SLIAMMON LAKE REPLACEMENT DAM

DESIGN BASIS REPORT

TLA'AMIN NATION

BBA Document No. / Rev.: 3774003-000000-40-EDC-0001 / R00

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Tla'amin Nation

Sliammon Lake Replacement Dam

Teeshohsum, BC

Design Criteria

Design Basis Report

BBA Document No. / Rev. 3774003-000000-40-EDC-0001 / R00

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FINAL

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1. INTRODUCTION

1.1 Purpose and scope

This Design Basis Report (DBR) has been prepared in support of the Sliammon Lake replacement dam to record the basic criteria for the design and construction of dam replacement.

This report provides preliminary details of the project, summarises basic project site data, and project design philosophy along with specified design criteria, relevant design guidelines, codes, and other information.

It is expected that design principles and details may change during design and construction based on site reconnaissance and exploration. Thus, this should be considered a living document that will be revised as necessary throughout the project phases. This document is not intended to be used as a project specification.

1.2 General description of the project facilities

Sliammon Creek Watershed is located about 4.5 km northwest of Powell River within the Sunshine Coast Forest District. Sliammon Creek (known as Kwahtums Teeshohsum following the effective date of the Tla'amin Final Agreement) flows into the Strait of Georgia at the community of Teeshohsum (formerly Sliammon IR). The project is located in the Georgia Depression area between Vancouver Island Ranges and Pacific Ranges of British Columbia. Most of the features visible today were formed during the last ice age, which ended in this area about 10.4 thousand years ago.

The Sliammon Lake area is about 1.8 km2 and located on the west side of Powell Lake. The Sliammon Lake watershed area is about 44 km2 at the existing dam's location. Sliammon Creek flows in a side valley to the Georgia depression. The study area spans between two (2) major physiographic regions including the Georgia Lowlands and the Pacific Ranges of the Coast Mountains as a transition zone. Local relief in the study area is about 1000 meters, with elevations ranging from about 120 meters above sea level at the Sliammon Lake to 1110 meters at the peak level.

The concrete dam is located at the outlet mouth of the Sliammon Lake. The development would be a replacement of the old dam with a concrete structure right upstream of the old dam (Photo 1).

The dam structure has been built as a concrete weir dam with W-shaped steel columns and angle supports used to install stop logs. The purpose of the weir dam is to store water in Sliammon Lake during summer using stop log installation to store and gradually release surplus water throughout the summer according to the water licence (WL) conditions for Fisheries and Oceans Canada

(DFO) to maintain fish habitat. It is BBA's understanding that there are no engineering records construction records regarding the weir dam.

Foundations were undermined on the downstream side and concrete cracks were observed on downstream areas between the W-shape steel columns and support angles (Photos 2 and 3; see also BBA. 2016c).

Photo 1: Sliammon Lake (looking from dam location)

Photo 2: Upstream area of the dam and jammed logs

Photo 3: Downstream area of the dam and undermined foundations

1.3 Applicability of Regulation

The Sliammon dam is subject to Section 1 of Part 3 of DSR, since the intake berm > 1 m in height and the headpond is capable of impoundment about 1.63 Mm^3.

1.4 Format of the report

This report discusses a design basis for the replacement dam with consideration of the following elements separated into various report sections:

- Section 2 – Summarizes the general operating criteria for the dam;
- Section 3 – Provides details on the site and environmental conditions;
- Section 4 – Provides in-depth information on the dam hazard classification for Sliammon dam and design criteria;

- Sections 5 – Design principles adopted for the dam and fishway;
- Sections 6 – Describes water withdrawal conditions for Slimmon lake; and
- Sections 7 and 8 – Summary of design exclusions and limitations of this report.

Additional factors have been put into consideration for the design basis and are included in the following appendices of this report:

- Appendix A – General list of the codes and references that will apply to the design of the various project components;
- Appendix B – General structural design methodology and design parameters that will be used in the structural design of components
- Appendix C – Hydrotechnical and environmental assessment report of the dam based on current flow and fish habitat information in the downstream aquatic ecosystem; and
- Appendix D – Drawings of the new dam design.
- Appendix E – Conditional Water Licences

1.5 Design level definition

The design life of the dam is fifty (50) years. Dam components will be designed for the following conditions:

- Normal Operating Conditions: The *Normal* Condition is defined as the maximum static; head and
- Exceptional Conditions: *Exceptional* Conditions are defined as the design maximum flood or earthquake loads with exceptional pressure loads beyond maximum storage capacity.

2. GENERAL OPERATING CRITERIA

Summary of key design parameters for the project are shown in the tables below.

Table 1:Preliminary design parameters

Item	Value
Min IFR Flow (summer)	0.13 m^3/s
Q PMF	500 m^3/s
Spillway design flow (Q1000) [2]	112 m^3/s
Diversion flow (Q2)	30 m^3/s

[2] From Hydrological Analysis of Kwahtum Teeshohsum by AQUARIUS

3. SITE AND ENVIRONMENT

3.1 Geotechnical conditions

Bedrock has outcropped at the creek bed along the concrete weir dam and the dam structure is found on the massive quartz diorite with widely-spaced vertical and horizontal fractures. These kinds of rocks are relatively resistant to weathering and erosion and have relatively stable rock slopes. Bedrock has outcropped along the Sliammon Creek in downstream area of the dam to some distance or is covered by colluvial material.

Bedrock outcrops were observed on the right and left abutments of the dam up to about 1m above lake level, then covered by fluvial material and colluvial materials on upper slope area. Both dam abutments have a gentle slope with 15-40% and a low terrain hazard but the right abutment slopes will get steeper in the downstream area of the dam. The upstream area of the dam axis is covered by rockfill and riprap material in cobble to boulder sizes .

For the purposes of this design, local stability of the structures will be included in the design. This is defined as sliding, overturning, and bearing failure of structures forming part of the Work for both static and seismic conditions. Global stability, defined as natural hazards originating from outside the area of the Works, both above or below the structures, is specifically excluded from the BBA design. This is termed to include damages from (but not limited to) slope instability, debris avalanches, snow avalanches, rockfall, slope failures, boulder detachment, debris flows, stream avulsion, and other similar natural hazards which originate from outside the area of the work, but directly impact the work.

3.2 Seismicity

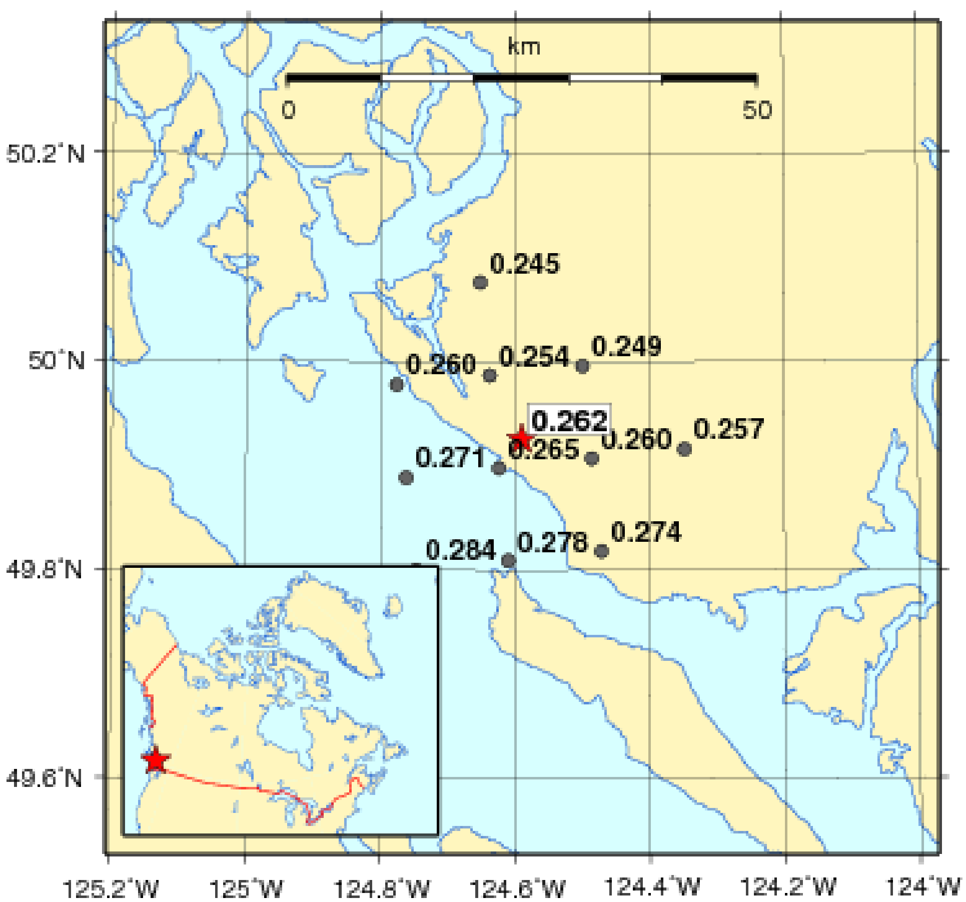
The Sliammon Dam Project is located on the North American Plate, and about 230 km east of the Cascadia subduction zone that marks the boundary with the adjacent Juan de Fuca plate. Relatively large earthquakes may affect the project area; all project components shall be designed to meet CDA and NBCC requirements. Based on Natural Resources Canada and 2015 National Building Code of Canada, the 2% in fifty (50) year seismic spectral acceleration (S(0.2)) in this area is about 0.566 of gravity. According to Peak Ground Acceleration (PGA) it is 0.262g as shown in Table 2 and Figure 1.

Project structures should be designed to resist the site specific design earthquake events. This typically is the 1:2500 year event for the dam, which is classified as a high hazard dam. The potential for liquefaction of foundations of major structures, like the proposed powerhouse, shall be considered.

Table 2 - Seismic Design Data Parameters

Return period	Peak ground acceleration	Spectral acceleration			
(Years)	PGA(g)	Sa(0.2)	Sa(0.5)	Sa(1.0)	Sa(2.0)
1:2,475	0.262	0.566	0.527	0.360	0.236
1:1,000	0.176	0.384	0.352	0.231	0.146
1:475	0.121	0.269	0.241	0.150	0.091

Source: 2015 National Building Code Seismic Hazard Calculation



Source: 2015 NBC Seismic Hazard Calculation - May 04 2016

Figure 1 – Peak Ground Acceleration (PGA) for 2% in 50 years in the Sliammon Creek dam location

Climatic data

Snow, wind, and rain loads should be provided by Environment Canada at a later stage.

Table 3: Site climatic data[1]

Parameters	Intake
Design Snow Load	
S_s	TBD
S_r	TBD
q_wind	TBD
Max and Min Ambient Temperatures	TBD

Provided by Environment Canada

[1]Missing parameters will be completed as the information is available.

