awarded
12	5	EPC Tendering Process
13	6	Award EPC Contract
14	7	Construction
15	8	Commissioning
16	9	Operations



Project: VA103-00556/02-A/2
Date: Thu 6/23/16
By: Daniel Rohn

Task | Task with Subtask(s) | Milestone | Subtask

File Location: \\KPL\VA-Prj$\1\03\00556\02\A\Report\2 - Small Hydro\Rev 0\Figure 4.6 Small Hydro Sched_DJR.mpp

5 – CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

A screening assessment of previously identified small hydro sites in the Yukon was completed to identify the better development options for future studies. A total of forty-four potential sites were assessed in a multi-stage screening process.

The most attractive (preferred) projects, based on a desktop level assessment of location, project layout, site characteristics, capacity, energy, and costs, are Drury Lake, Finlayson River, Anvil Creek, Tutshi – Windy Arm, and Wolf River. Summary of results for preferred sites is as follows:

- LCOC ranges from \$700 to \$1,200/kW-yr at the YEC real interest rate of 3.38 percent.
- LCOE ranges from \$0.13 to \$0.21/kWh at the YEC real interest rate of 3.38 percent.
- Based on a stand-alone assessment of hydropower development, the most attractive small hydro sites are the Finlayson River, Wolf River, and Tutshi – Windy Arm. Whereas, Drury Lake and Anvil Creek appear to be more expensive on a cost of energy basis.
- The optimal installed capacities for Finlayson River, Tutshi – Windy Arm, and Wolf River Projects are likely higher than reported in the present design and should be explored further. The purpose of this study was to evaluate sites of 20 MW or less based on the requirements, as such the optimal installed capacities were not determined.
- The Tutshi – Windy Arm project has the added benefit of increasing potential winter generation at the Yukon Generating Station downstream.
- If the Moon Lake – Tutshi Lake pumped storage project is developed, it may have material synergies with development of the Tutshi – Windy Arm small hydro project.

A summary of the Financial and Technical attributes of the preferred sites is presented in Table 5.1 below:

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TABLE 5.1

YUKON ENERGY CORPORATION
SMALL HYDRO ASSESSMENT

SUMMARY OF TECHNICAL & FINANCIAL ATTRIBUTES
PREFERRED SITES

10/6/2016 19:25

ATTRIBUTES	Drury Creek	Finlayson River	Anvil Creek	Tutshi - Windy Arm	Wolf River
TECHNICAL:					
Installed Capacity (MW)	8.1	17.6	9.8	7.2	20.0
Net Annual Generation (GWh)	31.7	138.9	41.3	56.6	95.6
Mean Annual Discharge (m^3/s)	4.9	16.5	4.1	16.1	40.3
Design Flow - Qd (m^3/s)	9.3	13.3	8.2	15.0	37.7
Gross Head (m)	99	150	135	54	60
Transmission Line Length (km)	1	5	11	1	23
FINANCIAL:					
Estimated Capital Cost	$ 97,250,000	$ 265,990,000	$ 109,210,000	$ 125,400,000	$ 220,170,000
O&M Costs - Fixed ($/yr)	$ 1,945,000	$ 5,320,000	$ 2,184,000	$ 2,508,000	$ 4,403,000
O&M Costs - Variable ($/yr)	$ 158,000	$ 695,000	$ 207,000	$ 283,000	$ 478,000
YEC Rate Scenario (3.38%)					
Levelized Cost of Energy ($/kWh)	$ 0.19	$ 0.12	$ 0.17	$ 0.14	$ 0.14
Levelized Cost of Capacity ($/kW-yr)	$ 700	$ 1,000	$ 700	$ 1,100	$ 700
IPP Rate Scenario (4.61%)					
Levelized Cost of Energy ($/kWh)	$ 0.23	$ 0.14	$ 0.20	$ 0.17	$ 0.17
Levelized Cost of Capacity ($/kW-yr)	$ 900	$ 1,100	$ 800	$ 1,300	$ 800
High Interest Rate Scenario (8.82%)					
Levelized Cost of Energy ($/kWh)	$ 0.24	$ 0.15	$ 0.21	$ 0.18	$ 0.18
Levelized Cost of Capacity ($/kW-yr)	$ 900	$ 1,200	$ 900	$ 1,400	$ 900

