



Technical Memorandum

DATE: May 28, 2012

TO: James Craig, BCCF

CC: Craig Wightman, BCCF

FROM: Craig Sutherland, P.Eng.

RE: **BC Conservation Foundation**
South Englishman River Water Balance and Hydrological Assessment
Shelton Lake Feasibility Assessment and Rationale
Our File 0673.010

1. Background

A part of the British Columbia Conservation Foundation's (BCCF) mandate is to identify and implement fish habitat rehabilitation and restoration on the east coast of Vancouver Island. One initiative is to investigate storage options to supplement summer baseflow discharges in streams having high fisheries values. The South Englishman River, a tributary to the Englishman River near Parksville, BC is one of the streams identified as having potential for summer baseflow augmentation.

This technical memorandum summarizes a hydrological assessment for the South Englishman River performed since the preliminary hydrological assessment in July 2008. In addition, a feasibility assessment has been carried out to investigate potential storage options at Shelton Lake in the headwaters of the South Englishman River (see Figure 1).

2. Hydrological and Storage Assessment

2.1 South Englishman River Watershed

The South Englishman River watershed has a total watershed area of approximately 100 km² with a median elevation of about 480m. The watershed is relatively low in comparison with the overall Englishman River watershed which has a median elevation of 571 m. The South Englishman River watershed consists primarily of second growth forests within privately held forests lands.

Centre Creek which is one of the largest tributaries to the South Englishman River at approximately 12 km² in area flows into the South Englishman River about 300 m upstream of the confluence with the Englishman River mainstem. As the Centre Creek flows contribute to a relatively short length of the South Englishman River, this study focuses on the hydrology of the South Englishman River upstream of Centre Creek.



2.1 South Englishman River Recorded Water Levels and Discharges

Since July 2008, water levels on the South Englishman River upstream of Centre Creek have been recorded using a Solinst level logger and barometric logger. This has provided a nearly continuous record of river levels, except for a period from May 12, 2009 to August 7, 2009 when the data recorded for the period appear to be suspicious. A plot of the river level hydrograph is shown in Figure 2.

Recorded water levels have been transformed into discharges using a water level versus discharge rating curve. This rating curve was developed by calculating discharges at lower water levels using the velocity-area method and estimating discharges at higher water levels with a calibrated hydraulic model. A copy of the rating curve is shown in Figure 3.

Using the rating curve and the water level records, a continuous measured discharge hydrograph for the period between July 2008 and April 2009 was prepared (see Figure 4).

2.2 Mean Annual Discharge

As previously discussed, the estimated MAD for South Englishman River upstream of Centre Creek during the preliminary hydrologic assessment in July 2008 was based on regional hydrological assessment with only limited low-flow records from the South Englishman River upstream of Centre Creek. Having now collected data for nearly two years, the MAD was updated to reflect what was found from this new data.

A correlation between the recorded flows for South Englishman River upstream of Centre Creek and the Englishman River main stem was developed using flow data collected by BCCF and the Water Survey of Canada (WSC 08HB002), respectively. The Englishman River flow data were adjusted to remove the influence of fall/winter storage and spring/summer releases from the Arrowsmith Lake reservoir. The “naturalized” hydrograph for the Englishman River is an estimate of the flows that would have been expected without the dam. A regression line was developed to represent the correlation between the “naturalized” Englishman River discharges and the South Englishman River upstream of Centre Creek discharges.

The regression analysis is shown in Figure 5. Results of the regression indicate the ratio between South Englishman River upstream of Centre Creek discharges and the discharges in the Englishman River main stem near Parksville remains constant (0.191) over the full range of recorded values. This flow ratio is slightly smaller than the watershed area ratio of 0.241, which reflects the drier conditions in the South Englishman River upstream of Centre Creek in comparison to the entire Englishman River watershed.

Using the estimated flow ratio, the MAD of the South Englishman River upstream of Centre Creek is estimated to be $2.75 \text{ m}^3/\text{s}$ based on the MAD of the Englishman River of $14.4 \text{ m}^3/\text{s}$. This estimate is slightly higher than the value of $2.72 \text{ m}^3/\text{s}$ estimated in the preliminary hydrological assessment of 2008. As both values estimated from streamflow records and from regional analysis are roughly the same, we have confidence the MAD of the South Englishman upstream of Centre Creek is between $2.7 \text{ m}^3/\text{s}$ and $2.8 \text{ m}^3/\text{s}$. For this analysis, we used the value of $2.75 \text{ m}^3/\text{s}$. For comparison, the MAD for South Englishman River at the mouth, including the Centre Creek watershed, is estimated to be approximately $3.5 \text{ m}^3/\text{s}$ based on the watershed area ratio.

2.3 Minimum Conservation Flows

Two minimum conservation flows were used in this assessment including an absolute minimum of $0.138 \text{ m}^3/\text{s}$ (5% of MAD) and a preferred minimum of $0.275 \text{ m}^3/\text{s}$ (10% of MAD). The conservation flows are estimated as a percentage of MAD based on a provincially modified version of the Tennant Method (see Table 1).



Table 1: Modified Tennant (Montana) Method In-Stream Flow Requirements

Flows	Descriptions
30-60% MAD	Excellent spawning/rearing
20-30% MAD	Good spawning/rearing
10-20% MAD	Fair spawning/rearing
5-10% MAD	Poor spawning/rearing
< 5% MAD	Severely degraded spawning/rearing

This method has been adopted as a general guideline by Water Stewardship Division of the Vancouver Island Region to determine minimum flows for water licensing purposes.

2.4 Storage Requirement Assessment

The required lake storage to support minimum conservation flows was estimated using a monthly water balance approach. The estimated average monthly flows for an average year, a 1:5-year return period drought and a 1:10-year return period drought were used to calculate the amount of storage required to support minimum conservation flows of 5% MAD and 10% MAD. The 1:5-year return period drought and 1:10-year return period drought estimates were calculated by assuming the same “drought versus MAD ratios” for the Englishman River near the Parksville WSC Gauge (WSC 08HB002). The same approach was used in the preliminary hydrological assessment.

The results of the storage assessment are shown in Table 2. In order to support a conservation flow of 0.275 m³/s (10% MAD) in the South Englishman River upstream of Centre Creek, required storage in the watershed would be 1,640,000 m³ and 1,990,000 m³, respectively, for the 1:5-year return period and the 1:10-year return period droughts. Options to provide this amount of storage are outlined in a later section of this memorandum.

2.5 Englishman River Main Stem Flow Augmentation

In addition to increased baseflows in the South Englishman River, providing storage at Shelton Lake would also supplement required minimum conservation flows in the Englishman River mainstem, downstream of the confluence with the South Englishman River. This would augment baseflows for about two-thirds of the anadromous fish reach in the Englishman River main stem. Another benefit of increasing baseflows in the South Englishman River would be the option of reducing or delaying storage released from the Arrowsmith Lake Reservoir by the Arrowsmith Water Service, especially during periods of droughts.

The impacts of providing storage at Shelton Lake on supplementing minimum conservation flow and water demands in the Englishman could be further assessed once the storage concept is confirmed.



TABLE 2 – Shelton Lake Storage Requirements

Current Climate Condition (1971-2000)

MAD	Mean Flow Condition		5-year Low Flow Condition		10-year Low Flow Condition	
	Volume	Depth ¹	Volume	Depth ¹	Volume	Depth ¹
	(1,000 m ³)	(m)	(1,000 m ³)	(m)	(1,000 m ³)	(m)
5% (0.138 m ³ /s)	-	-	284	0.7	530	1.4
10% (0.275 m ³ /s)	260	0.7	1,640	4.3	1,990	5.2

Future Climate (2050s) Low Estimate

MAD	Mean Flow Condition		5-year Low Flow Condition		10-year Low Flow Condition	
	Volume	Depth ¹	Volume	Depth ¹	Volume	Depth ¹
	(1,000 m ³)	(m)	(1,000 m ³)	(m)	(1,000 m ³)	(m)
5% (0.138 m ³ /s)	-	-	376	1.0	693	1.8
10% (0.275 m ³ /s)	510	1.3	1,849	4.8	2,204	5.8

Future Climate Change (2050s) High Estimate

MAD	Mean Flow Condition		5-year Low Flow Condition		10-year Low Flow Condition	
	Volume	Depth ¹	Volume	Depth ¹	Volume	Depth ¹
	(1,000 m ³)	(m)	(1,000 m ³)	(m)	(1,000 m ³)	(m)
5% (0.138 m ³ /s)	-	-	693	1.8	747	2.0
10% (0.275 m ³ /s)	489	1.3	2,154	5.6	2,244	5.9



2.6 Climate Change Impacts

A climate change assessment has also been completed to estimate storage needed under future climate conditions. The estimate was performed by using a range of future monthly temperature and precipitation forecasts for the 2041 to 2070 Normal Period (2050s period). These temperature and precipitation forecasts were used as input to a monthly hydrological model to forecast changes in runoff across the watershed.