3.3 Hydrology

A previous mean annual discharge (MAD) of ~1.7 m^3/s was estimated by Craig (2009), from a brief period of record (1949-1951), at a pre-existing Environment Canada gauging station for Sliammon Creek. Assumed to be “representative of flows during that era”, Craig (2009) deemed the MAD to be conservative compared to channel width measurements used to estimate MAD, which he figured placed the MAD at between 2.3 m^3/s and 3.8 m^3/s. The regional analysis of recent data estimated MAD to be 1.36 m^3/s at the Sliammon Lake outlet (see the detailed Hydrology Report of Appendix C). This indicates the flows in Kwahtums Teeshohsum have decreased relative to historic conditions.

Detailed analyses are provided in the Hydrotechnical and Environmental Assessment of Kwahtum Teeshohsum (Appendix C).

3.4 Aquatic ecology

Salmon production in Sliammon Lake and Kwahtums Teeshohsum consists of both natural spawning reaches of the creek and hatchery enhancement. Kwahtums Teeshohsum supports predominantly chum salmon (CM) and coho salmon (CO), with very limited Chinook salmon (CH) and historically pink salmon (PK). Coho salmon migrate into the lake through the dam’s fishway. Other species naturally spawn in lower spawning reaches, but a large percentage of escapement is retained by the hatchery for artificial production, with CO fry released in the lake to support ongoing enhancement.

Recent habitat assessments in Kwahtums Teeshohsum suggest the prescribed IFRs for summer could be increased to better address the environmental flow needs (EFN) under the *Water Sustainability Act*. This is relevant if surface flows are decreasing over time, as suggested. A storage model developed by Fathom Scientific Ltd. (Fathom) is contained in the hydrotechnical assessment (Appendix C). Results suggested a replacement of the current design could sustain active storage of winter surplus flows with controlled release into Kwahtums Teeshohsum during summer. This would allow for the minimum prescribed IFR of 0.13 m^3/s to be met. Requirements for a sustained upper IFR of 0.25 m^3/s over summer months were not met in August 2016 during associated drought conditions.

The environmental assessment in Appendix C suggested adaptive management using experimental flows that exceed an upper IFR of 0.25 m^3/s through the fishway; however, this cannot be achieved with existing licensed storage and withdrawals (including the water reservation held under Final Agreement). The hydrotechnical assessment by Fathom suggested any increase in IFR may warrant an increase in storage. Decreasing flows and more frequent drought conditions could impact the overall water security for both community use and EFN. These impacts on water security could mean that an increase of the dam height would be required to store additional water; however this also depends on several unknown factors, such as the time of year it would be required, given seasonal availability of surplus flows.

Further details on the analyses are provided in the Hydrotechnical and Environmental Assessment of Kwahtum Teeshohsum (Appendix C).

4. DAM HAZARD CLASSIFICATION

BC Dam Safety Regulation (DSR) sets requirements and best practices for all aspects of dam design, construction, operation, maintenance, removal, and decommissioning of dams. Regulated dams require a water licence under the *Water Sustainability Act* and must meet the requirements specified in DSR, which defines a dam. A barrier constructed for the purpose of enabling the storage or diversion of water and all its potential energy from a stream or an aquifer, or both, plus any other works incidental to or necessary for the barrier.

Regulation is composed of five (5) parts:

Part 1 – Provides definitions,interpretations, and describes application of the Regulation to minor dams that are less than 7.5 m high and store 10,000 m^3 or less of water, which may be exempt from the Regulation.

Part 2 – Sets requirements that apply to all other dams, except those which are exempt.

Part 3 – Sets additional requirements for specific dams, including those:

- 1 m ≥ height and capable of impounding a total storage volume of water > 1,000,000 m^3;
- 2.5 m ≥ height and capable of impounding a total storage volume of water > 30,000 m^3; and
- 7.5 ≥ height, regardless of the amount of capable storage.

Dams are classed with a failure consequence classifications significant, high, very high, or extreme.

Part 4 – Includes general provisions and offences applicable to all regulated dams.

Part 5 – Provides the transition periods for phasing out old requirements and phasing in new requirements. Presents the application of the regulation to dams in British Columbia.

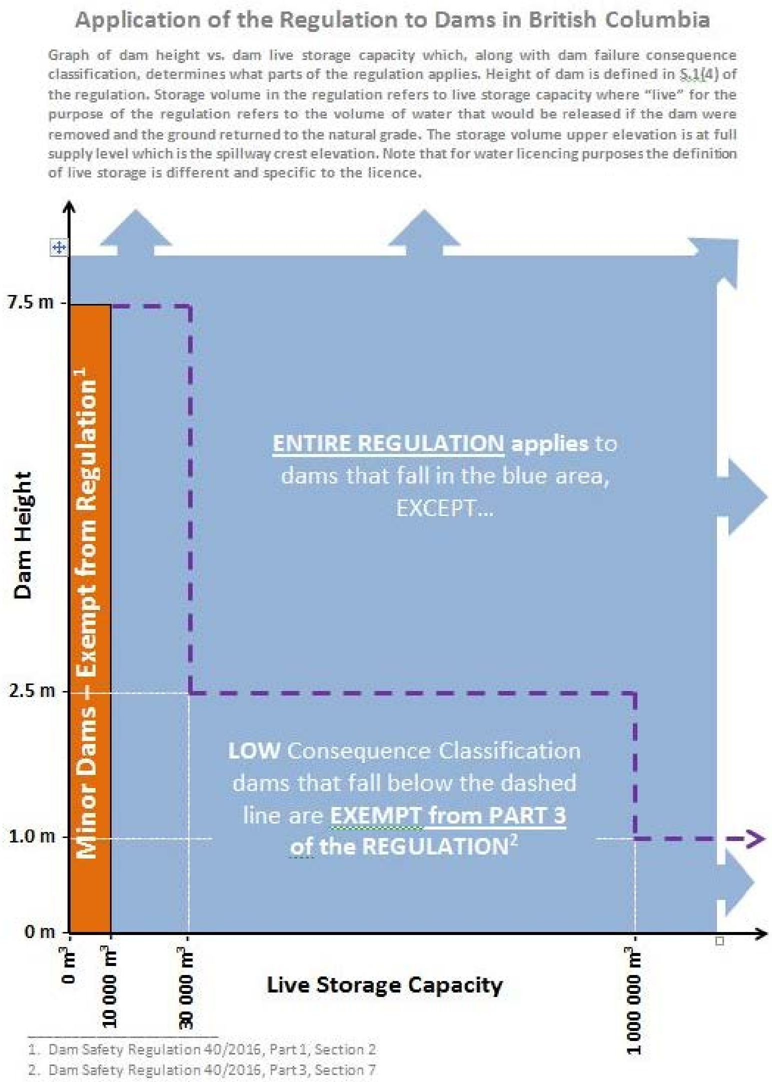


Figure 2: Application of the regulation to dams in British Columbia

4.1 Dam height

Part 1, Section 4 of DSR, which states:

(4) For the purposes of sections 2 (1) [application of regulation to minor dam] and 7 [application of Part 3], the height of a dam is the vertical distance to the top of the dam measured,

(a) *in the case of a dam across a stream, from the natural bed of the stream at the downstream outside limit of the dam, and*

(b) *in the case of a dam that is not across a stream, from the lowest elevation at the outside limit of the dam.*

Based on preliminary design drawings (Appendix D), part (a) of the definition is applicable for the Sliammon dam. The height of the dam from the downstream outside limit of the wall is 1.3m.

4.2 Headpond retention

Total volume of headpond is expected as > 1,000,000 m^3 .

4.3 Dam failure consequence evaluation

4.3.1 Assessment criteria

FLNRO guideline states that the term “consequence of failure” is defined in DSR and CDA guidelines as follows:

“Consequence of failure” means losses or damages that are caused by a failure of a dam (BCDSR, Schedule 1, Definitions);

“Failure”, in relation to a dam, means an uncontrolled release of all or part of the water impounded by the dam, whether or not caused by a collapse of the dam.

“Consequences of failure” impacts on the downstream or upstream area of a dam as a result of failure of the dam or its appurtenances. In these guidelines, the term consequences refers to the damage above and beyond the damage that would have occurred in the same event or conditions had the dam not failed. These may also be called incremental consequences of failure. (CDA Guidelines – Glossary)

The consequences of failure should be evaluated for all three (3) categories in Schedule 1 of the BC Dam Safety Regulation:

- Loss of life;
- Environmental and cultural values; and
- Infrastructure and economics.

The category with the worst potential consequences is the classification of the dam as per Section 2 of Schedule 1 of DSR.

Under the regulation, the consequence of failure is based on losses, damage, deterioration, or destruction “caused by the failure of the dam”, (see Schedule 1, Definitions; “consequences of failure”, clause (a)). The term “incremental” as related to consequences of failure is not defined or addressed in the regulation but is implied by that phrase “caused by the failure of the dam”. Therefore, the dam owner should assume that the consequences of failure only include the damages that would have occurred over and above any losses or damage that would have occurred in the same event or conditions had the dam not failed, as defined by “incremental consequences of failure” in the CDA Guidelines.

The following features have been identified in downstream of the dam regarding potential dam breach impact assessment that pertains to the criteria listed above:

- Residential area within the flood zone (Photo 4);
- Wastewater treatment plant and related pipings (Photo 5 &7);
- Forest Service roads (FSRs) and bridges (Photo 6);
- Sliammon Salmon Hatchery[2] (Photo 8); and
- Sunshine Coast Highway and bridge.

[2] Sliammon Salmon Hatchery recently sustained fairly severe flood damages (October 2014) from excess debris flows.

Table 4: Downstream dam failure consequences classification (Schedule 1, BCDSR)

Item	Dam failure consequences classification	Population at risk	Loss of life	Environmental and cultural values	Infrastructure and economics
1	Low	none[3]	no possibility of loss of life other than through unforeseeable misadventure	minimal short-term loss or deterioration and no long-term loss or deterioration of (a) fisheries habitat or wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value	minimal economic losses mostly limited to the dam owner's property, with virtually no pre-existing potential for development within the dam inundation zone
2	Significant	Temporary only[4]	low potential for multiple loss of life	no significant loss or deterioration of (a) important fisheries habitat or important wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d)sites having significant cultural value, and restoration or compensation in kind is highly possible	low economic losses affecting limited infrastructure and residential buildings, public transportation or services or commercial facilities, or some destruction of or damage to locations used occasionally and irregularly for temporary purposes
3	High	Permanent[5]	10 or fewer	significant loss or deterioration of (a) important fisheries habitat or important wildlife habitat, (b) rare or endangered species, (c)unique landscapes, or (d)sites having significant cultural value, and restoration or compensation in kind is highly possible	high economic losses affecting infrastructure, public transportation or services or commercial facilities, or some destruction of or some severe damage to scattered residential buildings

[3] There is no identifiable population at risk.

[4] People are only occasionally and irregularly in the dam-breach inundation zone, for example stopping temporarily, passing through on transportation routes or participating in recreational activities.

[5] The population at risk is ordinarily or regularly located in the dam-breach inundation zone, whether to live, work or recreate.