M:\1\03\00556\02\A\Report\2 - Small Hydro\Rev 0\Tables\[Preferred Sites Rev0.xlsx]Table 4.2

NOTES:

1. DOES NOT INCLUDE UPFRONT ENVIRONMENTAL, PERMITTING AND OWNERS COSTS.
2. DOES NOT INCLUDE APPLICABLE SALES TAXES.
3. EPCM COSTS INCLUDE DETAILED ENGINEERING, TENDERING OF CIVIL AND WATER-TO-WIRE CONTRACTS, SITE SUPERVISION, OVERALL PROJECT MANAGEMENT AND ENVIRONMENTAL MONITORING.
4. COSTS ARE PRELIMINARY AND ARE CONSIDERED EQUIVALENT TO AN AACE CLASS 5 ESTIMATE.

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To determine the optimal small hydro site will require further assessment of a number of factors, including desired capacity, development of proposed transmission lines, environmental impacts, political/societal conditions and capital cost estimates based on site quantities. Consideration of these factors, in conjunction with detailed site investigations and engineering studies on the preferred sites, will be required.

5.2 RECOMMENDATIONS

Further evaluation of the preferred sites is recommended, to improve the design basis, project configurations, and understanding of hydrological and geotechnical conditions. The following activities are recommended:

- Preliminary site visits to the following projects to further evaluate technical viability:
    - Drury Lake
    - Finlayson River
    - Anvil Creek
    - Tutshi – Windy Arm, and
    - Wolf River.
- Obtain accurate mapping (such as PhotoSat satellite topography) for the proposed project areas to confirm project configurations and details including dam sizes, water conveyance routings, powerhouse locations, access roads, and transmission lines.
- Implement hydrological data collection programs at the preferred sites.
- Update energy estimates based on hydrology data and accurate depth-area-capacity curves for reservoirs.
- Update quantity and cost estimates.
- Undertake a screening assessment of social and environmental permitting constraints at each of the five preferred sites.

Should the above assessment indicate that there are no technical or environmental showstoppers, detailed evaluation of the sites through pre-feasibility and feasibility studies should be pursued to prove economic viability.

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7 – CERTIFICATION

This report was prepared and reviewed by the undersigned.

Prepared:

Scott Rees, P.Eng.
Project Engineer

PROFESSIONAL
7 October 2016
YUKON
TRAVIS JESS BROWN
TERRITORY
ENGINEER

Reviewed:

Travis Brown, P.Eng.
Senior Engineer

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Approval that this document adheres to Knight Piésold Quality Systems: SRM

APPENDIX A

PRELIMINARY CAPACITY & ENERGY

(Pages A-1 to A-4)