The results indicate that future runoff will likely increase in the winter as a result of increased winter precipitation and temperatures, while summer runoff will decrease due to increased summer temperatures and drier conditions. The most significant change would occur in the spring. It is anticipated that runoff will decrease earlier in the year due to reduced snowmelt. However, as the South Englishman River basin is at relatively low elevation (mostly below an elevation of 800 m), the impact of reduced snowmelt is not as pronounced as in other watersheds. The existing and forecast monthly average discharge hydrographs for the South Englishman River above Centre Creek are shown in Figure 6.

The storage assessment was also carried out using the forecast monthly flows for the future 2050s period (see Table 2). Results indicate that storage requirements are likely to increase in the future as a result of reduced runoff in the watershed as well as increased evaporation from Shelton Lake. To support a 10% MAD conservation flow for the 1:10-year drought condition under future climate conditions, the required storage increases from about 1,990,000 m³ to about 2,200,000 m³ in the future.

2.7 Storage Options

Two lakes are located in the headwaters of the South Englishman River, Healy and Shelton. Lakes surface areas are 28.9 ha and 38.2 ha for the two lakes, respectively. The preliminary hydrological assessment completed in 2008 considered utilizing storage in both lakes. However, preliminary environmental assessments of Healy Lake indicate that changing lake levels through storage development could have significant detrimental impacts on wetland habitat and species biodiversity in the lake. Therefore, the focus of this assessment is to provide storage only at Shelton Lake.

The storage assessment performed indicates that about 4.3 m and 5.2 m of top storage would be required at Shelton Lake to support a 10% MAD conservation flow in the South Englishman River during a 1:5-year and 1:10-year return period drought, respectively. These are significantly higher than the values determined in the preliminary hydrological assessment which assumed that storage could be captured in both Shelton Lake and Healy Lake. Reducing the conservation flow to 5% MAD decreases the required top-storage to 0.7 m and 1.4 m for the 5-year and 10-year return period droughts, respectively.

Due to the relatively small contributing drainage area to Shelton Lake (3.5 km²), the ability of runoff to re-fill storage also needs to be considered. The maximum storage that can be re-filled has been calculated using a monthly water balance of the Shelton Lake watershed. This indicates the watershed would be capable of refilling the lake for 2 m of the top storage while releasing a minimum conservation flow of 16 L/s (10% MAD at the outlet of Shelton Lake) during the refill period. The 2 m of top-storage would not support the full 10% MAD during the 5-year and 10-year drought condition, but would be adequate to meet the 5% MAD target flow in the South Englishman River.



3. Shelton Lake Storage Concept Design

3.1 Concept Design Options

Two conceptual dams and outlet structure options were considered for providing 2 m of top storage in Shelton Lake, including:

1. An earthfill dam with a low level outlet pipe installed to allow flow releases. High flows would be diverted around the structure through an excavated spillway channel on the right (east) abutment.
2. A concrete weir structure with earthfill embankments on each side. The weir structure could be fitted with stop logs or overshot gate structure to allow increased storage capacity during summer months while still allowing sufficient freeboard.

Conceptual design sketches of the options are shown in Figures 7 and 8, with a comparison of the two options in Table 3. A detailed outline of the conceptual designs is provided in the Technical Memorandum prepared by Trow Associates Ltd. (see Appendix A.).

Table 3 – Comparison of Storage Concept Options

Option	1 – Earthfill embankment with separate spillway channel	2 – Earthfill embankment with central concrete gravity spillway
Dam Crest Elevation	551.50 m	551.50 m
Spillway Invert Elevation	550.00 m	550.00 m
Storage at spill level	573,000 m ³	573,000 m ³
Flashboards crest elevation	n/a	550.50 m
Storage with flashboards	n/a	764,000 m ³
Conceptual (Level-D) Cost Estimate	\$1.68 million	\$1.57 million

Note: 1. Conceptual (Level-D) cost estimates are suitable for long-term capital planning and comparative purposes and include a 30% contingency. Costs should be refined once more detailed site information is available. 2. Live storage volume starts from the invert elevation of the low-level outlet at about 548.50 m.

3.2 Dam Safety Regulation

Under the Provincial Dam Safety Regulation, both of the proposed structures would need to include a dam. The structures are to be designed and constructed in accordance with criteria set-out in the Canadian Dam Association (CDA) guidelines. Under the guidelines, the proposed structure would likely be classified as having LOW downstream consequences due to its height, amount of stored water and limited downstream development. However, to be conservative, the conceptual design was based on the dam having HIGH downstream consequences. The HIGH consequence rating is a middle classification on the scale of five classifications from LOW to EXTREME.



The design criteria for HIGH consequence dams are:

- Inflow Design Flood 1:3,000-yr return period event;
- Minimum freeboard such that no overtopping occurs for 95% of waves generated by the 2-yr wind event at the maximum water level during the IDF; and
- Maximum Design Earthquake is the 1:2,500-yr return period event.

Based on a preliminary assessment of these criteria, a 12 m wide concrete spillway with minimum freeboard from the spillway crest to the dam crest of 1 m was required. The earthfill embankments would require a minimum crest width of 5 m and side slopes of 2:1. These are conceptual values for preliminary evaluation of options and more detailed calculations would be required at preliminary and final design stages to confirm these values.

Based on the review of the two concepts, we believe the option with the concrete spillway structure would provide the best balance between cost and increased storage. This option is less expensive than the full earthfill structure. The concrete spillway structure would also allow the flexibility of using stop logs or gates to store additional water in the summer while providing sufficient freeboard in the winter to safely pass large rain events. However, this option would require additional operational controls and maintenance in comparison with the full earthfill embankment. This is especially true at the end of the summer period to ensure that stop logs are removed or gates are opened prior to the start of fall rains.

4. Conclusions

Based on the results of the hydrological assessment and review of storage options, it is feasible to reserve storage at Shelton Lake to supplement summer baseflows in the South Englishman River to maintain 10% MAD under average flow conditions. However, to maintain 10% MAD ($0.275 \text{ m}^3/\text{s}$) under drought conditions (both the 1:5-year return period and 1:10-year return period droughts) would require providing up to 5.0 m of storage in Shelton Lake. This would likely not be acceptable as it would result in significant changes to the water level regime in the lake and would require a major dam structure at the outlet.

Construction of a smaller dam and weir structure at the outlet of the lake would allow baseflows to be supplemented but not to the full 10% MAD target during drought conditions. The assessment results indicate that 0.7 m to 1.4 m of top-storage in the lake would be adequate to provide 5% MAD ($0.138 \text{ m}^3/\text{s}$) in the river channel during 5-year return period and 10-year return period droughts, respectively.

A 2.0 m high dam was proposed and the cost to construct such a dam with outlet structure at Shelton Lake is estimated to be about \$1.52 million.

Under the Provincial Water Act, to store water at Shelton Lake would require a water licence. The water licence will have to be held by a proponent who will be responsible for on-going operation and maintenance of the dam. We understand that BCCF is not in a position to be the proponent. Consequently, any development of storage on Shelton Lake will need to be supported \ licensed by another agency or organization.

The Arrowsmith Water Service (AWS) is a joint partnership between the City of Parksville, the Town of Qualicum Beach and the Nanaimo Regional District. AWS maintains and operates the Arrowsmith Lake Dam which is also located within the Englishman River watershed. The Arrowsmith Lake Dam supports both conservation flows in the Englishman River mainstem and municipal water supply requirements. AWS is currently reviewing potential new intake locations as part of the water system and water treatment upgrades to support future water demands. Presently, the maximum monthly withdrawal from the river is approximately $0.12 \text{ m}^3/\text{s}$. The withdrawal rate is



expected to increase to 0.34 m³/s by 2050¹. In order to satisfy future water demands, AWS needs to either provide additional storage in the watershed or expand current groundwater withdrawals.

Providing storage in Shelton Lake would support a release of 0.138 m³/s (5% MAD of South Englishman River upstream of Centre Creek) up to the 1:10-year drought condition in the South Englishman River, and could also provide additional flows in the mainstem of the Englishman River to support the increase in future maximum monthly demand during drought conditions (about 62%).

The advantages of using potential storage at Shelton Lake include:

1. Supporting summer baseflow augmentation in the South Englishman River to 10% MAD for fisheries purposes during average baseflow conditions, and 5% MAD during drought conditions (1:10-year drought).
2. Partially supporting Englishman River mainstem baseflow augmentation during drought conditions (1:10-year) and reducing the amount of additional storage required from the Arrowsmith Lake.
3. Low-head structure at outlet of Shelton Lake would not significantly change natural water levels fluctuations on the lake and would likely have minimal impacts on lakeshore habitat.

4. It appears to be a cost effective solution

However, there are also some limitations with potential Shelton Lake, including:

1. Shelton Lake storage cannot support the full 10% MAD target conservation flow during drought conditions (1:5-yr and 1:10-yr).
2. The amount of storage that can be provided at Shelton Lake is limited due to the relatively small catchment basin discharging into Shelton Lake. However, our assessment indicates the proposed 2 m top-storage would be re-filled during the dry years while the 10% MAD conservation flow could be maintained in the river during the re-fill period (fall/winter).
3. Although increased losses (evaporation and seepage) have been assumed for Healy Lake in this assessment, it is not clear at this time how losses in Healy Lake would impact the transfer of storage released from Shelton Lake to the South Englishman River. Further assessment of these losses may be required.