Item	Dam failure consequences classification	Population at risk	Loss of life	Environmental and cultural values	Infrastructure and economics
4	Very High	Permanent[4]	100 or fewer	significant loss or deterioration of (a) critical fisheries habitat or critical wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value, and restoration or compensation in kind is possible but impractical	very high economic losses affecting important infrastructure, public transportation or services or commercial facilities, or some destruction of or some severe damage to residential areas
5	Extreme	Permanent[4]	More than 100	major loss or deterioration of (a) critical fisheries habitat or critical wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value, and restoration or compensation in kind is impossible.	extremely high economic losses affecting critical infrastructure, public transportation or services or commercial facilities, or some destruction of or some severe damage to residential areas

Based on these downstream features and potential impacts described in Table 4, consequence rating for the Sliammon dam could be categorized as very high.

4.3.2 Conclusion and additional requirements

The assessment concludes that the DSR applies to the Sliammon Dam. The downstream consequence rating of “very high” warrants greater consideration for the hydrotechnical assessment provided in Appendix C which provides the hydraulic analysis required to assess the downstream flooded areas and the potential for downstream impacts to occur at later stage.

Photo 4: Residential area

Photo 5: Wastewater treatment plant

Photo 6: Forestry road and bridge

Photo 7: Wastewater treatment plant piping

Photo 8: Sliammon Salmon Hatchery

5. DAM AND FISHWAY DESIGN

The new dam is designed as a concrete retaining wall structure with 350 mm thick foundation doweled into the rock to reduce the footprint and also the concrete volume.The total length of the new dam is aproximatley 24m with including four (4) 1.5mx0.5m slidegates with removable stems. The gates are designed to for sluicing and also regulating the water for the downstream. The capacity of the gates are 1.64 m3/sec for each gate at normal water elevation.

The height of the concrete wall at the left side of the fishway (looking downstream) is designed to be 280 mm above the right side for safe access operation of the gates and stoplogs. The excess water will spill from top of the wall during the flood event.

As it was mentioned in section 4, this dam is categorized as a “very high “failure consequence and based on the CDA dam safety guideline, the inflow design flood (IDF) should be considered to be 2/3 between 1/1000 and PMF and therefore the IDF for this dam is considered 370 m^3/sec. More detailed flood analysis and dam breach analysis are required at later stage to evaluate the downstream flooded zone for more detailed impact assessment.

Based on the IDF flood elevation 3.35m of water height is estimated to spill from top of the weir wall.consequently ,protection berm is required to prevent flooding the dam access road and surrounding terrain.

A protective log boom is designed in the upstream of the dam to protect the dam from logs and debris flow impacts during flood events.

This original fishway design, as built by DFO, has been the basis of the hydrotechnical and environmental assessment (Appendix C). The concept of the fishway was kept as its original design with the retaining walls and adjustable stoplogs. The concrete walls were extended to the new dam. See Appendix B for concrete specs and for other structural criteria, refer to Appendix D and general notes drawings.

6. WATER WITHDRAWAL

Provincial water licence (WL) conditions are in place for withdrawal from Sliammon Lake and the system of lower Kwahtums .Water licences are included in Appendix E.Based on 1.628 M m^3/year of storage licenced by the weir dam (WL 116139), Tla’amin Nation has two (2) WLs to divert, store, and use water from the lake. Conditional WL 112612 can divert up to 183,189 m^3/year and WL 113456 can divert up to 165,932 m^3/year. The amount diverted annually as a percentage of the amount stored is 21.4%. These numbers do not factor in the water reservation of 11,225,000 m^3/yr for domestic, agricultural, and industrial uses held by Tla’amin Nation under Final Agreement. Under this water reservation, only up to 29% of the monthly available flow can be withdrawn from Kwahtums Teeshohsum (i.e., Sliammon Creek below the lake outlet) or Appleton Creek (the principal upstream input draining into Sliammon Lake) within the catchment area. Details of the water licences for storage and withdrawal have been factored into the hydrotechnical and environmental assessment included in Appendix C.

Photo 9: Existing fishway

7. EXCLUSIONS

The following items are excluded from BBA Engineering's scope of work:

- Global Stability of the project site;
- Engineering design of all temporary works;
- Topographic surveys;
- Environmental permitting and monitoring;
- Equipment used for geotechnical investigations;
- Hydrology studies and reports;
- Studies on sedimentation of the headpond and methodology or design in maintaining live storage;

- Slope stability of the headpond, except the area around the dam and in its immediate vicinity; and
- Debris flow studies.

8. LIMITATIONS

The recommendations presented in this report are based on BBA's interpretation and understanding of the site conditions and preliminary information. To properly understand the suggestions, recommendations, and opinions expressed in this report, reference must be made to the report in its entirety. We cannot be responsible for use, by any party, of portions of the report without reference to the whole report. Further geotechnical investigation is required during detailed design to have a better understanding about ground conditions and foundation requirements for the structure. In addition, any variations in structure locations or anticipated loading from those utilized in this report should be brought to our attention immediately; as such changes may affect and alter our conclusions.

It is understood that the Owner is commissioning an assessment to address overall stability (defined elsewhere in this report), as opposed to local instability which may originate as a result of, or be impacted by the proposed Works. Local instability adjacent to the works will be addressed by geotechnical evaluations completed both prior to construction or concurrent with construction, by the Geotechnical Engineer of Record. The overall Global stability assessment, as defined in this report, is to be provided by the Owner, and where possible, the Designer will provide mitigation measures in the design where possible, with the understanding that significant mitigation lies outside the scope of the Works.

This report has been completed for the exclusive use of Tla'amin Nation and other parties involved in the design and construction of the proposed Project. Any use of the information contained in this report by third parties or for other than the intended purpose must be first approved in writing by BBA. Any use a third party makes of this report, or any decisions made based on it, is the responsibility of such third parties. BBA accepts no responsibility for damages, if any suffered by any third party, as a result of decisions made or actions based on this report.

Appendix A: Codes and References

Codes and References

- British Columbia Dam Safety Regulation 2000. B.C. Reg 44/2000. Water Act.
- Canadian Dam Association, 2007, Dam Safety Guidelines and Technical Bulletins.
- Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition, 2012
- EM 1110-2-1603 (1992): Hydraulic Design of Spillway, US Army Corps of Engineers
- EM 1110-2-2100 (2005): Stability Analysis of Concrete Structures, US Army Corps of Engineers
- EM 1110-2-2104 (1992): Strength Design for Reinforced-Concrete Hydraulic Structures, Change 1, 2003, US Army Corps of Engineers
- EM 1110-2-2200 (1995): Gravity Dam Design, US Army Corps of Engineers
- EM 1110-2-2400 (2003): Structural Design and evaluation of outlet works, US Army Corps of Engineers
- EM 1110-2-2502 (1989): Retaining and Flood Walls, US Army Corps of Engineers
- EM 1110-2-6053 (2007): Earthquake Design and Evaluation of Concrete Hydraulic Structures, US Army Corps of Engineers
- Natural Resources Canada (1994-2008). National Air Photo Library, Sliammon Lake Area.
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- BBA. 2016a. Biological Resources Technical Data Report prepared by Chad Wilkinson, RPBio for Tla'amin Capital Assets Inc., T'shohsum, BC. 220 pp.
- BBA. 2016b. Hydrology Update Memo – January 2016. Prepared by Dan Kovacek, P. Eng. for Sliammon Development Corporation. 6 pp.
- BBA. 2016c. Initial Geotechnical & Dam Assessment Technical Report prepared by Alireza Aboutalebi, P.Eng. for Tla'amin Capital Assets Inc., Powell River, BC. 19 pp.
- Craig, JDC. 2009. Sliammon Creek Flow Augmentation Biological Rationale for Sliammon Lake Dam Rehabilitation. BC Conservation Foundation, Nanaimo, BC. 24 pp.

Appendix B: General Structural Design Criteria

Structural design loads

The following is a summary of the general loads specified to be used in the design of the project, as specified by codes and references that are applicable to this project for general structural design.

1. Dead Loads (D)

Unit weights of materials for calculating dead loads due to own-weight of structural members and building components:

- Mass concrete: 23 kN/m^3
- Reinforced concrete: 24 kN/m^3
- Steel: 78.5 kN/m^3
- Composite deck-slab (steel deck with concrete slab): 4.2 kPa

Dead load of finishes and non-structural elements:

- Hollow concrete block masonry (reinforced and partially grouted): 3.0 kPa
- Roofing (insulated): 0.25 kPa
- Wall cladding (insulated): 0.30 kPa
- Partition walls (drywall and steel studs): 0.30 kPa
- Suspended ceilings, including luminaires and HVAC: 0.50 kPa
- Collateral equipment (mechanical, electrical, and sprinkler system): 0.15 kPa
- The self-weight of the gates and equipment is considered as a dead load

2. Live Loads Due to Use and Occupancy (Usage) Loads (L1)

Vertical usage loads due to human and vehicular traffic, equipment (pending equipment suppliers loading drawings) and lay-down of parts are:

- Plant areas, storage rooms, all ground floor rooms: 12.5 kPa (Generator room floor slab structural members shall also be designed for the lay-down and storage of the heaviest mechanical equipment)
- Upper story areas housing control rooms, offices, toilets: 2.4 kPa or 9 kN
- Roof areas: 1.0 kPa or 1.3 kN
- Allowance for building services supported from roof: 0.15 kPa

Horizontal usage loads due to persons:

- Railings and partition walls, applied at 1.0 m above floor: 0.75 kN/m or 1.0 kN

- Vehicle loading (as per Forest Service Bridge Design and Construction Manual)

3. Hydrostatic Loads (H1) and (H2)

Hydrostatic loads H1 and H2 shall be applied for normal water level and flood case, respectively, using the flood flow rates and corresponding water levels given in this Design Basis Report. Uplift pressures shall be calculated by the line-of-seepage method based on the expected water levels and considering dimensions of structures that adequately satisfy all stability requirements.

Structures located at sufficient distance from streams not to be influenced by stream water levels, will be designed for geo-hydrostatic loads obtained using presumed groundwater tables. The factored geo-hydrostatic loads in these cases will be limited to those obtained by assuming the groundwater table is coincident with the finished ground level.

4. Environmental Loads

Environmental loads such as, wind (Wind), snow and rain (L3) will be used as mentioned in the main text of the Design Basis Report.

Ice loading (L2) of 150 kN/m acting 0.3m below the water level will be used in the design of the Diversion Weirs and Intake Structures, as per CDA guidelines.

5. Earth, backfill Loads (SO.)

The static lateral loads exerted by the backfill on the structural elements shall be determined for the at-rest condition using the following parameters to be provided by the geotechnical engineer based on site specific conditions:

γ_{wet}:	moist unit weight
γ_{sat}:	saturated unit weight
γ':	buoyant unit weight
c:	cohesion
ϕ':	effective internal friction angle
K_0:	at-rest earth pressure coefficient ($K_0 = 1 - \sin \phi$)

6. Seismic Loads (E)

- Hydrodynamic Pressure due to earthquake (E)

The hydrodynamic effects from the reservoir shall be calculated according to the theory of Westergard for incompressible fluid.