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TABLE A1

YUKON ENERGY CORP.
SMALL HYDRO STUDY

SMALL HYDRO SITES
ESTIMATED AVERAGE CAPACITY

Site #	Name	Estimated Power at Turbine (1) (MW)												Power Summary (GWhr)	
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Minimum Monthly	Average Monthly
1	Anvil Creek	3.1	3.1	2.8	3.3	9.8	9.8	8.6	5.2	5.0	4.1	4.4	3.5	2.8	5.2
3	Campbell Creek	1.4	1.3	1.2	1.5	6.7	7.5	7.5	5.8	4.6	2.8	2.1	1.6	1.2	3.7
5	Drury Creek(3)	8.1	8.1	8.1	8.1	0.0	0.0	0.0	0.0	0.0	0.0	8.1	8.1	0.0	8.1
8	Finlayson River	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6
9	Frances River	3.0	4.0	3.6	4.7	20.0	20.0	20.0	20.0	18.1	11.0	6.0	4.1	3.0	11.2
11	Homan Lake	1.0	1.0	0.9	1.1	2.7	2.7	2.4	2.2	2.1	1.9	1.4	1.1	0.9	1.7
12	Hoole River	0.4	0.3	0.3	0.4	1.8	2.0	2.0	1.6	1.3	0.8	0.4	0.3	0.3	1.0
14	Kathleen River	0.8	0.6	0.5	0.4	0.8	4.1	4.1	3.6	2.3	1.8	1.2	1.0	0.4	1.8
17	Lapie River	0.8	0.7	0.6	0.9	7.5	8.3	8.3	6.5	5.2	3.1	1.7	1.1	0.6	3.7
22	Mica Creek(3)	1.4	1.4	1.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.4	0.0	1.4
25	North Fork Klondike	1.7	1.4	1.3	1.9	15.1	16.9	16.8	13.2	10.5	6.3	3.4	2.3	1.3	7.6
26	North McQuesten	1.0	1.0	0.9	1.1	4.2	4.7	4.6	3.6	2.9	1.7	0.9	0.6	0.6	2.3
27	Orchay River	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
28	Pleasant Creek	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
29	Pleasant Cr with Rogue	3.4	3.2	2.9	3.6	18.6	20.0	20.0	16.2	12.9	7.7	5.5	4.1	2.9	9.8
33	Reid Lakes & Lake Creek	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
34	Rock Creek	0.4	0.3	0.3	0.5	3.7	3.7	3.3	2.0	1.9	1.6	0.9	0.6	0.3	1.6
39	Squanga Creek	0.3	0.2	0.2	0.3	2.6	2.9	2.9	2.2	1.8	1.1	0.6	0.4	0.2	1.3
43	Tutshi - Windy Arm	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
47	Watson Lake & McDonald Cr (3)	1.1	1.1	1.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.1	0.0	1.1
48	Watson River	0.1	0.2	0.2	0.2	0.8	0.8	0.7	0.4	0.4	0.3	0.2	0.1	0.1	0.4
49	Wolf River	4.3	3.5	3.2	4.7	20.0	20.0	20.0	20.0	20.0	15.2	8.3	5.7	3.2	12.1

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NOTES:
1. MONTHLY CAPACITY VALUES ARE PRELIMINARY ESTIMATES, CALCULATED USING THE ESTIMATED 50TH PERCENTILE HYDROLOGY VALUES FOR SMALL AND LARGE CATCHMENTS AS DETAILED IN REPORT SECTION 3.2.2.
2. INSTREAM FLOW REQUIREMENTS (ECOLOGICAL FLOWS ASSUMED TO BE 5 PERCENT OF MEAN ANNUAL DISCHARGE.
3. POWER VALUES DO NOT ACCOUNT FOR MINIMUM TURBINABLE FLOW (DEPENDENT ON NUMBER AND TYPE OF GENERATING UNITS).