Although potential storage at Shelton Lake is limited, we believe that construction of a small dam and concrete structure would provide a feasible means to augment summer baseflow in the South Englishman River, as well as partially support minimum baseflow requirements in the Englishman River mainstem.

¹ The future (2051) water demand of 0.34 m³/s is based on a maximum monthly demand of 67,400 m³/day (0.78 m³/s), minus the maximum currently available ground water withdrawal of 39,000 m³/day (0.45 m³/s). These values are for supporting the entire future AWS population including CoP, ToQB and RDN and are derived from estimates prepared by Koers and Associates as part of the Englishman River Intake Study (2010).



5. Recommendations

Based on the results of the Shelton Lake storage assessment and feasibility, we recommend that the BCCF present the results of this study to AWS for consideration as potential additional storage as part of the Englishman River Water Supply Intake and Treatment Plant project that is currently underway. Should the AWS consider Shelton Lake for additional storage, we recommend the following be completed as part of more detailed analysis and design:

1. Continue streamflow monitoring on South Englishman River upstream of Centre Creek as well as lake level monitoring at Shelton Lake;
2. Consider installation of streamflow monitoring downstream of the outlet of Shelton Lake to monitor outflow from Shelton Lake;
3. Discuss with Ministry of Forests, Lands and Natural Resource Operations the possibility of installing a small temporary structure (sand bag weir or similar) near the outlet of Shelton Lake which could be used to test the feasibility of storage on the lake;
4. Use temporary structure to release water from Shelton Lake to investigate the impact of storage in Healy Lake streamflows in the South Englishman River;
5. Complete a detailed geotechnical investigation at the site to assess suitability of foundation materials at the proposed dam location; and
6. Based on the results of storage test and geotechnical investigation, prepare a detailed design and cost estimate for the proposed dam structure.



5. Closing

We hope that this feasibility report provides a rationale for augmenting summer baseflows in the South Englishman and Englishman rivers by providing additional storage at Shelton Lake. If you have any questions about this document, please contact the undersigned at (250) 595-4223.

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:

Reviewed by:

The image shows two handwritten signatures. The signature on the left is for Craig Sutherland, and the signature on the right is for Wendy Yao. A red circular professional engineer stamp is placed over the signature of Craig Sutherland. The stamp contains the following text: "PROFESSIONAL ENGINEER", "PROVINCE OF BRITISH COLUMBIA", "C. E. SUTHERLAND", "# 29725", and "MAY 28 2012".

Craig Sutherland, P.Eng.
Water Resources Engineer

Wendy Yao, P.Eng.
Technical Reviewed

CS/

Encl.



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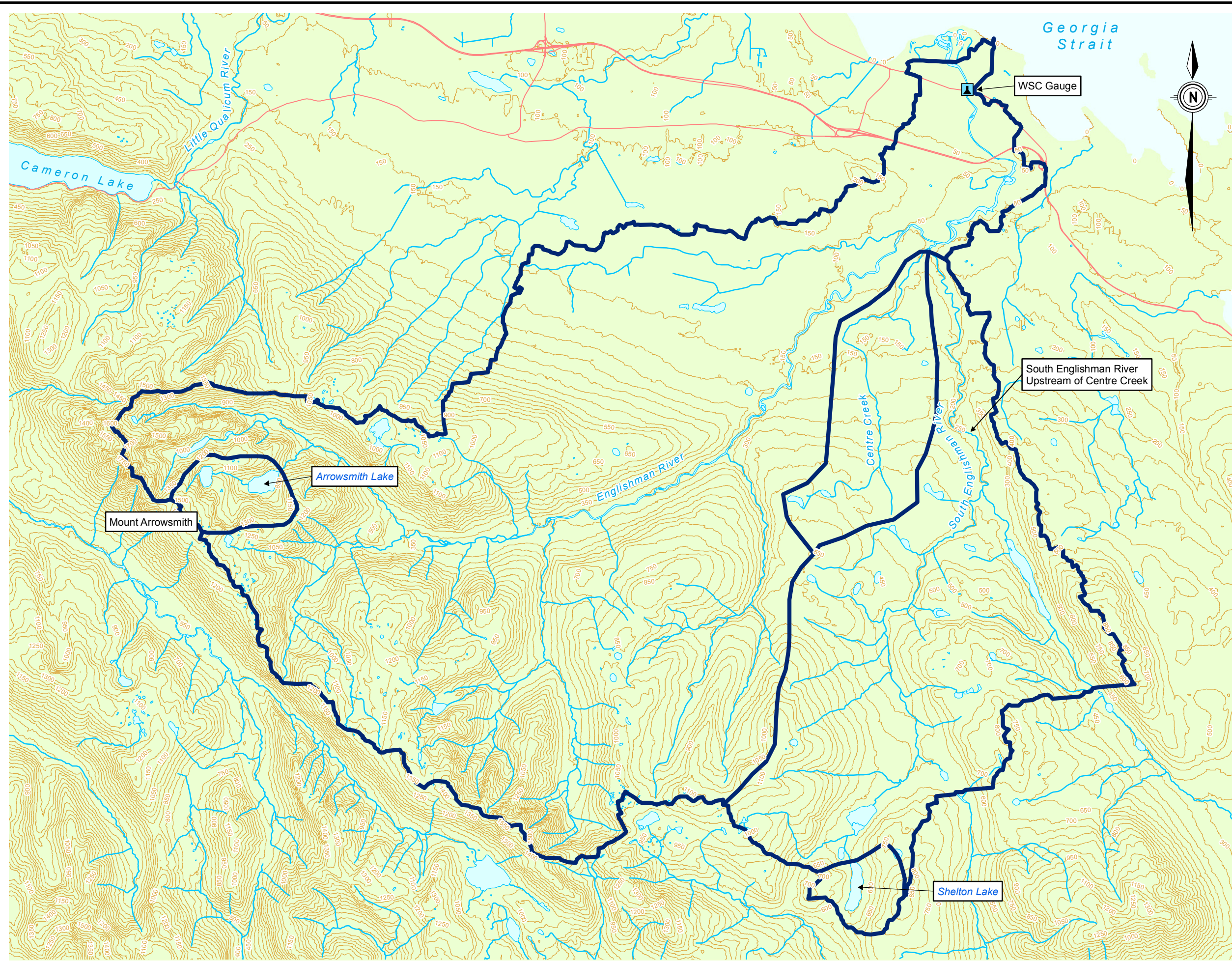
This document represents KWL's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.

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Revision History

Revision #	Date	Status	Revision	Author
0	Jan 17, 2011		DRAFT – for review	
1	May 28, 2012		FINAL – added reference to Centre Creek	CS



**BC Conservation Foundation -
Shelton Lake Storage Assessment
and Rationale, May 2012**

Legend

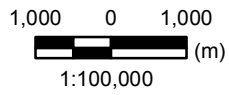
-  Englishman River Basin
-  Major Road
-  50m Contour
-  Water Body (WSA)
-  Stream Line (WSA)
-  WSC Gauge (Active)