- Seismic Earth Pressure (E)

The increase in pressure of earth and rock fill shall be in accordance to US-ACE EM 1110-2-2502 (1989). The equation is a form of the theory of Mononobe-Okabe. It conservatively assumes no cohesion of the soil.

- Structural Seismic Loads due to mass of structures (E)

The seismic loads due to mass of structure shall be applied according to seismicity parameters provided in the report.

Load combinations

1. Operating (Serviceability) Load Combinations

The following load combinations, using the load factors shown, will be considered:

Table 5: Operating (serviceability) load combinations

	Loads									
	D	L1	L2	L3	H1	H2	SO	Wind	E	T
Cracking	1		1	1	1		1			1
	1	1			1		1			1
Deflection	1			1	1		1			
	1	1			1		1			
Elastic Strength	1	1	1	1	1		1			1
	1	1		1	1		1	1		
	1	1			1		1		1	

2. Design Basis (Strength) Load Combination

The following load combinations, using the load factors shown, will be considered:

Table 6: Design basis (stability) load combinations

	Load Condition	Loads								
		D	L1	L2	L3	H1	H2	SO	Wind	E
Stability	**Usual**	1	1	1	1	1		1	1	
		1	1			1		1	1	
	Unusual	1	1		1		1	1		
	Extreme	1	1		1		1	1		1

Table 7: Design basis (strength) load combinations

	Loads								
	D	L1	L2	L3	H1	H2	SO	Wind	E
Strength	1.4				1.4		1.4		
	1.25	1.5	0.5	0.5	1.5		1.5		
	1.25	1.5		0.5		1.5	1.5		
	1.25	1.5			1.5		1.5	0.4	
	1.25	0.5	1.5	1.5	1.5		1.5		
	1.25		1.5	1.5	1.5		1.5	0.4	
	1.25	0.5			1.5		1.5	1.4	
	1.25		0.5	0.5	1.5		1.5	1.4	
	1	0.5		0.25	1		1		1
	1	0.5			1		1		1

Structural design

The reinforced concrete structures have to be checked for:

- Serviceability
- Stability
- Strength design

1. Serviceability

Cracking Limits

Cracking of concrete sections must be limited by providing sufficient reinforcement such that the cracks are controlled over the effective tension zone of the concrete section. Limiting characteristic crack widths are:

- Surfaces not continuously exposed to water ≤ 0.30 mm
- Surfaces continuously exposed to water ≤ 0.20 mm
- Surfaces of water-tight elements ≤ 0.10 mm

Deflection Limits

Unless otherwise stipulated by equipment suppliers, characteristic deflections of structural elements such as columns, slabs, and beams will be kept below the following limits:

- Under permanent dead and live loads ≤ span length/300
- Under temporary live loads ≤ span length/240

- Vertical crane runway girder deflection ≤ span length/800
- Lateral crane runway girders deflection ≤ span length/600
- Building sway ≤ span length/400

Elastic Strength Limits

All structural members are to behave elastically under operating (serviceability) load combinations. To ensure this, section stresses must remain below the following limits:

- Concrete compression stress:

$$f_c \leq \varphi_c f'_c$$

Where the φ_c is the resistance factor equal to 0.6 or alternatively:

$$\frac{P^2 + M^2}{P_r^{\,2} + M_r^{\,2}} \leq 0.36$$

Where P and M are the Elastic Strength Limit State section axial force and moment; P_r and M_r are the corresponding factored section resistances.

Structural steel:

$$\frac{\text{Factored Resistance}}{\text{FactoredAction}} \geq 1.0$$

Where the Factored Resistance is determined using resistance factor φ_s of 0.9 and elastic section properties in all cases. In the case of elastic stability limits (buckling) it is calculated using a resistance factor φ_s of 0.6.

2. Stability

The following checks have to be performed for all load combinations at service level. Live loads shall only be considered where they decrease the factor of safety. In addition, soil bearing has to be checked.

3. Buoyancy

The safety factor against buoyancy is calculated by

$$SF_B = \frac{\Sigma W_V}{\Sigma F_V}$$

Where

SF_B = Safety factor against buoyancy

$\sum W_V$ = Sum of dead loads

$\sum F_V$ = Sum of uplift forces

4. 11.3.2.1 Sliding

The safety factor against sliding along the rock-concrete interface is calculated as follows:

$$SF_{S\Phi} = \frac{\Sigma F_V * f}{\Sigma F_H}$$

$$SF_{SC} = \frac{\sum F_V * f + c * A}{\sum F_H}$$

Where

$SF_{S\Phi}$ = Safety factor against sliding without cohesion

SF_{SC} = Safety factor against sliding with cohesion

$\sum F_V$ = Sum of vertical forces (including uplift forces)

$\sum F_H$ = Sum of horizontal forces

f = Friction coefficient of rock-concrete interface (f = tan Φ')

c = Cohesion coefficient

A = Area of foundation in compression

Φ' should include the effect of cohesion at rock-concrete interface in case of no cohesion sliding stability check for structures founded on rock. The Φ' and c' are only indicative and presents the resistance in the rock-concrete interface.

5. 11.3.2.2. Overturning

The safety factor against overturning is determined as follows:

$$SF_O = \frac{\Sigma RM}{\Sigma OM}$$

Where

SF_O = Safety factor against overturning

∑RM = Sum of resisting moments

∑OM = Sum of overturning moment

Instead of calculating the safety factor, the safety against overturning may also be considered to be satisfied if the resultant force is located within a prescribed region of the base of the structure corresponds to the load combinations.

6. Minimum Required Safety Factors

The calculated safety factors shall not exceed the values listed below:

Table 8: Load combination safety factors

Load combination	Buoyancy [1)]	Sliding [1)] without cohesion	Sliding [2)] with cohesion	Requirement for resultant location at base [1)]	Foundation bearing Pressure [2)]
Normal	1.3	1.5	2.0	100% of base in compression	≤ allowable
Unusual	1.2	1.3	1.7	75% of base in compression	≤ allowable
Extreme	1.1	1.1	1.3	Resultant within base	≤ 1.33 x allowable

- USACE, EM 1110-2-2100, Stability Analysis of Concrete Structures
- USACE, EM 1110-2-2200, Gravity Dam Design

Strength design

The weir structures will be governed by the stability limit state rather than strength, and the intake channels will be allowed to flood during maximum credible floods.

Concrete design properties

Detailed concrete class, concrete cover, and reinforced steel specifications are provided in the following sections.

1. Concrete Classes

Concrete Class C15

- For blinding concrete and mud slab applications.
- Specified cylinder compression strength at 28 days: f'_c = 15 MPa

<u>Concrete Class C25</u>

- For mass concrete applications.
- Specified cylinder compression strength at 28 days: f'_c = 25 MPa
- Modulus of elasticity: E_c = 25 GPa
- Poisson's ratio (cracked section): v = 0.2Concrete Class C30
- For structural reinforced concrete applications
- Specified cylinder compression strength: f_{ck} = 30 MPa
- Modulus of elasticity: E_c = 26 GPa
- Poisson's ratio (cracked section): v = 0.2

Concrete Class C35

- Specified cylinder compression strength: f_{ck} = 35 MPa
- Modulus of elasticity: E_c = 27 GPa
- Poisson's ratio (cracked section): v = 0.2

<u>Concrete Cover</u>

The distance from the face of a concrete member to the edge of reinforcement (cover) will be as follows:

Concrete surfaces exposed to climatic weather and soil backfill:

- Unformed surfaces in contact with foundation: 100 mm
- Concrete cast directly against soil or rock: 75 mm
- Top of footings and base slabs: 50 mm
- Walls, slabs, beams, roofs: 50 mm

Reinforcing Steel

Reinforcing steel will be CSA G30.18 Grade 400 W, with the following design parameters:

- Yield strength: f_y = 400 MPa
- Ultimate tensile strength: f_{tk} = 550 MPa
- Elongation at yield: ε_y > 0.2 %
- Ductility: ε_{50mm} > 12 %
- Modulus of elasticity: E_s = 200 GPa

Minimum Reinforcement

1. Beams

Reinforcement contents must fall within the following limits:

Flexural reinforcement:

- Minimum: $A_{smin} = .003\ b_t\ h$

Where b_t and h are the gross concrete section dimensions.

Web face reinforcement:

- Minimum reinforcement content: $A_{sface} = 0.01\ s_{face}\ (2c + ø)$

Where c is the concrete cover of the face bars.

- Maximum spacing: s_{face} = 200 mm
- Stirrups:
- Minimum reinforcement content: $A_{sw} = 0.0008\ (s\ b_w)$

Where b_w is the web cross-section and s the stirrup spacing.

2. Slabs

Reinforcement must be spaced at less than:

- Maximum slab reinforcement spacing: 1.5 h ≤ 300 mm
- Minimum reinforcement content: 0.002 A_c

Where h is the slab thickness and A_c the gross concrete section area.

Free edges of slabs must be reinforced with U-bars whose legs extend at least 2h away from the edge.

3. Mass Concrete

For the mass concrete sections, the provisions CSA A23.3 will be modified to take into account the absence, or low ratio, of reinforcement. Where reinforcement is provided to balance overturning moments, the steel strain will be checked to assure the elongation limit is not exceeded. This is in lieu of the minimum reinforcement (ductility) requirements of CSA A23.3, which are not appropriate for mass concrete sections that would fail by overturning or sliding rather than flexure.

Structural Steel Design Properties

1. Sections

I sections, CSA G40.21 Grade 350W:

- Yield strength: f_y = 350 MPa
- Ultimate tensile strength: f_u = 450 to 650 MPa
- Elongation at yield: ε_y > 0.18 %
- Ductility: ε_{50mm} > 23 %
- Modulus of elasticity: E_s = 200 GPa
- Poisson's ratio: v = 0.3
- Square hollow structural shapes (HSS) CSA G40.21 Grade 350W, Class C:
- Yield strength: f_y = 350 MPa
- Ultimate tensile strength: f_u = 450 to 620 MPa
- Elongation at yield: ε_y > 0.18 %
- Ductility: ε_{50mm} > 22 %
- Modulus of elasticity: E_s = 200 GPa
- Poisson's ratio: v = 0.3

C and L sections and structural platework, ASTM A36:

- Yield strength: f_y = 250 MPa
- Ultimate tensile strength: f_u = 410 to 550 MPa
- Elongation at yield: ε_y > 0.13 %
- Ductility: ε_{50mm} > 21 %
- Modulus of elasticity: E_s = 200 GPa
- Poisson's ratio: v = 0.3

Cold formed girts, ASTM A653 Grade 345

Structural steel roof decking, ASTM A653 Grade 230

Light gauge standing-seam roofing, ASTM A653 Grade 230

Slenderness: Members will be chosen to have a slenderness of less than 200

2. Connections

Bolted Connections

All bolted connections will be designed as bearing connections. Bolts will however be tensioned by the turn of nut method to ensure slip-free behaviour under service loads.

Bolts will be high strength to ASTM A325M - Type 1 with:

- Yield strength: f_y = 417 MPa
- Tensile strength: f_u = 830 MPa

Welded Connections

When a welded connection introduces stresses perpendicular to the surface of a plate element, the connection must be detailed to account for laminar tearing if the plate thickness exceeds 15 mm.