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TABLE A2

YUKON ENERGY CORP.
SMALL HYDRO STUDY

SMALL HYDRO SITES
AVERAGE MONTHLY ENERGY ESTIMATES

Site #	Name	Estimated Net Energy Output (1) (GWhr)													Energy Summary (GWhr)	
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Energy Total	Minimum Monthly	Average Monthly
1	Anvil Creek	2.1	1.9	1.9	2.2	6.5	6.3	5.7	3.5	3.2	2.8	2.8	2.3	**41.3**	1.9	3.4
3	Campbell Creek	0.9	0.8	0.8	1.0	4.5	4.8	5.0	3.9	3.0	1.9	1.4	1.1	**29.0**	0.8	2.4
5	Drury Creek(3)	5.4	4.9	5.4	5.3	0.0	0.0	0.0	0.0	0.0	0.0	5.3	5.4	**31.7**	4.9	5.3
8	Finlayson River	11.8	10.7	11.8	11.4	11.8	11.4	11.8	11.8	11.4	11.8	11.4	11.8	**138.9**	10.7	11.6
9	Frances River	2.0	2.4	2.4	3.0	13.4	13.0	13.4	13.4	11.7	7.4	3.9	2.7	**88.7**	2.0	7.4
11	Homan Lake	0.7	0.6	0.6	0.7	1.8	1.8	1.6	1.4	1.4	1.2	0.9	0.7	**13.5**	0.6	1.1
12	Hoole River	0.2	0.2	0.2	0.2	1.2	1.3	1.4	1.1	0.8	0.5	0.3	0.2	**7.7**	0.2	0.6
14	Kathleen River	0.5	0.4	0.3	0.3	0.5	2.7	2.8	2.4	1.5	1.2	0.8	0.6	**12.6**	0.3	1.2
17	Lapie River	0.6	0.4	0.4	0.6	5.0	5.4	5.6	4.3	3.3	2.1	1.1	0.8	**29.6**	0.4	2.5
22	Mica Creek(3)	1.0	0.9	1.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.0	**5.6**	0.9	0.9
25	North Fork Klondike	1.1	0.8	0.9	1.2	10.1	11.0	11.3	8.8	6.8	4.2	2.2	1.5	**60.0**	0.8	5.0
26	North McQuesten	0.7	0.6	0.6	0.7	2.8	3.0	3.1	2.4	1.9	1.2	0.6	0.4	**18.0**	0.4	1.5
27	Orchay River	2.1	1.9	2.1	2.0	2.1	2.0	2.1	2.1	2.0	2.1	2.0	2.1	**24.6**	1.9	2.0
28	Pleasant Creek	1.3	1.1	1.3	1.2	1.3	1.2	1.3	1.3	1.2	1.3	1.2	1.3	**14.9**	1.1	1.2
29	Pleasant Cr with Rogue	2.3	1.9	1.9	2.4	12.4	13.0	13.4	10.8	8.3	5.2	3.6	2.8	**77.9**	1.9	6.5
33	Reid Lakes & Lake Creek	2.8	2.5	2.8	2.7	2.8	2.7	2.8	2.8	2.7	2.8	2.7	2.8	**32.4**	2.5	2.7
34	Rock Creek	0.3	0.2	0.2	0.3	2.5	2.4	2.2	1.3	1.2	1.1	0.6	0.4	**12.6**	0.2	1.1
39	Squanga Creek	0.2	0.1	0.1	0.2	1.7	1.9	1.9	1.5	1.1	0.7	0.4	0.3	**10.2**	0.1	0.8
43	Tutshi - Windy Arm	4.8	4.3	4.8	4.6	4.8	4.6	4.8	4.8	4.6	4.8	4.6	4.8	**56.6**	4.3	4.7
47	Watson Lake & McDonald Cr (3)	0.8	0.7	0.8	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.8	**4.4**	0.7	0.7
48	Watson River	0.1	0.1	0.1	0.2	0.5	0.5	0.5	0.3	0.3	0.2	0.1	0.1	**2.9**	0.1	0.2
49	Wolf River	2.8	2.1	2.2	3.0	13.4	12.9	13.4	13.4	12.9	10.2	5.4	3.8	**95.6**	2.1	8.0

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NOTES:
1. AVERAGE ENERGY VALUES ARE PRELIMINARY ESTIMATES, CALCULATED USING THE ESTIMATED 50TH PERCENTILE HYDROLOGY VALUES FOR SMALL AND LARGE CATCHMENTS AS DETAILED IN REPORT SECTION 3.2.2.
2. INSTREAM FLOW REQUIREMENTS (ECOLOGICAL FLOWS ASSUMED TO BE 5 PERCENT OF MEAN ANNUAL DISCHARGE.
3. ENERGY VALUES DO NOT ACCOUNT FOR MINIMUM TURBINABLE FLOW (DEPENDENT ON NUMBER AND TYPE OF GENERATING UNITS).