Location Plan



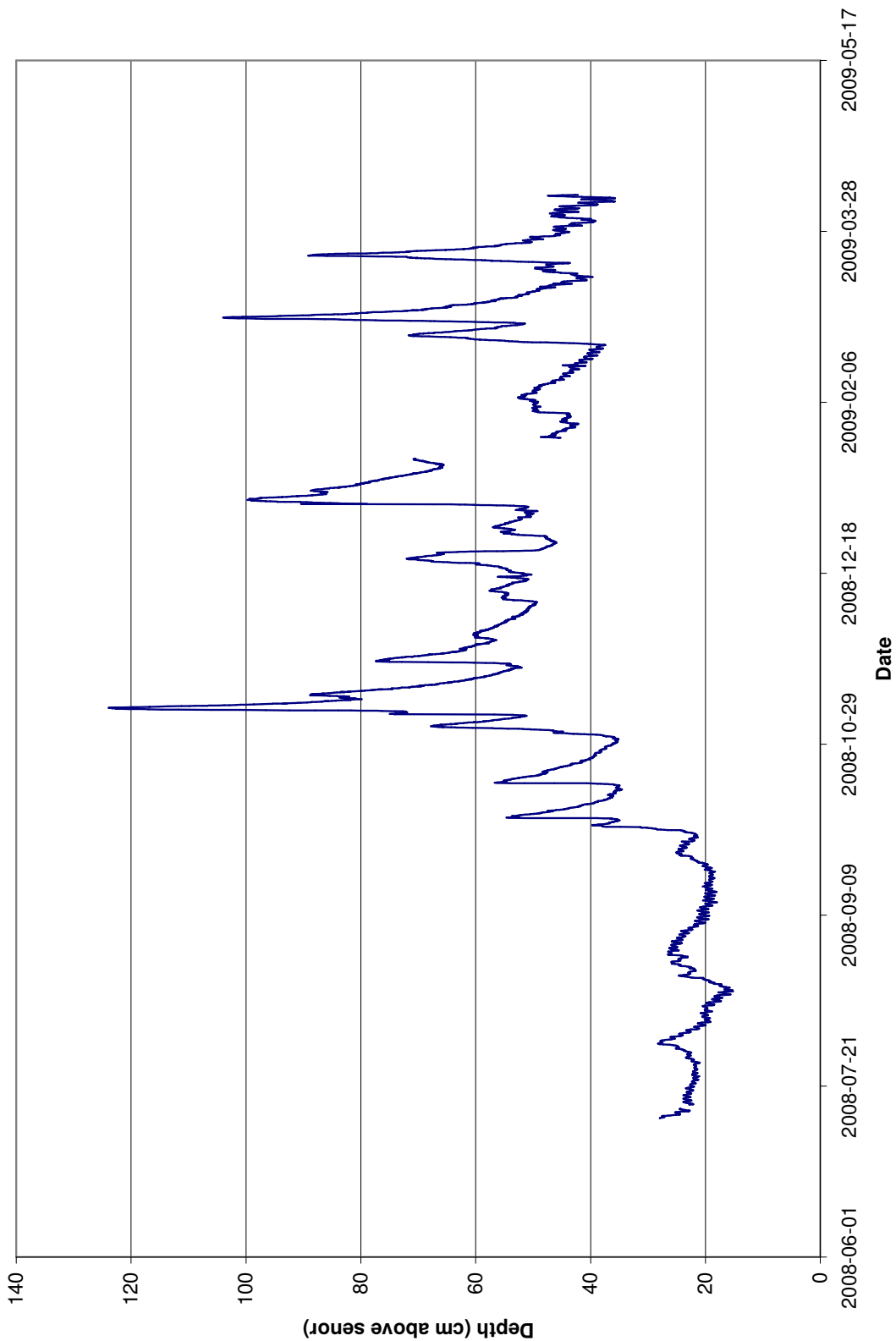
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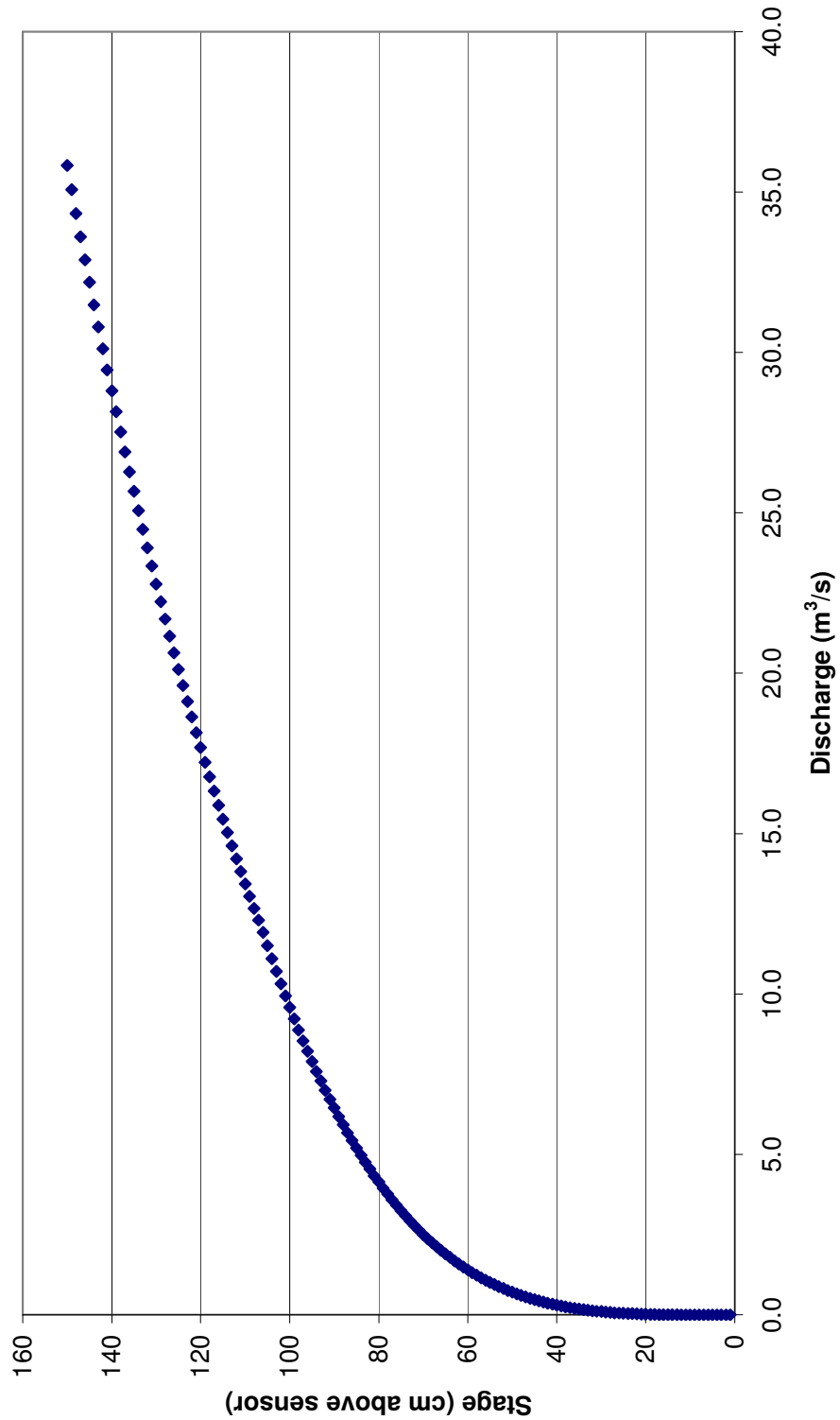
Project No. 673-010	Date May 2012
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Watershed Map

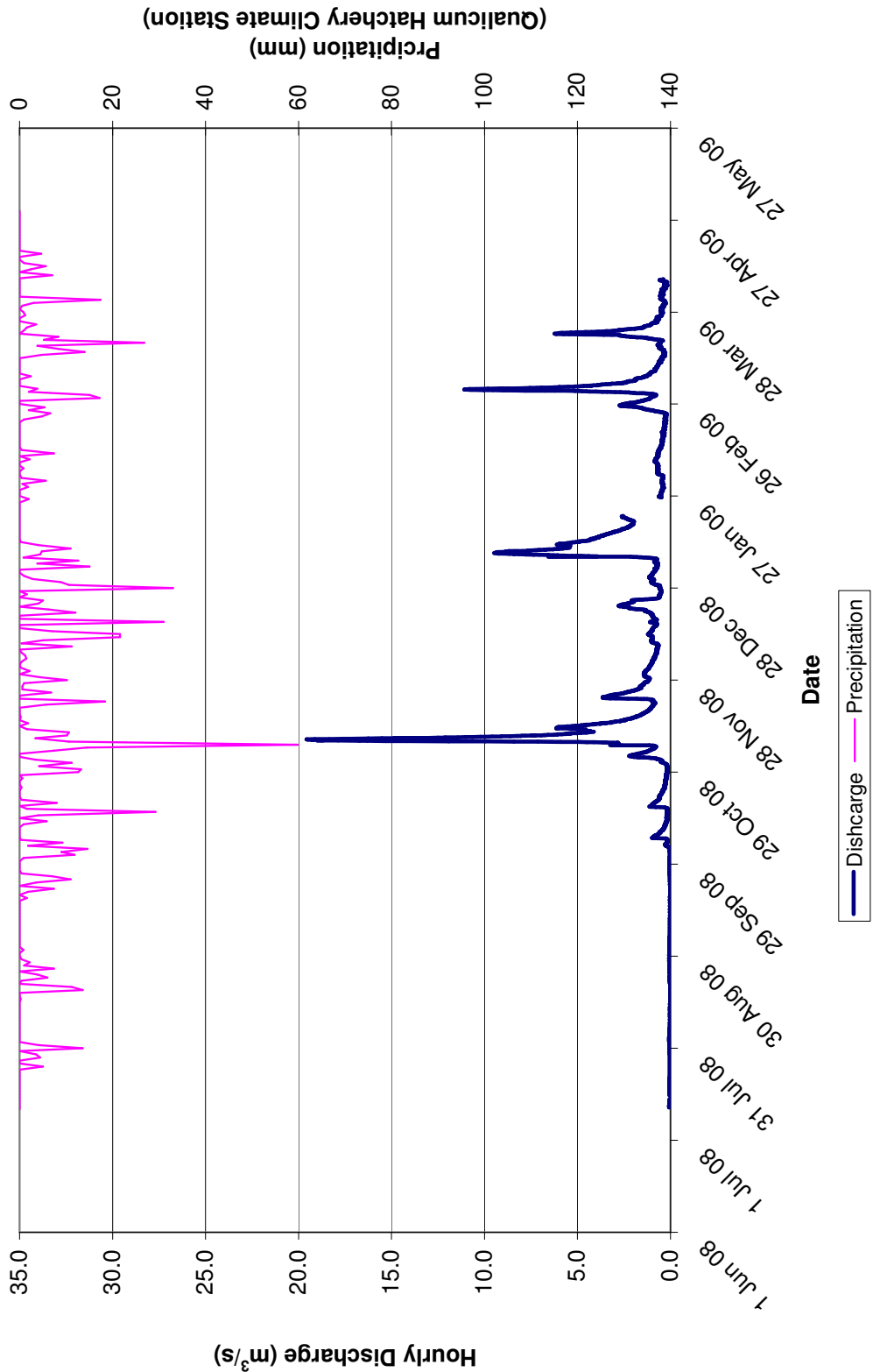
Figure 1



South Englishman River near Mouth
(BC Conservation Foundation Monitoring Station - May 2009)