Fillet weld dimensions must fall within the following limits:

Minimum weld leg: $a_{leg} \geq 6$ mm

Minimum weld length: $L_{weld} \geq 4\ a_{leg}$ or ≥ 40 mm

Angle included between weld legs:

- Minimum: 60°
- Maximum: 120°

Maximum pitch of discontinuous welds: $6\ t_{min} \geq 200$

Weld material is to match base metal in accordance with CSA W59:

- For Grade 350W and 350WT steels: E480XX
- For A36 and A20/A516 steels: E410XX or E480XX

Appendix C: Hydrotechnical and Environmental Assessment

Tla'amin Nation

Sliammon Lake Replacement Dam

Teeshohsum, BC

Appendix C

Hydrotechnical and Environmental Assessment

BBA Document No. / Rev. 3774003-001000-4E-ERA-0001 / R00

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FINAL

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EXECUTIVE SUMMARY

Hydrotechnical and environmental assessment of Kwahtums Teeshohsum (formerly Sliammon Creek) supports a plan by Tla'amin Nation (Tla'amin) to replace an aging dam constructed by Fisheries and Oceans Canada (DFO). It was designed to store lake water for conservation purposes using stop logs at the outlet of Sliammon Lake. Prescribed instream flow requirements (IFRs) regulate downstream flows into Kwahtums Teeshohsum under conditional water licence (WL) 116138 previously held by DFO.

Total licensed storage for WL 116139 is 1,320 acre feet/year or 1.63 M m^3/year. Two (2) WLs divert, store, and use water from the lake and represent annual withdrawals of 21.4% amount stored annually under WL 116138. Recent hydrometric data estimated the mean annual discharge (MAD) to be 1.36 m^3/s, which is considerably less than ~1.7 m^3/s previously estimated (Craig 2009).

Salmon production in Sliammon Lake and Kwahtums Teeshohsum consists of both natural spawning reaches of the creek and hatchery enhancement. Kwahtums Teeshohsum supports predominantly chum salmon (CM) and coho salmon (CO), with very limited Chinook salmon (CH), and historically pink salmon (PK). Coho salmon migrate into the lake through the dam's fishway. Other species naturally spawn in lower spawning reaches, but a large percentage of escapement is retained by the hatchery for artificial production, with CO fry released in the lake to support ongoing enhancement.

Recent habitat assessments in Kwahtums Teeshohsum suggest the prescribed IFRs for summer could be increased under an adaptive management strategy to better understand the environmental flow needs (EFN) under the *Water Sustainability Act*. This is relevant if surface flows are decreasing over time, as suggested. A storage model was developed by Fathom Scientific Ltd. (Fathom). Results suggested a replacement of current design could sustain active storage of winter surplus flows with controlled release into Kwahtums Teeshohsum during summer. This would allow for minimum prescribed IFR of 0.13 m^3/s to be met. Requirements for a sustained upper IFR of 0.25 m^3/s over summer months were not met in August 2016 during associated drought conditions (<0.01% of all months over a 22-year period of record).

Storage of water for conservation can allow licensed withdrawals under the established IFRs for most, but not all, years. When considering additional withdrawals under a water reservation of the Tla'amin Final Agreement, sustained IFRs above 0.25 m^3/s may not be attainable without additional storage or more precise regulation at dam in response to changing surface runoff in the lake. Decreasing flows and increased frequency of drought conditions could impact the overall water security for both the community use and EFN. This impact could mean that an increase of the dam height would be required to store additional water; however this further depends on several unknown factors, such as the time of year it would be required, given seasonal availability of surplus flows.

Replacement of the dam is necessary, not only because of its hazardous state, but also given current and future water withdrawals along with changing environmental conditions, such as drought frequency and reduced surface runoff. This assessment is based on a conceptual model, built with numerous assumptions and provided for information only, and should not be considered for design basis.

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APPENDICES

1. INTRODUCTION

BBA completed the mandate initiated by Kawa Engineering Ltd. in support of a hydropower project development plan (DP) for Tla'amin Management Services LP (formerly Sliammon Development Corporation). This included the design flow and environmental baseline studies of Kwahtums Teeshohsum (formerly called Sliammon Creek). The following studies were conducted to support the DP:

- Biophysical studies that included water quality, fish and aquatic habitat (BBA 2016a),
- Hydrologic studies that included hydrometric modelling over two years below the dam from March 2015 through to 2017 (BBA 2016b, Aquarius 2017), and
- Initial Geotechnical & Dam Assessment Technical Report (BBA 2016c).

The geotechnical assessment included inspection of the dam constructed by Fisheries and Oceans Canada (DFO) in 1984 on Sliammon Lake outlet. The dam is now held by Tla'amin Nation under conditional water licence (WL) to store water for conservation purposes. BBA (2016c) observed it to be in a state of disrepair and documented the associated hazards and safety risks. Mitigation measures were proposed to extend its lifespan by up to two years.

2. SLIAMMON LAKE WATER USE

Water allocation describing storage and withdrawals is summarized in Table 1 (see Fathom's output in Appendix C; Table C-1). Key values from this table are the licensed storage of 1.63 Million m^3 (Mm^3) and the licensed withdrawal of 0.01494 m^3/s. The evaluation has also factored in the water reservation held by Tla'amin Nation under Final Agreement (Table 1; see also Appendix C, Table C-1).

Table 1: Annual Water Allocation for Tla'amin Nation

WL	Date Issued	Condition		Allocation
WL112612	15 July 1998	Divert, store, and use.	Withdrawal	(183,189 m3)
WL113456	15 July 1998	Divert store, and use		(165,932 m^3)
WL116139	8 May 2003	Conservation	Storage	1,628,196 m^3
Water Reservation	11 Apr 2014	Under Final Agreement	Withdrawal	(112,250 m^3)
			Net storage allocation:	1,166,825 m^3

2.1 Tla'amin Nation

Following the effective date of the Tla'amin Final Agreement in April 2016 and cancellation of BC Hydro's Standing Offer Program for energy procurement, BBA understands that Tla'amin Nation has now prioritized the need to address risks associated with the dam's condition. A replacement of the current dam with a new design is intended to restore the original function and expected to alleviate seasonal water use constraints recently faced by the community. Environmental data previously collected to support the initial hydroelectric project assisted in further assessing aquatic conditions for the dam replacement, given existing and planned water use for Sliammon Lake..

Under Final Agreement, Tla'amin also holds water reservation of 11,225,000 m^3/year for domestic, agricultural, and industrial uses. This does not include water use for a separate hydropower reservation (INAC 2017). Under the water reservation, up to 29% of the monthly available flow can be withdrawn from Kwahtums Teeshohsum (i.e., Sliammon Creek below the lake outlet) or Appleton Creek, which represents the principal inflow stream to the lake.

Under paragraph 6 of the Final Agreement, the water reservation has priority over all WLs other than those issued or applied for prior to June 2003 (INAC 2017). That includes the conditional WL 116139 previously held by DFO for storage and the two separate withdrawal licences for diversion, storage, and use. All three existing WLs are now held by Tla'amin Nation.

2.2 Fisheries and Oceans Canada

Water use and dam safety are top priorities of the mandate for dam replacement. DFO inquired about the fate of the current dam and recommended replacement due to its state of disrepair and associated hazards. The original design was based on limited flow information, which may no longer be relevant or appropriate to the current fisheries productivity and conservation goals in Kwahtums Teeshohsum. DFO recommended that Tla'amin Nation consider more recent flow information to support a new design.

2.3 Assessment objectives

This hydrotechnical and environmental assessment combines previous information (BBA 2014, 2016a, 2016b, 2016c; Aquarius 2017; Knight Piésold 2017) combined with water licence details. The dam is intended to uphold storage capacity on Sliammon Lake, maintain licensed withdrawals, and sustain instream flow requirements (IFR) established by Hill (1985). Its replacement will also eliminate existing hazards and safety risks.

Information on the operation of the dam and fishway (Hill 1985) has been considered in deliberating a feasible replacement design. The objective of the hydrotechnical and environmental assessment is to determine whether seasonal water use and prescribed IFRs (now considered environmental flow needs, or EFN under the current *Water Sustainability Act*) can be sustained by the current storage capacity. It is unclear whether replacement of the existing design will allow Tla'amin Nation to exercise rights held in the water reservation for Kwahtums Teeshohsum under the Final Agreement.

3. ENVIRONMENTAL AND FISH HABITAT ASSESSMENT

The environmental assessment considered the following environmental data and regulatory information:

- Baseline hydrology data from Sliammon Lake outlet (BBA 2016b, Aquarius 2017);
- Fish and fish habitat data in Kwahtums Teeshohsum (BBA 2016a), and
- Licensed seasonal water use by Tla'amin Nation with respect to:
  - Fisheries management objectives, and
  - Community water supply.

The storage model developed by Fathom for the hydrotechnical assessment is based on additional information from Aquarius (2017) and is included as Appendix A.

3.1 Seasonal discharge from Sliammon Lake

A stream gauging station was set up in March 2015 at a stable bedrock pool of Reach 6 on Kwahtums Teeshohsum below the lake outlet. As part of the hydropower project feasibility, BBA used the station for both hydrometric (i.e., design basis) and microhabitat considerations (Figure 1). Stage and discharge data were used to simulate hydrometric data for up to 22 years (Aquarius 2017) using nearby Environment Canada gauging stations.

Figure 1: Hydrometric Station on Reach 6 – April 30, 2015

The hydrotechnical assessment provided by Fathom Scientific (Fathom) for this dam replacement determined whether the functionality of the dam can be restored to uphold WL objectives while sustaining prescribed IFR below the lake during summer months. Aquarius (2017) estimated a mean annual discharge (MAD) of 1.36 m^3/s and mean annual runoff (MAR) of 31 $L/s/km^2$ at the lake outlet. Water licence requirements were considered in terms of storage and withdrawals given seasonal requirements for salmon production. Licensed withdrawals and active storage support natural and artificial salmon production in Kwahtums Teeshohsum, although it is unclear whether the level of flow release are sufficient to sustain the EFN.

3.2 Kwahtums Teeshohsum fish habitat

BBA (2016a) set up ten microhabitat monitoring stations from Reach 2 upstream to the Sliammon Lake outlet (Figure 2). Monitoring a range of seasonal flows in the diversion reach in 2015 and 2016 (see Appendix B) supported the habitat assessment required for the DP instream flow study. Evaluation of habitat involved provincially standard procedures applied at the macrohabitat (i.e., reach) scale.

The hatchery uses surface water from lower Sliammon Creek and raw water from the lake (Lee George, pers. comm.). Reach 1 directly below the hatchery contains enhanced spawning and rearing channels fed by mainstem flow year-round (S. Galligos, pers. comm., as cited in Craig 2009). Several hundred metres upstream is a licensed water intake for the hatchery (Figure 3).