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TABLE A3

YUKON ENERGY CORP.
SMALL HYDRO STUDY

SMALL HYDRO SITES
PRELIMINARY ESTIMATED DEPENDABLE CAPACITY

Site #	Name	Estimated Power at Turbine[1] (MW)												Power Summary (GWhr)	
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Minimum Monthly	Average Monthly
1	Anvil Creek	2.7	2.8	2.5	2.9	6.5	8.7	5.1	3.0	3.5	2.9	3.7	3.0	2.5	3.9
3	Campbell Creek	1.1	1.1	1.0	1.2	4.4	6.5	4.9	3.8	3.5	2.1	1.7	1.3	1.0	2.7
5	Drury Creek[3]	8.1	8.1	8.1	8.1	0.0	0.0	0.0	0.0	0.0	0.0	8.1	8.1	0.0	8.1
8	Finlayson River	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6
9	Frances River	2.1	3.2	2.9	3.7	17.0	20.0	19.0	14.8	13.9	8.3	4.4	2.9	2.1	9.3
11	Homan Lake	0.9	0.9	0.8	1.0	1.8	2.4	1.4	1.5	1.7	1.5	1.2	1.0	0.8	1.3
12	Hoole River	0.3	0.3	0.3	0.3	1.2	1.8	1.3	1.0	1.0	0.6	0.3	0.2	0.2	0.7
14	Kathleen River	0.6	0.4	0.4	0.3	0.5	3.0	3.9	2.3	1.8	1.4	0.9	0.7	0.3	1.3
17	Lapie River	0.6	0.5	0.4	0.6	4.9	7.3	5.5	4.2	3.9	2.3	1.2	0.8	0.4	2.7
22	Mica Creek[3]	1.4	1.4	1.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.4	0.0	1.4
25	North Fork Klondike	1.2	1.0	0.9	1.3	9.9	14.8	11.1	8.5	8.0	4.7	2.5	1.6	0.9	5.4
26	North McQuesten	0.9	0.9	0.8	0.9	2.7	4.1	3.0	2.4	2.2	1.3	0.7	0.5	0.5	1.7
27	Orchay River	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
28	Pleasant Creek	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
29	Pleasant Cr with Rogue	2.8	2.6	2.4	3.0	12.1	18.1	13.6	10.5	9.8	5.8	4.4	3.3	2.4	7.4
33	Reid Lakes & Lake Creek	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
34	Rock Creek	0.2	0.2	0.2	0.3	2.5	3.3	1.9	1.1	1.3	1.1	0.6	0.4	0.2	1.1
39	Squanga Creek	0.2	0.2	0.1	0.2	1.7	2.5	1.9	1.4	1.4	0.8	0.4	0.3	0.1	0.9
43	Tutshi - Windy Arm	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
47	Watson Lake & McDonald Cr [3]	1.1	1.1	1.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.1	0.0	1.1
48	Watson River	0.1	0.2	0.2	0.2	0.5	0.7	0.4	0.2	0.3	0.2	0.1	0.1	0.1	0.3
49	Wolf River	3.0	2.4	2.2	3.3	20.0	20.0	20.0	20.0	19.1	11.5	6.1	4.1	2.2	11.0

\\KPL\VA-Prj$\1\03\00556\02\A\Data\Task 400 - Small Hydro\Energy\[Appendix A - Energy Summary Table.xlsx]A3

NOTES:
1. DEPENDABLE CAPACITY VALUES ARE PRELIMINARY ESTIMATES, CALCULATED USING THE ESTIMATED 85TH PERCENTILE HYDROLOGY VALUES FOR SMALL AND LARGE CATCHMENTS AS DETAILED IN REPORT SECTION 3.2.4.
2. INSTREAM FLOW REQUIREMENTS (ECOLOGICAL FLOWS ASSUMED TO BE 5 PERCENT OF MEAN ANNUAL DISCHARGE.
3. POWER VALUES DO NOT ACCOUNT FOR MINIMUM TURBINABLE FLOW (DEPENDENT ON NUMBER AND TYPE OF GENERATING UNITS).