South Englishman River - Hydrograph July 2008 to April 2009



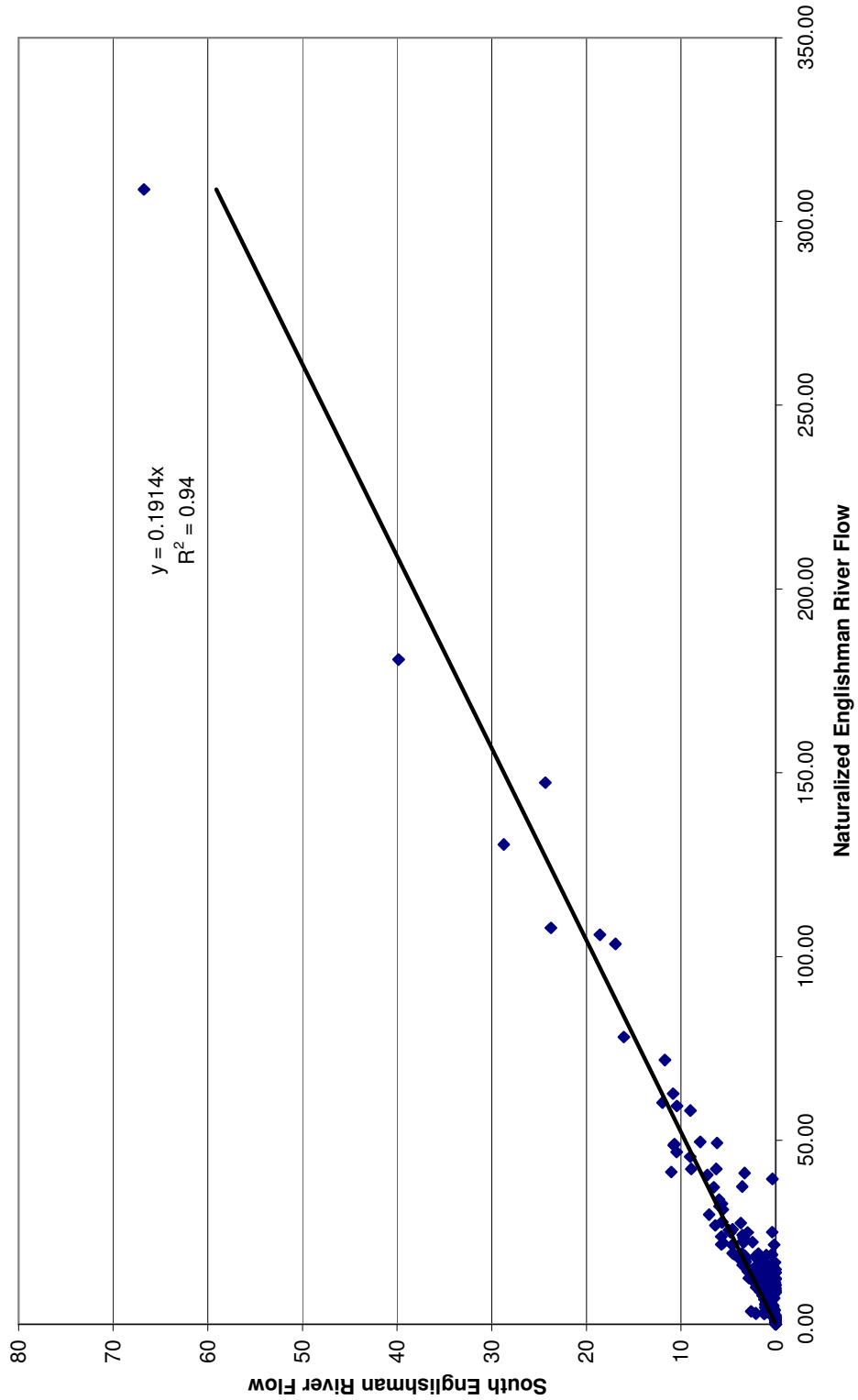
BC Conservation Foundation – Shelton Lake Rationale

Project No. 0673.010	Date June 2012
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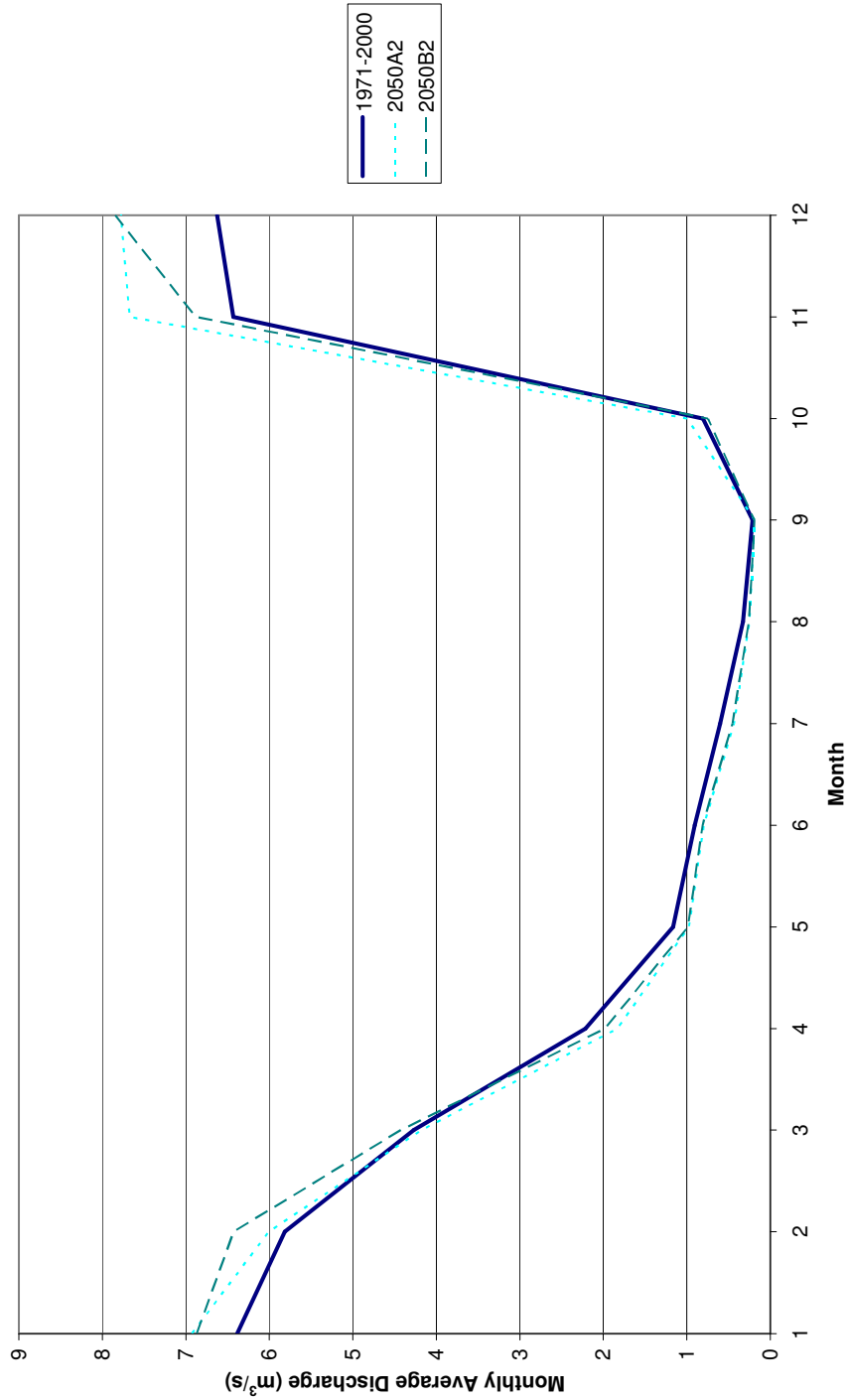
**South Englishman River above Centre Creek
Recorded Hydrograph
Figure 4**