Lower reaches support naturally spawning habitat for CM below physical obstructions present in Reach 4. Adult CO spawns throughout (Hancock and Marshall 1985) and is capable of passing through the fishway into the lake. From the lake, fish have access to potential spawning habitats in Lower Appleton Creek, although it is unknown from BBA (2016a) whether this occurs.

Six distinct reaches consist of rearing habitat extending from the Salish Sea to the outlet at Sliammon Lake. Naturally spawning Pacific salmon species deposit eggs in gravel substrates that need to remain submerged over winter to prevent desiccation (Figure 4). This requires ample flows from the lake during winter months.

An ability to capitalize on surplus availability and use it to enhance seasonal flows benefits both fish production and food availability (invertebrate production). Craig (2009) also noted that the augmented flow from storage at the lake would benefit juvenile CO and SH (or RB) trout, but not juvenile Pacific salmon during spring seaward migrations, whether produced naturally or through hatchery enhancement.

Figure 2: Microhabitat Station on Reach 3 – November 17, 2015

Figure 3: Licensed Intake on Lower Sliammon Creek – February 24, 2016

Figure 4: Exposed Spawning Gravels in Reach 3 – August 10, 2015

3.3 Kwahtums Teeshohsum fisheries productivity

To determine the appropriate flow for sustaining fisheries productivity, BBA first considered species periodicity of the fish community in the creek. Table 2 represents a chart constructed from observations by BBA (2016a) and information supplied from a range of sources (Hancock and Marshall, McPhail 2007, Craig 2009).

Observed species in 2015 and 2016 included juvenile chum salmon CM *Oncorhynchus keta*, juvenile coho salmon CO *O. kisutch*, rainbow trout RB (possibly steelhead SH) *O. mykiss*, and cutthroat trout CT *O. clarkii clarkii* (Figure 5). Juvenile Chinook salmon CH *O. tshawytscha* were not observed in the study, but a small broodstock is reared and released by Tla'amin Fisheries along with CM and CO under the current hatchery enhancement program (Scott Galligos, pers. comm.). Pink salmon PK *O. gorbuscha* was not observed, but is known to historically occupy the creek (Hancock and Marshall 1985).

All three salmon species including PK, CH, and CM immediately migrate to sea upon release while CO fry are released into Sliammon Lake and Appleton Creek. Juvenile CO typically overwinter in freshwater habitats for the first year (McPhail 2007) then undergo seaward migrations in the following spring as smolts (Lee George, pers. comm.).

Table 2: Species Periodicity Chart

Month	Migration	Spawning	Incubation	Smoltification	Rearing
January			CM/CO		
February	RB*/CT		CO	CM	
March	RB/CT	RB/CT		CM	
April		RB/CT	RB/CT	CO/CM	
May			RB/CT	CO/CM	RB/CT/CO
June			RB/CT	CO	RB/CT/CO
July					RB/CT/CO
August	CM				RB/CT/CO
September	CM/CO	CM			RB/CT/CO
October	CO	CM/CO	CM		RB/CT/CO
November		CM/CO	CM/CO		
December		CO	CM/CO		

*RB = rainbow trout, but possibly also steelhead (SH); CT = cutthroat trout, CM = chum salmon; CO = coho salmon. Chinook salmon (CH) and Pink salmon (PK) are also potentially present, but have not been included in the table.

Figure 5. Juvenile CO and RB in Sliammon Creek – August 12, 2015

Summer flows provide rearing habitats for trout (e.g., RB/SH and CCT) and CO in the creek. Augmented flows do not benefit wild juvenile salmon that migrate to sea prior to the period of active storage in the lake (April 15th). Returning adult CM may enter the stream during the late summer, but Craig (2009) noted that use of any lake storage to release a pulse flow would not be justified due to licensed water allocations for the community (i.e., downstream hatchery needs and community water use).

4. HYDROLOGY AND HYDROTECHNICAL ASSESSMENT

A previous MAD of ~1.7 m^3/s was estimated by Craig (2009) from a brief period of record (1949-1951) at a pre-existing Environment Canada gauging station for Sliammon Creek. Assumed to be "representative of flows during that era", Craig (2009) deemed the MAD to be conservative compared to channel width measurements used to estimate MAD, which he figured placed the MAD at between 2.3 m^3/s and 3.8 m^3/s. The regional analysis estimated MAD to be 1.36 m^3/s at the Sliammon Lake outlet with a mean annual runoff (MAR) of 31 L/s/km^2 the catchment (Appendix A) indicating a decrease in flows relative to historic conditions.

4.1 Water availability

From the 22-year synthetic flow series spanning a period of record between January 1988 and March 2017 (excluding years 1996-2003 inclusive; Aquarius 2017), mean monthly discharges (MMD) at the lake outlet are presented in Table 3 and displayed in in relation to MAD and the prescribed range of IFRs of 0.13 – 0.25 m^3/s (Figure 6; Hill 1985).

Table 3: Mean Monthly Discharge at Sliammon Lake Outlet from 1988-2017*

Month	MMD (m^3/s)	%MAD	Water Availability
January	2.20	162%	Surplus
February	2.06	151%	Surplus
March	1.82	134%	Surplus
April	1.84	135%	Surplus
May	1.20	89%	Deficit
June	0.55	40%	Deficit
July	0.24	17%	Deficit
August	0.16	11%	Deficit
September	0.46	32%	Deficit
October	1.44	106%	Surplus
November	2.44	179%	Surplus
December	1.86	137%	Surplus

*Excludes 1996 – 2003.

Mean monthly flows exceed MAD at the lake outlet during fall, winter, and into early spring (i.e., October – May), which is typical of rain-dominated maritime climate with no glacial runoff present during summer. This provides winter surplus flows relative to MAD in Sliammon Lake for storage purposes and controlled release during summer months.

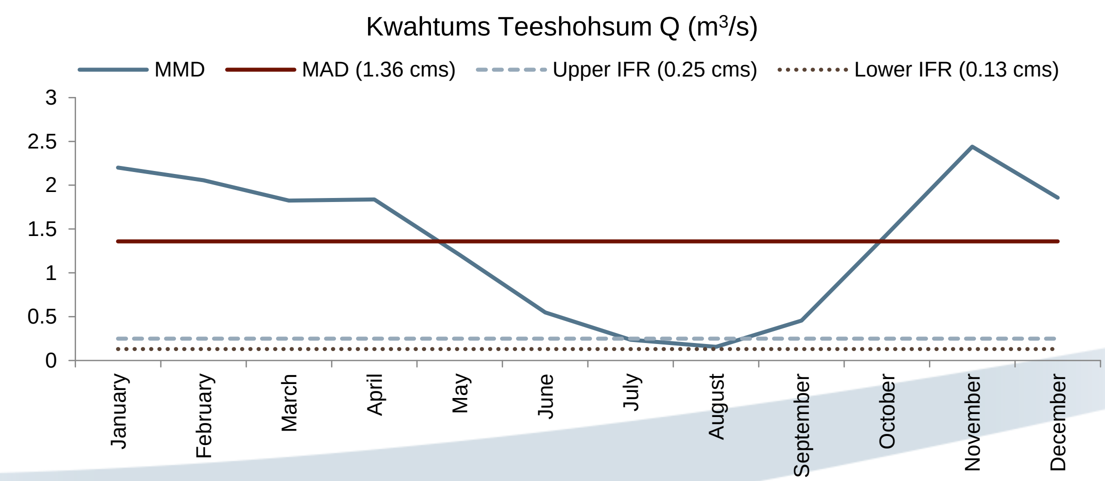


Figure 6: Mean Monthly Discharge Relative to MAD and IFRs at the Fishway

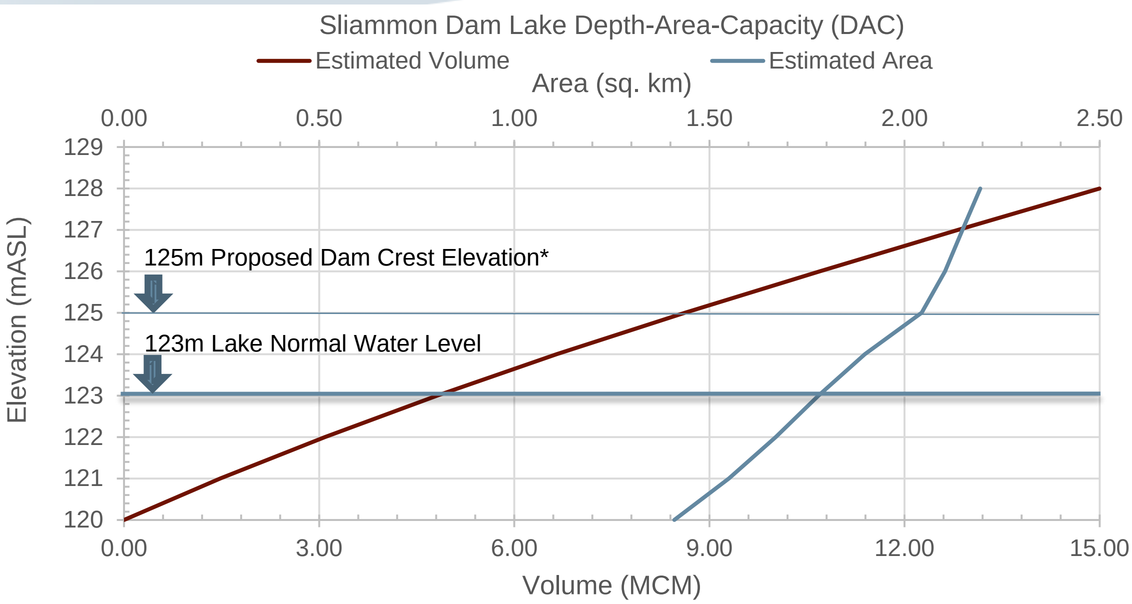
The hydrotechnical assessment was led by Gabe Sentlinger of Fathom, who also led the hydrology study for Aquarius (2017). Fathom considered existing WL information to evaluate a range of storage scenarios under which the IFR prescribed by Hill (1985) could be sustained along with licensed withdrawals by Tla'amin Nation. In order to determine water availability under the current dam design and water licenses, a daily storage model was developed. Fathom's primary data sources were:

- Drawing 33-16-10 of the original dam structure from Hill (1983);
- Sliammon Lake Weir: Operations Manual from Hill (1985);
- Sliammon Lake DAC Curve.xlsx from BBA (2014; Figure 7); and
- Drawing 3774003-000000-41-D20-1000 (provided as Appendix D of the design basis report).