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TABLE A4

YUKON ENERGY CORP.
SMALL HYDRO STUDY

SMALL HYDRO SITES
PRELIMINARY ESTIMATED FIRM ENERGY

Site #	Name	Estimated Net Dependable Energy Output (1) (GWhr)													Energy Summary (GWhr)	
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Energy Total	Minimum Monthly	Average Monthly
1	**Anvil Creek**	1.8	1.7	1.7	1.9	4.3	5.6	3.4	2.0	2.3	1.9	2.4	2.0	**31.0**	1.7	2.6
3	**Campbell Creek**	0.8	0.7	0.7	0.8	2.9	4.2	3.3	2.5	2.3	1.4	1.1	0.9	**21.6**	0.7	1.8
5	**Drury Creek(3)**	5.4	4.9	5.4	5.3	0.0	0.0	0.0	0.0	0.0	0.0	5.3	5.4	**31.7**	4.9	5.3
8	**Finlayson River**	11.8	10.7	11.8	11.4	11.8	11.4	11.8	11.8	11.4	11.8	11.4	11.8	**138.9**	10.7	11.6
9	**Frances River**	1.4	1.9	1.9	2.4	11.4	13.0	12.7	9.9	9.0	5.5	2.8	1.9	**74.0**	1.4	6.2
11	**Homan Lake**	0.6	0.6	0.6	0.6	1.2	1.6	0.9	1.0	1.1	1.0	0.8	0.7	**10.6**	0.6	0.9
12	**Hoole River**	0.2	0.2	0.2	0.2	0.8	1.2	0.9	0.7	0.6	0.4	0.2	0.1	**5.6**	0.1	0.5
14	**Kathleen River**	0.4	0.3	0.2	0.2	0.3	2.0	2.6	1.6	1.2	0.9	0.6	0.5	**9.6**	0.2	0.9
17	**Lapie River**	0.4	0.3	0.3	0.4	3.3	4.7	3.6	2.8	2.5	1.6	0.8	0.5	**21.3**	0.3	1.8
22	**Mica Creek(3)**	1.0	0.9	1.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.0	**5.6**	0.9	0.9
25	**North Fork Klondike**	0.8	0.6	0.6	0.9	6.6	9.6	7.4	5.7	5.2	3.2	1.6	1.1	**43.1**	0.6	3.6
26	**North McQuesten**	0.6	0.5	0.5	0.6	1.8	2.6	2.0	1.6	1.4	0.9	0.4	0.3	**13.4**	0.3	1.1
27	**Orchay River**	2.1	1.9	2.1	2.0	2.1	2.0	2.1	2.1	2.0	2.1	2.0	2.1	**24.6**	1.9	2.0
28	**Pleasant Creek**	1.3	1.1	1.3	1.2	1.3	1.2	1.3	1.3	1.2	1.3	1.2	1.3	**14.9**	1.1	1.2
29	**Pleasant Cr with Rogue**	1.8	1.6	1.6	1.9	8.1	11.7	9.1	7.0	6.4	3.9	2.8	2.2	**58.2**	1.6	4.8
33	**Reid Lakes & Lake Creek**	2.8	2.5	2.8	2.7	2.8	2.7	2.8	2.8	2.7	2.8	2.7	2.8	**32.4**	2.5	2.7
34	**Rock Creek**	0.2	0.1	0.1	0.2	1.7	2.2	1.3	0.8	0.9	0.7	0.4	0.2	**8.7**	0.1	0.7
39	**Squanga Creek**	0.1	0.1	0.1	0.1	1.1	1.6	1.3	1.0	0.9	0.5	0.3	0.2	**7.3**	0.1	0.6
43	**Tutshi - Windy Arm**	4.8	4.3	4.8	4.6	4.8	4.6	4.8	4.8	4.6	4.8	4.6	4.8	**56.6**	4.3	4.7
47	**Watson Lake & McDonald Cr (3)**	0.8	0.7	0.8	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.8	**4.4**	0.7	0.7
48	**Watson River**	0.0	0.1	0.1	0.1	0.3	0.4	0.3	0.2	0.2	0.2	0.1	0.1	**2.1**	0.0	0.2
49	**Wolf River**	2.0	1.4	1.5	2.1	13.4	12.9	13.4	13.4	12.4	7.7	4.0	2.7	**86.9**	1.4	7.2

\\KPL\VA-Prj$\1\03\00556\02\A\Data\Task 400 - Small Hydro\Energy\[Appendix A - Energy Summary Table.xlsx]A4

NOTES:
1. FIRM ENERGY VALUES ARE PRELIMINARY ESTIMATES, CALCULATED USING THE ESTIMATED 85TH PERCENTILE HYDROLOGY VALUES FOR SMALL AND LARGE CATCHMENTS AS DETAILED IN SECTIOIN 3.2.4 OF REPORT VA103-00556/2-2.
2. INSTREAM FLOW REQUIREMENTS (ECOLOGICAL FLOWS ASSUMED TO BE 5 PERCENT OF MEAN ANNUAL DISCHARGE.
3. ENERGY VALUES DO NOT ACCOUNT FOR MINIMUM TURBINABLE FLOW (DEPENDENT ON NUMBER AND TYPE OF GENERATING UNITS).

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REV	DATE	DESCRIPTION	PREP'D	RVW'D