Note: Data provided by BCCF, May 2009

Naturalized Englishman River vs South Englishman River



South Englishman River Climate Change Impact



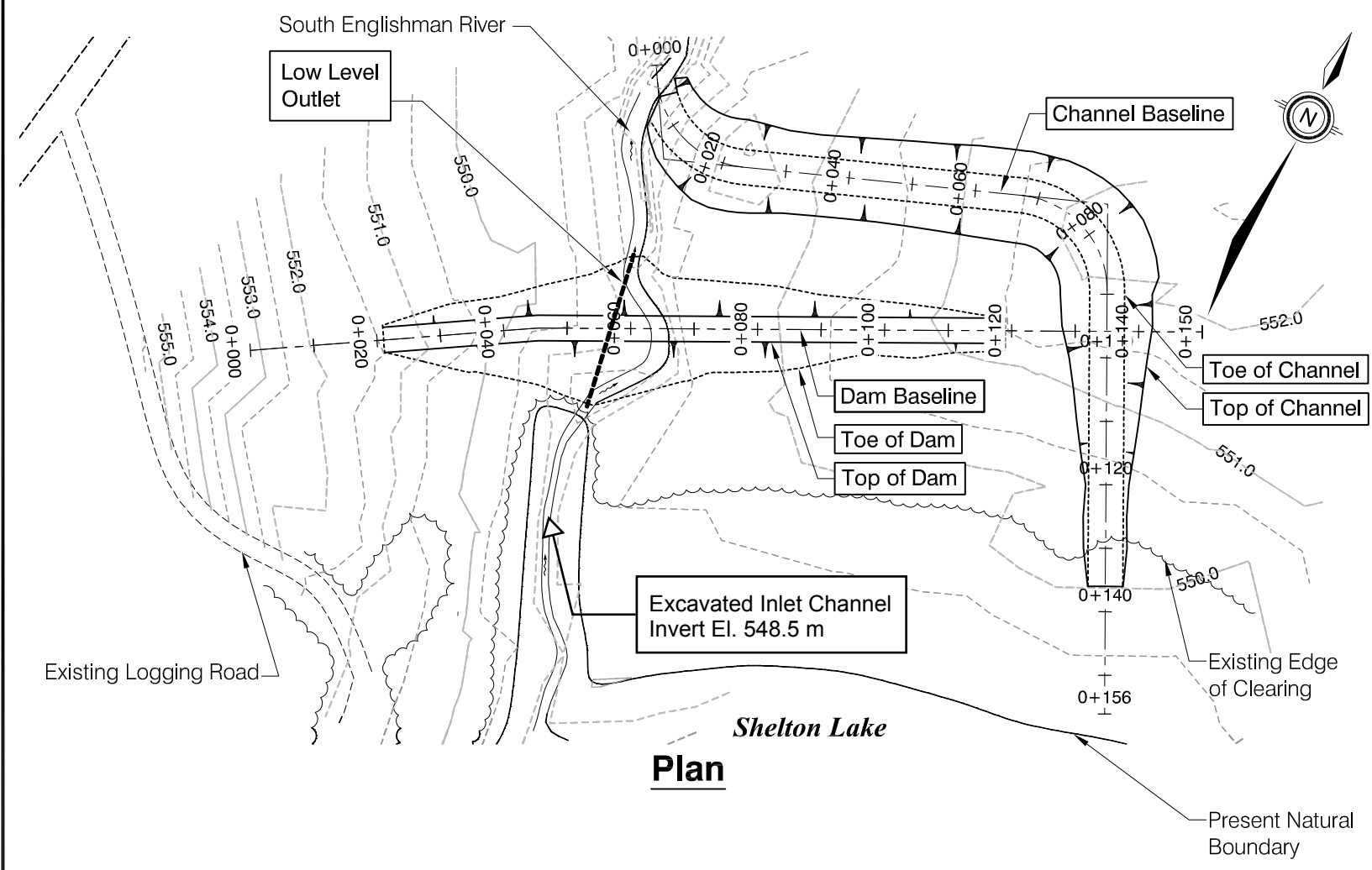
Note: Comparison of current (1971-2000) and future (2041-2060) periods (2050A2 high emissions scenarion and 2050B2 low emissions scenario)



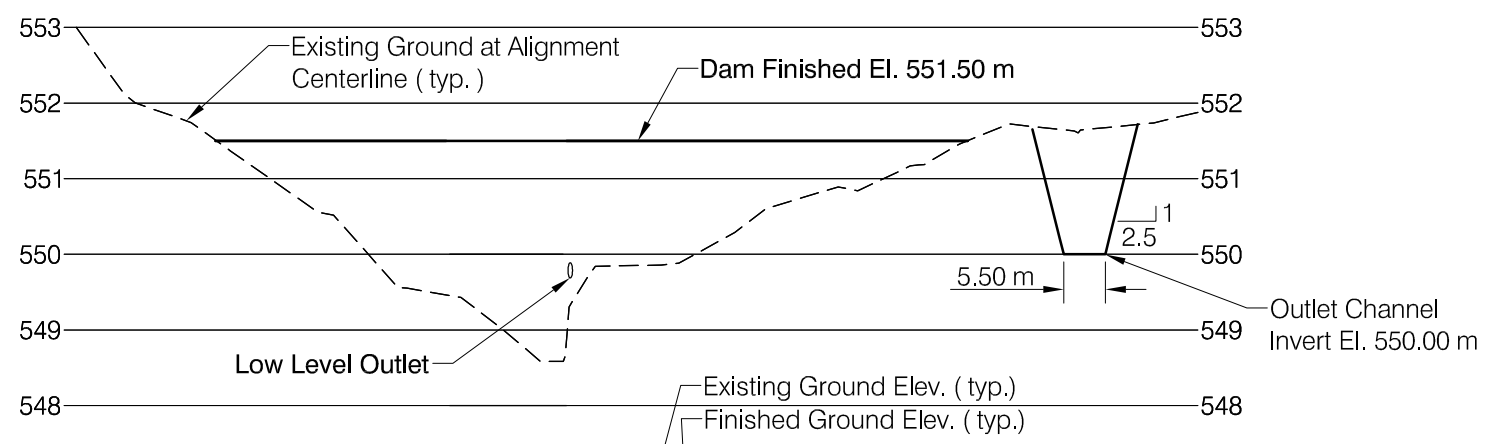
BC Conservation Foundation – Shelton Lake Storage Assessment and Rationale

Project No. 0673.010 Date May 2012

**South Englishman River upstream of Centre Creek
Climate Change Impact
Figure 6**

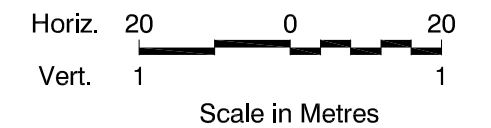


Plan



Profile

553.23	551.51	550.03	551.50	548.84	551.50	549.87	551.50	550.82	551.50	551.52	551.70	Existing and Finished Dam Elevations
0+000	0+020	0+040	0+060	0+080	0+100	0+120	0+140	0+150				



kwl KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

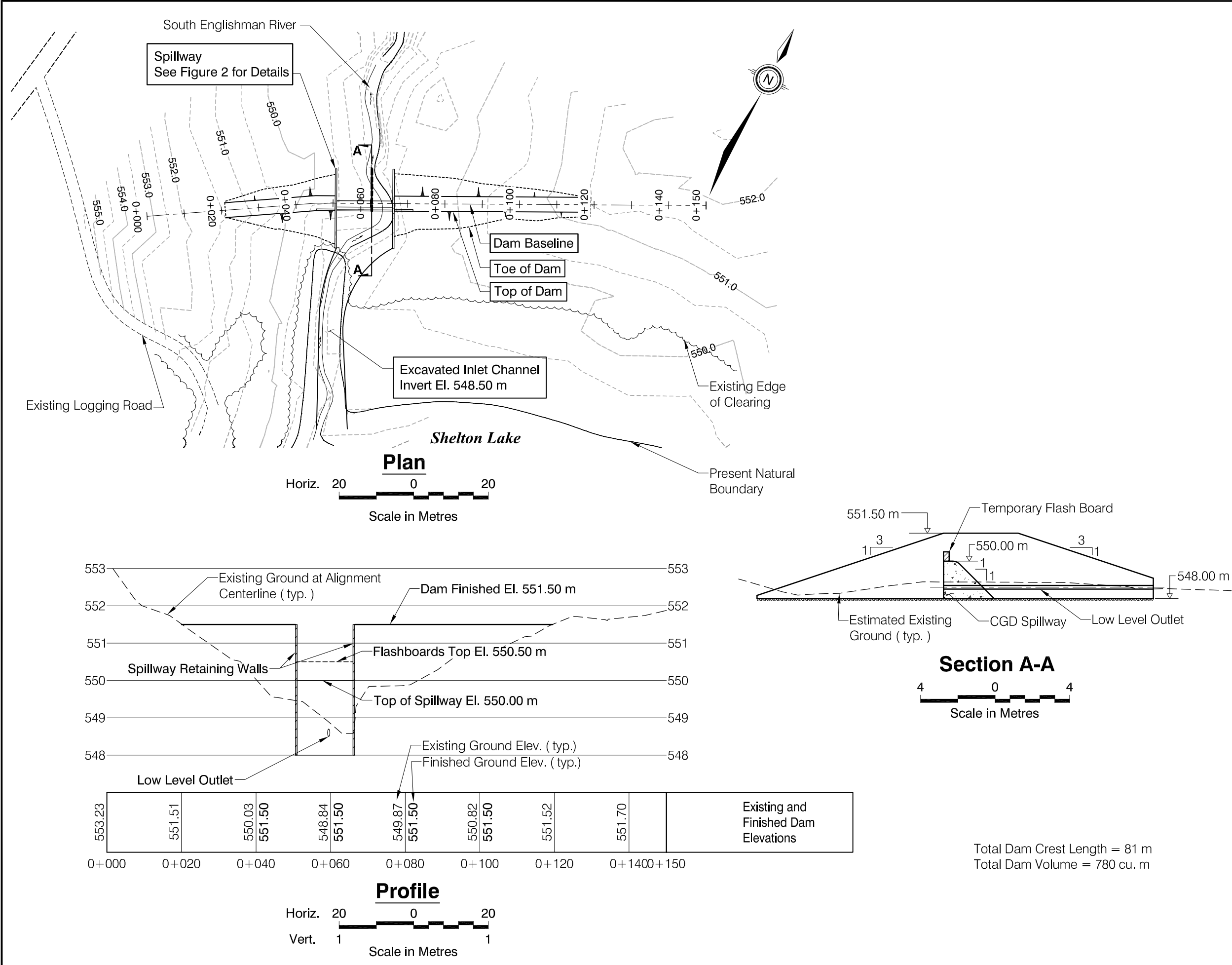
Project No. 673-005	Date June 23, 2010
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Total Dam Crest Length = 81 m
Total Dam Volume = 780 cu. m

**Dam Concept
Option 1**

Figure 7

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Total Dam Crest Length = 81 m
Total Dam Volume = 780 cu. m

**Dam Concept
Option 2**

Figure 8

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KERR WOOD LEIDAL
consulting engineers

Appendix A

Geotechnical Report

Buildings

Environment

Geotechnical

Infrastructure

Materials & Quality

www.trow.com

One Company.