Model assumptions were as follows:

- Existing dam crest at 123 m above sea level (mASL) and natural lake level at 122 mASL, although exact levels are not important as this is volume modeling exercise;
- Fishway opening of 1.25 m wide and 1 m tall, as per DFO (1983);

- Variable IFRs between 0.136 and 0.25 m³/s as per Hill (1985), and 0.5 m³/s (37% MAD) equal to twice the upper IFRs;
- When the lake level is above the weir crest at 123 mASL, there is no storage and all inflow leaves the lake within 1 day, minus the licensed withdrawal of 0.01494 m^3/s;
- The fishway sill can be adjusted up and down:
  - 0.23 m below the top of the weir provides an upper IFR of 0.25 m³/s through the fishway,
  - The IFR doubles (i.e., increases to 0.50 m³/s) at 0.37 m below the weir, and
  - The IFR increases to 2.2m³/s when completely open to a depth of 1.0m;
- Flow estimates were based on a broad crested weir equation calibrated against the rating curve developed by Hill (1985; see Figure 2 of the manual);
- When the lake level is below the weir crest and above the bottom of the fishway, the outlet discharge is attenuated (smoothed) and water is stored in the lake;
- When the outlet discharge is less than the nominal IFR, no licensed withdrawal occurs and all Inflow immediately leaves the lake.
- It is possible to set the maximum fishway Q equal to the IFR, which assumes it has automated regulation to always permit only the IFR to pass the fishway; however, it remains unclear whether this is possible (as it is mainly a modeling exercise).



*Based on storage model for initial hydropower proposal.

Figure 7: Depth-Area-Capacity Curve for Sliammon Lake (BBA 2014)

4.1.1 Sliammon Lake storage model

The Area-Storage-Elevation curve provided by Fathom (see Appendix C, Table C-2) used data provided by BBA (2015; Appendix A) and a lake area of 1.78 km² at 123 mASL. The dam replacement design basis report (see drawings in Appendix D of the main report) considered the natural lake level elevations to be slightly lower (121.77 mASL on March 18, 2016). Lake area from the BC Freshwater atlas is 1.75 km², which is slightly less than the area at 123 mASL. Fathom therefore assumed the BBA (2014) elevation to be 1m too high and adjusted it by 1 m, further assuming the areas were reasonably accurate based on the following assumptions:

- Natural lake area at 122 mASL is 1. 78 km2;
- Lake area is 1.90 km² at 123 mASL;
- Lake Area is 2.04 km² at 124 mASL; and
- Lake area is 2.10 km².at 125 mASL.

Note that the natural lake area times 1 m of elevation equates to 1.78 Mm^3, which is greater than 1.63 Mm³ as the licensed storage amount. The existing Sliammon Lake dam is approximately 1m tall leading Fathom to believe it was designed to hold approximately 1.63 Mm^3 of lake storage.

Model operation

The synthetic flow series derived by Aquarius (2017; see Appendix A) was based on daily regression against measured flows-and is used in the daily storage model. Each day, the inflow is compared to the outflow and the delta-volume calculated. This is converted to lake elevation using the Area-Storage-Elevation curve (Appendix C, Table C-2). The lake elevation is used to calculate the flow through the fishway based on the broad crested weir equation:

$$Q = \left(\frac{2}{3}\right)^{3/2} g^{1/2} b C {h_1}^{3/2}$$

Where Q is the discharge from the fishway only (i.e., it does not include flows above the fishway or at other areas of the weir dam) g is the acceleration due to gravity, b is the width of the fishway, C head discharge co-efficient, and h_1 is the head above the fishway sill. Fathom determined C to be equal to 1.1 based on Hill (1985; Figure 2). A value of 1.1 is larger than the expected range of 0.84 m^3/s - 0.92 m^3/s.

Model scenarios

The model was then run by Fathom over seven scenarios that considered the recent synthetic flow series (Aquarius 2017; see Appendix A). Each scenario has been developed in consideration of the range of prescribed IFR (between 0.136 and 0.25 m^3/s) for the fishway (Hill 1985) with the following rationale (see also Appendix C):

- **S1** – This is the base case scenario with no storage, but sustained withdrawal;
- **S2** – Uses an IFR of 0.136 m^3/s (lower limit prescribed for the fishway) with a maximum fishway flow of 0.5 m^3/s and a lake storage volume of 0.5 Mm^3 – the maximum fishway flow is larger than the IFR to simulate how Fathom believes the weir has been previously operated;
- **S3** – Uses an IFR of 0.136m^3/s and lake storage volume of 1.1 Mm^3 – this is the smallest volume of storage required to achieve the IFR and licensed withdrawal 100% of the time;
- **S4** – Uses an IFR of 0.136m^3/s and the total lake storage volume of 1.63 Mm^3 – this is the normal condition for the lower limit of the prescribed IFR.
- **S5** – Uses an IFR of 0.25m^3/s and the total licensed storage volume of 1.63 Mm^3 – this is the normal condition for the upper limit of the prescribed IFR;
- **S6** – Uses an IFR of 0.50 m^3/s and total licensed storage volume of 1.63 Mm^3 – this could allow for additional flows of up to twice the upper limit of the prescribed IFR to support adaptive management using experimental flows to better determine the EFN.
- **S7** – Uses an IFR of 0.50 m^3/s and lake storage volume of 5.1 Mm^3 – over three times the total licensed storage representing the smallest volume required to achieve a hypothetical IFR of 0.50 m^3/s and licensed withdrawals 100% of the time.

4.2 Storage model scenarios results summary

Results of each scenario are described as follows based on the output provided in Appendix C; Table C-3 over 22-years synthetic flow series (depending on the month):

- **S1** – the lower IFR cannot be maintained 100% of the time between May and October and ranges from 2% of the time during August to 90% of the time in May;
- **S2** – the lower IFR cannot be maintained 100% of the time between May and October and ranges from 43% of the time during August to 95% of the time in the months of May and October;
- **S3** – the lower IFR can be met 100% of the time if the storage volume ≥ 1.1 Mm^3 (67% or two thirds the total licensed storage);
- **S4** – Lower IFR can be met 100% of the time at the current licensed storage;
- **S5** – Upper IFR cannot be met 100% of the time and only 95% of the time in August, which is (associated with the drought of 2016. This also requires lowering the fishway sill incrementally, and possibly raising it during higher flow periods, which is impractical to achieve using stop logs;
- **S6** – IFR of 0.50 m^3/s is twice the upper IFR and cannot be met 100% of the time between June and November and ranges from 3% of the time during September to 90% of the time in the months of June and November;

- **S7** – IFR of 0.50 m³/s is twice the upper IFR and can be met 100% of the time with a storage volume of 5.1 Mm³s, which is over three times the licenced storage and would raises the lake about 2.5-3.0 m above the current lake level.

Several scenarios were considered. After understanding how the existing structure was meant to be operated, it became clear the height of the dam was meant to capture the licensed storage of 1.63 Mm³, or more likely the 1.63 Mm³ was calculated based on raising the lake by 1m. This coincides with targeted IFR presented in Hill (1985) of 0.13 - 0.25m³/s during low flow periods.

This is a conceptual model, built rapidly, for information only. More detailed modeling is required for design basis and these results are not to be used for design basis.

4.3 Kwahtums Teeshohsum Environmental Flow Needs

BBA observed the fish habitat in Kwahtums Teeshohsum over a range of seasons and flows. Transects SCIF-4 to SCIF-6 from Reach 3 (Appendix B) represent habitat in the principal spawning reach. Winter flows need to be well above the summer IFRs (0.13 - 0.25 m^3/s; Hill 1985) at the lake outlet in order to keep spawning gravels submerged. A conservative estimate of 0.82 m^3/s (roughly 60% MAD) was observed to be the minimum winter EFN required to keep the spawning gravels submerged over winter. This is about 3.3 times the upper IFR established for summer.

Summer rearing habitat consists of limited glide habitat and various distinct pools preferred by juvenile CO. Clumps of large woody debris (LWD) and overhanging vegetation (OV) represent available cover, although boulders are the most frequently observed cover throughout the stream. Stream conditions in summer yielded relatively reduced amount of flowing habitat preferred by RB/SH. This may result in some degree of crowding and isolation in distinct pools as well as loss of preferred RB rearing habitat (Figure 8).

Recent observations indicated limitations in summer rearing habitat for a number of coastal streams on Vancouver Island and the Sunshine Coast. This suggests that IFRs previously developed by Hill (1985) may limit overall fisheries productivity. The contribution of summer rearing habitat to overall fisheries productivity in Kwahtums Teeshohsum represents the main uncertainty in determining an overall EFN of the creek. This uncertainty could be addressed experimentally by increasing the summer IFR at the fishway under an adaptive management strategy. Increase in summer flows must still consider licensed withdrawals by Tla'amin Nation and any additional use of the water reservation under its Final Agreement.

:

Figure 8: Pool and Cover Habitat in Reach 3 – August 10, 2015

5. CONCLUSION

The current storage capacity is vulnerable to drought conditions and limited by the leaky state of the dam. Droughts, along with observed decrease in surface flows compared to historic data along are relevant factors to consider for future water use planning. Results show the replacement design could restore community water use needs without further impacting stream-rearing species in Kwahtums Teeshohsum; however this is based on a conceptual model that involves a number of assumptions and uncertainties that require further study.

Improved understanding of EFN is recommended.by increasing IFRs above the upper range at the fishway. Flow experimentation using adaptive management could allow Tla'amin Nation to examine effects on fisheries productivity under a broader range of IFRs (i.e., up to 0.5 m^3/s); however, results showed that prescribed IFRs could not be increased without increasing storage. Increased storage (and hence WSE) of the lake also needs to consider environmental and socioeconomic issues resulting from further inundation of the lake.

Under the scenarios examined, the dam as built sustained licensed withdrawal within the range of prescribed IFRs. Results suggested a design could include additional measures for more precise adjustments of the IFRs. Options for acquiring any additional storage and future water use could either consider optimal timing (i.e., winter withdrawals) to draw upon surplus flows or whether to raise the dam above the current height.

Replacement of the dam is necessary, not only because of its hazardous state, but also given current and future water withdrawals along with changing environmental conditions, such as drought frequency and reduced surface runoff.

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Appendix A: Hydrology Report

Hydrometric Program for Kwahtum Teeshohsum

REV 0.4

(Apr 7, 2017)

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ACRONYMS AND ABBREVIATIONS

CMS	DA Drainage Area
DEM	Digital Elevation Model
FDC	Flow Duration Curve
GIS	Geographical Information System
IQ	Instream Q (Flow)
MSC	Meteorological Services of Canada
MAD	Mean Annual Discharge
MAR	Mean Annual Runoff
WSC	Water Survey of Canada

1 INTRODUCTION

A hydropower project is proposed on Kwahtum Teeshohsum, located ~10km north of Power River on the west coast of British Columbia. Kwahtum Teeshohsum flows directly into Georgia Strait. In order to estimate the power available on a long-term basis, as well as the environmental impact of diverting water, a stream gauge was installed just downstream of the lake on Mar 12, 2015 by Kawa Engineering Ltd. Aquarius R&D Inc. (ARD) has been asked to review and assess the existing hydrometric and hydrological information that is being used as the basis for the design and economic feasibility analysis of the project, and to generate a synthetic dataset based on regional expectations.

This report describes the primary gauge site, methods, rating curve development, and uncertainty analysis associated with the resulting rating curves. Whenever possible, Resource Inventory Standards Committee (RISC, 2009) standards have been observed in order to reduce the uncertainty associated with the streamflow estimates. The LWBC Hydrological Guidelines (LWBC, 2005) have also been followed in the preparation of this report. No analysis of sediment transport is performed or presented in this report.