One Contact.

One Stop.



ISO
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MEMORANDUM

Date: May 25, 2010

Reference No.: 081-01361

To:	cc:	Company	Contact	email
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From: Bruce Musgrave, P.Eng.

Total No. of Pages:

SUBJECT: Shelton Lake Dam – Conceptual Arrangements and Costs

1.0 GENERAL

Trow is pleased to provide Kerr Wood Leidal Associates Limited (KWL) with input for the conceptual arrangements and costs for a small storage dam on Shelton Lake on central Vancouver Island. It is understood that consideration is being given to developing additional storage on Shelton Lake for late summer flow release into the upper South Englishman River for fisheries purposes. This technical memorandum summarizes our discussions and provides some details regarding potential arrangements and costs for a small storage dam located near the outlet of Shelton Lake.

A brief one day site visit was carried out on October 7, 2008. Photographs take at that time are included in Appendix A.

The discussion that follow should be considered as preliminary in nature since site-specific information is very limited and the conceptual arrangement and rough costs have essentially been based on topographic information provided by KWL. The comments, therefore, should be considered as general, providing only an overview of the issues that exist. The conceptual cost estimates contained herein should also be considered to be “order of magnitude” only and no better than a Class D estimate. More detailed analyses, field investigations and site-specific information would be necessary to allow a more accurate concept arrangement and cost estimate to be prepared.

2.0 CONCEPTUAL ARRANGEMENTS

2.1 Design Considerations

Two conceptual general arrangements are provided for comparison purposes including a continuous embankment and separate abutment spillway (Concept 1) and a central concrete gravity spillway with adjoining embankments (Concept 2).

In both cases, little is known regarding the foundation conditions at this time, but dense glacial soils or bedrock is assumed to be at a reasonable depth, for the purposes of this work. If this is the case, it is considered that a dam and spillway could be constructed over these foundation conditions with appropriate design to accommodate stability issues and seepage flows. If adverse foundation conditions are encountered, the conceptual arrangements and cost estimates presented will require significant modification.

Consideration of appropriate design parameters for both concepts are required for earthquakes, floods and foundation seepage. Due to the dam height and volume of stored water, the dam would likely be classified as LOW Consequence dam under Canadian Dam Safety Guidelines and BC Dam Safety Regulations, but downstream consequences need to be verified. At this stage of the project, it is prudent to assume the dam may be classified as HIGH. Design parameters will therefore include:

Inflow Design Flood (IDF):

1:3000 yr event (CDA Guidelines for HIGH Consequence). Based on the CDA Guidelines, the inflow design flood for a high consequence dam is the 1:3,000 year return period flood event. The guidelines recommend that this be estimated by:

$$\text{IDF (1:3,000-yr)} = \text{Q1:1,000} + 1/3(\text{PMF} - \text{Q1:1000})$$

where

IDF is the Inflow Design Flood

Q1:1,000 is the 1:1,000 flood calculated using flood frequency statistics

PMF is the Probable Maximum Flood calculated using PMF procedures.

No long term discharge records exists on the South Englishman River to estimate 1:1,000 year peak flow. Therefore, the 1:1,000 year flood has been estimated from a flood frequency analysis for the Englishman River. Based on 32 years of peak flow data available for the Englishman River near Parksville Water Survey of Canada Gauge (WSC 08HB002), the instantaneous 1:1,000 year return period event is estimated to be 35 m³/s for the 324 sq. km watershed. As part of Dam Safety Review at the Jump Creek Dam, part of the City of Nanaimo water supply system, the PMF for jump creek was estimated to be 283 m³/s for the 51 sq km watershed. The PMF was also estimated using 24 hour Probable Maximum Precipitation (PMP) estimate of 400 mm from the PMP in Southwest BC prepared for BC Hydro and simple rational method calculation. The 1:1,000-year and PMF floods for Shelton Lake have been estimated using the watershed area ratios between the Shelton Lake watershed and the Englishman River and Jump Creek watersheds using an adjustment factor of 0.95. For example, the Q1:1,000 year event was calculated as:

$$Q_{\text{Shelton Lake}} = Q_{\text{Englishman River}} \times (\text{Area Shelton Lake} / \text{Area Englishman River})^{0.95}$$

Based on the procedure outlined above, the PMF, 1:1,000 year, and IDF for Shelton Lake have been estimated to be:

$$\text{PMF} = 51 \text{ m}^3/\text{s}$$

$$1,1000\text{-yr} = 22 \text{ m}^3/\text{s}$$

$$\text{IDF} = 32 \text{ m}^3/\text{s}$$

Based on a review of available Rainfall Intensity-Duration-Frequency Curves for the region the ratio of 24-hr intensity to 6-hr intensity is about 2.0. Assuming a direct relationship between rainfall intensity and peak flow which is valid for extreme events the Instantaneous IDF discharge is estimated to be:

IDF' = 64 m³/s

Note that this IDF estimate is considered to be only a preliminary estimate for conceptual design purposes. It is based on estimating peak flows based on watershed area alone and does not consider other effects such as changes in precipitation and snowmelt due to orographic effects and changes in watershed storage between larger and smaller watersheds. However, we feel that for conceptual design purposes it provides a reasonable estimate as it is likely that the 1:1,000 year estimate based on Englishman River flows would under-estimate the actual 1:1000-year event at Shelton Lake while the PMF estimated from Jump Creek Dam analysis would likely over-estimate the peak PMF at Shelton Lake. A more detailed analysis will be required at preliminary design stage.

Spillway Size and Freeboard (Concept 1):

For Conceptual Arrangement 1, the spillway will be comprised of a free overflow structure located within a separate excavated channel on the right abutment as shown on Figure 1. The spillway channel should be located no closer than 5m from the right end of the dam crest and the channel and entrance invert should allow for a freeboard of at least 0.5m above IDF levels (including wave run-up) for the embankment. For preliminary purposes, excavated channel side slopes of 2.5H:1V and base width of 5.5 m or larger depending on required discharge, may be assumed.

The channel will be lined with suitable erosion protection and will include entrance, discharge and dissipation structures. Consideration of the potential use of stoplogs for the summer period (May – September) may be included, but this may also pose a risk (if they are not taken out) for the winter months.

Spillway Size and Freeboard (Concept 2):

For Conceptual Arrangement 2, the spillway will be comprised of a free overflow central concrete gravity structure located within or near the existing river channel. Adjoining embankments would provide retainment on each side of this structure and should allow for a freeboard of at least 0.5m above IDF.

For preliminary purposes, the concrete gravity spillway structure will have a vertical upstream face, 1h:1v downstream slope, and ogee crest. It will also require embankment retaining walls and wing walls on each side, as shown on Figure 2.

Max Design Earthquake (MDE):

1:2500 yr event (CDA Guidelines for HIGH). For Conceptual Arrangement 1, a cross-section with 2H:1V upstream and downstream slopes and heavily compacted materials, is anticipated to be adequate for seismic stability, but confirmation of the MDE and its associated ground accelerations are required.

For conceptual Arrangement 2, a downstream slope of 1h:1v is anticipated to be adequate for seismic stability, but details with respect to the foundation contact may require modification.

Conceptual Cross-Section (Concept 1):

Either a homogeneous embankment coupled with a vertical chimney drain or with an embankment comprising an upstream core and random downstream shell, depending the availability and suitability of local borrow materials are the envisioned conceptual embankment cross-sections. The embankment footprint will require stripping and an upstream cutoff trench, 2 to 3m depth may be

required for seepage control, depending on the subsurface conditions. Erosion protection on the upstream face will also be required.

Conceptual Cross-Section (Concept 1):

A mass concrete gravity structure with surface reinforcing steel will provide adequate stability and durability. The gravity structure would require a very dense till or bedrock foundation and must be designed to be stable under all design conditions. In addition, special arrangements on each side of this block where it connects with embankment fills will be required.

Low Level Outlet:

The low level outlet structure (LLO) including flow control and piping will likely require enclosure within a concrete outlet structure for either concept. Depending on the elevations required, this may be incorporated into the foundation and covered with a continuous embankment (Concept 1) or include the concrete gravity structure (Concept 2).

3.0 CONCEPTUAL COST ESTIMATES

Order of magnitude conceptual cost estimates have been developed using areas and volumes developed from typical cross sections and topography surveyed by Bazzet Land Survey in July 2009. It is emphasized that these conceptual cost estimates are order of magnitude only, as site-specific information, including foundation conditions and accurate unit costs were not available. The estimates provided are based on general construction costs that prevail at the present time. At the time of construction these could vary depending on the availability of equipment and material sources. The cost estimate, therefore, should be considered to be no better than a Class D estimate.

The costs for construction of the a new dam and outlet facilities at Shelton Lake will include general requirements, embankment costs as well as costs associated with diversion, low level outlet and spillway. Unit costs for these items and related materials have not yet been accurately determined but would include the following:

- **General Requirements** - General contract requirements are normally considered to be about 5% of construction costs. Additional costs may include construction diversion requirements and environmental impact assessment (BCEAA), if required.
- **Material Costs** – Embankment and cast in place concrete costs will include foundation preparation under the footprint, extensive preparation for the core and concrete contact areas, long term seepage control measures, as well as supply and placement costs. Most of these costs are subject to the potential variation in unit price as they are dependent on the location and quality of the supply/borrow sources.
- **Spillway, Diversion and Outlet Costs** - The requirements for a low level outlet have also not been defined, but will likely include, as is currently required for new dam construction, the ability to drawdown the reservoir within a reasonable period of time (say 1 week) in the case of a dam safety emergency. This may require a conduit of up to 300 m or more in diameter as well as the associated concrete reinforcement, valves, controls and valve house.

4.0 CLOSURE

The above-noted and attached information is provided for the exclusive use of Kerr Wood Leidal and their designated consultants and agents and may not be used by other parties without the written consent of Trow Associates Inc. The attached “Interpretation & Use of Study and Report” forms an integral part of this report and must be included with any copies of this report.

Should you have any questions regarding the contents of this report, please call the undersigned.

Yours truly,

Trow Associates Inc.

Reviewed by:

Bruce Musgrave, P.Eng.
Senior Engineer

Don Sargent, P.Eng.
Senior Engineer

Attachments: Concept 1 - (Marked-up) KWL Dwg., SLD El. 551.50m
 Concept 2 - Concrete Gravity Spillway, sketch
 Preliminary Conceptual Cost Estimates, March 2010
 Appendix A, Site Reconnaissance Photos, October 7, 2008

Shelton Lake Dam		Rough Conceptual Cost Estimate				6/23/10
BC Conservation Foundation		Zoned Earthfill Embankment - Separate Spillway				
Shelton Lake Dam - Conceptual Costs		Crest El. 550.5m		Crest El. 551.5m		
		Storage ² : 191,000 m ³		Storage ² : 573,000 m ³		
		Estimates		Estimates		
Unit	Unit Rate	Qty	Cost	Qty	Cost	
<u>Information from KWL:</u>						
Crest Length	m	56		100		
Footprint Area	sq.m.	550		1220		
Embankment Volume	c.m.	390		1250		
<u>General Requirements</u>						
Mob/ Demobilization	\	1	\$ -	1	\$ -	
Construction Facilities	\$ 150,000	1	\$ 150,000	1	\$ 150,000	
Environmental Protection	/	1	\$ -	1	\$ -	
Construction Diversion	l.s. \$ 50,000	1	\$ 50,000	1	\$ 50,000	
BCEAA	l.s. \$ 500,000		\$ -		\$ -	
<u>Embankment Costs:</u>						
Clear, Strip & Prep Footprint	sq.m. \$ 25	550	\$ 13,750	1220	\$ 30,500	
Construction Seepage Control	l.s. \$ 25,000	1	\$ 25,000	1	\$ 25,000	
Core Contact Preparation	sq.m. \$ 75	183	\$ 13,750	406.667	\$ 30,500	
Seepage Core Trench	c.m. \$ 250	168	\$ 42,000	300	\$ 75,000	
Embankment Fill	cu.m. \$ 35	390	\$ 13,650	1250	\$ 43,750	
Upstream Face Erosion Protection	sq.m. \$ 100	330	\$ 33,000	732	\$ 73,200	
Instrumentation	l.s. \$ 50,000	1	\$ 50,000	1	\$ 50,000	
<u>Spillway & Outlet Costs:</u>						
Spillway Excavation	cu.m. \$ 50	800	\$ 40,000	625	\$ 31,250	
Spillway Channel - Erosion Protection	sq.m. \$ 200	900	\$ 180,000	800	\$ 160,000	
Spillway Inlet & Discharge Structures	l.s. \$ 150,000	1	\$ 150,000	1	\$ 150,000	
Low Level Outlet Structure	l.s. \$ 100,000	1	\$ 100,000	1	\$ 100,000	
LLO - Piping, Gate & Controls	l.s. \$ 150,000	1	\$ 150,000	1	\$ 150,000	
Subtotals			\$ 1,011,150		\$ 1,119,200	
Engineering	20%		\$ 202,230		\$ 223,840	
Contingency	30%		\$ 303,345		\$ 335,760	
Estimated Construction Cost:			\$ 1,520,000		\$ 1,680,000	

Note: 1 - Conceptual (Level-D) Cost estimate is a preliminary estimate which, due to little or no site information, indicates the approximate magnitude of cost of the proposed project. This overall cost estimate is derived from lump sum and unit costs for a similar project. It is suitable for developing long-term capital plans and for preliminary discussion of proposed capital projects. The estimated cost does not include possible professional fees associated with Environmental Assessment

2 - Storage that would be provided to the invert level of the outlet channel.

Shelton Lake Dam		Rough Conceptual Cost Estimate		6/23/10		
BC Conservation Foundation		Zoned Earthfill Embankment - Central CG Spillway				
Shelton Lake Dam - Conceptual (Level-D) Costs ¹		Crest El. 550.5m Storage ² : 382,000 m ³ Estimates		Crest El. 551.5m Storage ² : 764,000 m ³ Estimates		
	Unit	Unit Rate	Qty	Cost	Qty	Cost
<u>Information from KWL:</u>						
Crest Length	m		56		100	
Footprint Area	sq.m.		550		1220	
Embankment Volume	c.m.		390		1250	
<u>General Requirements</u>						
Mob/ Demobilization	\		1	\$ -	1	\$ -
Construction Facilities	10%	\$ 150,000	1	\$ 150,000	1	\$ 150,000
Environmental Protection	/		1	\$ -	1	\$ -
Construction Diversion	l.s.	\$ 50,000	1	\$ 50,000	1	\$ 50,000
BCEAA	l.s.	\$ 500,000	0	\$ -	0	\$ -
<u>Embankment Costs:</u>						
Clear, Strip & Prep Footprint	sq.m.	\$ 25	550	\$ 13,750	1220	\$ 30,500
Construction Seepage Control	l.s.	\$ 25,000	1	\$ 25,000	1	\$ 25,000
Core Contact Preparation	sq.m.	\$ 75	183	\$ 13,750	407	\$ 30,500
Seepage Core Trench	c.m.	\$ 250	168	\$ 42,000	300	\$ 75,000
Embankment Fill	cu.m.	\$ 35	390	\$ 13,650	1250	\$ 43,750
Upstream Face Erosion Protection	sq.m.	\$ 100	330	\$ 33,000	732	\$ 73,200
Instrumentation	l.s.	\$ 50,000	1	\$ 50,000	1	\$ 50,000
<u>Concrete Gravity Spillway & Outlet Costs:</u>						
Foundation Excavation & Prep	cu.m.	\$ 75	150	\$ 11,250	150	\$ 11,250
Concrete Gravity Structure	cu.m.	\$ 750	150	\$ 112,500	200	\$ 150,000
Foundation Grouting (if required)	l.s.	\$ 75,000	1	\$ 75,000	1	\$ 75,000
LLO - Piping, Gate & Controls	l.s.	\$ 150,000	1	\$ 150,000	1	\$ 150,000
Inlet & Outlet Channel Excavations	cu.m.	\$ 75	750	\$ 56,250	750	\$ 56,250
Inlet & Outlet Erosion Protection	sq.m.	\$ 250	300	\$ 75,000	300	\$ 75,000
Subtotals				\$ 871,150		\$ 1,045,450
Engineering	20%			\$ 174,230		\$ 209,090
Contingency	30%			\$ 261,345		\$ 313,635
Estimated Construction Cost:				\$ 1,310,000		\$ 1,570,000

Note: 1 -Conceptual (Level-D) Cost estimate is a preliminary estimate which, due to little or no site information, indicates the approximate magnitude of cost of the proposed project. This overall cost estimate is derived from lump sum and unit costs for a similar project. It is suitable for developing long-term capital plans and for preliminary discussion of proposed capital projects. The estimated cost does not include possible professional fees associated with Environmental Assessment

2 - Storage that would be provided with optional flashboards installed



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