2 SITE DESCRIPTION

A gauge was installed on Kwahtum Teeshohsum by WSC in 1949 and deactivated in 1951. The gauge name was Sliammon Creek Near Powell River (08GB005). Unfortunately, there are no other relevant and concurrent long-term WSC records with which to derive a long-term synthetic series. Key catchment parameters of this gauge site are included in Table 1. The location of this gauge, and other regional gauges, is shown in MAP202. The Kwahtum Teeshohsum gauge sites are shown in MAP100.

Tla'amin First Nation engaged FSCI Biological Consultants to conduct a water volume study in 2004. The results are summarized in "Sliammon Traditional Territory Water Volume Study A Summary" (Bates and Paul 2005). The derived daily flow series is available from this study, however the manual discharge measurements do not have an associated date and time. This data is therefore considered anecdotally.

In 2015, Sliammon Development Corp. engaged Kawa Engineering Ltd. (now BBA Engineering Ltd.) to instantiate a new hydrometric program. A hydrometric monitoring station was installed at Kwahtum Teeshohsum on Mar 12, 2015. A satellite image of the gauge location is shown in Figure 1. Site photos and site descriptions are included in the appendix. A preliminary assessment of this hydrometric record was conducted in 2016 by ARD and documented in a letter report "Re: Preliminary Hydrological Analysis of the Kwahtum Teeshohsum Project" (Sentlinger 2016). In that report, a total hydrometric uncertainty of ±26% was estimated (95% confidence interval) and using ARDRC001. Since that report, the Soleo Calibration points have been collected, shown in Figure 2. From this figure, we can see how ARDRC001 was feasible, and how the additional points have resulted in ARDRC001.1. This figure underscores the value of a wide range (5%-200%MAD) of calibration points.

3 DEVELOPMENT OF RATING CURVE

To date, there have been 26 valid stage-discharge measurements taken at the Kwahtum Teeshohsum 125 mASL gauge site over 18 unique days. These include 5 current metering measurements. Measurements span a range of 1% to 411% of the estimated MAD for this site. Stage values associated with each measurement are the average of recorded values during the measurement, typically 2 or 3 values from the 15 minute log intervals. Measurement times and associated stage at the Kwahtum Teeshohsum 125mASL gauge are documented in Table 1, with discharge measurements summarized in Table 3.

3.1 Measurement Methods

3.1.1 Velocity-Area

Discharge measurements at all gauge sites were taken using the mid-section velocity area method (primarily with a calibrated Swoffer Flo-Mate 2100) and Salt Dilution method with a QiQuac conductivity instrument. The QiQuac is a novel conductivity instrument designed and built by Fathom Scientific Ltd, a B.C. company specializing in innovative techniques for flow measurements.

In the mid-section method the velocity at 60% depth is used as the average cell velocity. Where the bed substrate is large relative to the depth of water, this assumption is not valid, and significant error can be introduced into the measurement. For this reason, a nominal 15% error is associated with most measurements. The average velocity of each cell is multiplied by the cell width and depth and summed to give the discharge.

3.1.2 Salt Dilution

Given the steep gradient and turbulent nature of the gauge site reach, the salt-dilution method was also used. The salt-dilution measurements were taken following the mass conservation method outlined in Hudson (2005). A known mass (pre-weighed) of dry salt (NaCl) was injected upstream of the conductivity probe at a distance of approximately 10-20 times the width of the stream; the actual distance was determined by channel characteristics, site limitations and previous results at the site. Conductivity probe readings were recorded with the QiQuac data logging instrument at 5 second intervals. A calibration was performed after each measurement using measured volumes of stream water and a salt-solution standard. The CF.T (temperature compensated concentration factor) was corrected for the solute in the standard.

3.1.3 Gauge Level Checks

Gauge level checks were performed on the transducer depth by measuring down from a nearby rockbolt Dipping Point (DP) on the Left Bank (LB) and surveys. The surveyed elevation of the DP is 1.19m based on a local datum with the PT at zero. This gauge level check captured any drift or discrepancy in the digital stage measurements and is shown in Table 4.

BM to WL measurements from Nov 18, 2016 to Jan 12, 2017 were taken from the wrong BM on the Right Bank (RB) and at an angle. These have been roughly corrected using trigonometry and measured deltas between the correct LB DP and the water level below the RB BM. Unfortunately, the Solinst Levellogger had also filled its memory around Oct 30, 2016. While the discharge measurements appear to be of good quality, there is significant uncertainty, estimated at 7cm, associated with the corresponding stage measurements.

The highest flow measurement of 6.0m^3/s occurred on Jan 20, 2017 when the author was on site with survey gear. The water level was surveyed to be 1.58m between 11:10 and 11:30am PST. This nicely captures the upper end of the rating curve and served as an anchor point with which to base other decisions. Unfortunately the DP was beneath turbid water on this date and no DP-WL measurement was made.

DP-WL measurements on Jan 22 and Jan 24 (field notes state Jan 21 and Jan 23 but photos and emails suggest Jan 22 and Jan 24) were recorded as 12cm and 21 cm respectively. We could not make these measurements agree with the established DP-WL delta of 19cm. However, on Feb 3, 2017 a delta of 25cm was measured. While we cannot explain the ~5cm change, using -12cm for Jan 22 also results in delta of 25cm. Using 2.1cm on Jan 24 results in a delta of 25cm. So while there is no concrete evidence to make these changes, it provides a consistent DP-BM delta post Jan 20, 2017. Based on this, a shift of -0.05m is applied to the stage record from Jan 20, 2017 to present. This also allows agreement with post-Jan 20, 2017 flow measurements and ARDRC001.1. So while these changes and assumptions should be re-assessed in the future, they currently represent our best attempt to make sense of the field data.

3.2 Rating Curve Fit: Theory

The developed rating curve for the Kwahtum Teeshohsum Gauge site is shown in Figure 2, along with the relevant rating curve equations. The y-axis represents the recorded stage level at the creek gauges and the x-axis the discharge. The rating curve equation is taken from Handbook of Hydrology (Maidment, 1992) and represents the hydraulic reaction of a smoothly varying channel with increasing stage.

$$Q = C(h-a)^N \tag{1}$$

The exponent represents the shape of the channel, the constant factor roughly represents the width of the channel, and the constant subtracted from h is the zero flow stage value. Maidment gives rule-of-thumb values of N as the following:

- Rectangular N =1.67
- Parabolic N=2.17
- Triangular N=2.67

Conventionally, a rating curve is drawn through the calibration points based on judgment, considering the validity of each calibration point, or using a least squares fit. The Maximum Likelihood solution for a hydraulic rating curve fits a hydraulically valid line based on an uncertainty weighted minimizing technique, also referred to as maximum likelihood. Taking the natural logarithm of each side of equation 1:

$$\begin{aligned} \ln Q &= \ln C + N\ln(h+a) \\ \mu &= b + Nx \end{aligned} \tag{2}$$

Which describes a line on a log-log plot where ln C is the offset *(b)*, ln Q is the function μ, and N is the slope of the line as a function of ln(h+a), here represented by x. It is then possible to find a simple least squares fit for N and b, provided with an estimate of a, using the Sum of the Squared Error (SSE):

$$\begin{aligned} SSE &= \sum_i^m (q_i - \mu_i)^2 \\ SSE &= \sum_i^m (q_i - (b + Nx_i))^2 \end{aligned} \tag{3}$$

Where q_i is the natural logarithm of the i^{th} observed discharge measurement. The least squares estimator of the model parameters (N, C, and a) does not take into account the uncertainty of each point however, and a more useful quantity to minimize is the log of the likelihood function:

$$\ln\left[L(\vec{w}|\vec{q})\right] = \sum_i^m \left(\frac{q_i - \vec{\mu}_i}{\sigma_i}\right)^2 \tag{4}$$

where σ_i is the uncertainty associated with each data point. This gives more weight to calibration points that the hydrologist has more confidence in: a small value of σ_i results in a large contribution to the final sum, which the fitting routine seeks to minimize. This sum is also known as the Mahalanobis distance, as opposed to the more common Euclidean distance measured in the SSE sum. If σ is constant for all data points, it can similarly be removed from the sum to give the sum of squared error (SSE), which can be minimized as a least squares fit. The Mahalanobis distance is a more useful measure for our purposes as it considers the quality of each data point, and measures an error weighted distance between the model and the observed data points. The Mahalanobis distance is unitless; it is measured in number of standard deviations from the model. For the maximum likelihood, hydraulically based rating curve, we seek to minimize the Mahalanobis distance, for a given value of *a,* in order to determine the maximum likelihood solution to N and C.

3.3 Rating Curve Fit: Kwahtum Teeshohsum 125mASL Gauge

The Kwahtum Teeshohsum 125mASL Gauge rating curve is shown in Figure 2. The hydraulic control for the gauge is composed of bedrock outcropping and loose cobble and boulders in the bottom of a notch, as shown in Photo 1 and in the Appendix.

The best fit to the calibration points was a 2 regime compound rating curve, with 1 transition at 0.86m. This was previously described by ARDRC001. However, the measurements on Nov 22, 2016 and Jan 20, 2017 have provided sufficient evidence that a rating curve drawn much further to the left is warranted. The new rating curve is named ARDRC001.1 and applied to all stage data at this site. It's compared to ARDRC001 in Figure 2. It results in much lower peak flows than originally estimated using ARDRC001.

Below 0.86m, the C value is 2.9. This is within a factor of 2 of the estimated channel width at the control of 5m. The n values for ARDRC001.1 is 2.10, which is associated with a parabolic control.

Above 0.86m, the C value is 7.61. This is within a factor of 2 of the estimated channel width at the control of 5m. The n values for ARDRC001.1 is 1.93, which is associated with a rectangular-parabolic control.

The average error between the 26 valid calibration points and the rating curves is 6.8%. This is better than the 7% error suggested in the RISC Grade A standard, and is considered to be very good for a coastal mountain stream.

The instantaneous discharge together with the daily average discharge is shown in Figure 3. **The average flow over the period of record is 1.34 m^3/ or 31 l/s/km^2 using a 43.6 km^2 drainage area.**

3.4 Quantitative Estimates of Uncertainty

Given the difficulty of flow measurement and gauging of steep mountain streams, there are several potential sources of uncertainty. For Velocity-Area (VA) and Salt Dilution (SD) metering, these include:

- uncertainty in velocity of cells during V-A flow measurement;
- uncertainty in depth of cells during V-A flow measurement;
- non-homogeneity of flow within each cell during V-A flow measurement;
- changing discharge over course of flow measurement;
- uncertainty in mass of salt, CF.T relationship, and breakthrough curve area in a SD measurements.
- changing morphology of gauge site over time;
- natural deviation of actual discharge from theoretical stage-discharge curve; and
- lack of discharge measurements at very low and very high flows;

We begin by dividing error into two components: error in discharge measurement and error in discharge estimation from stage.

It is difficult to quantify all of the components leading to uncertainty in the actual discharge measurement, however the combined effect can be estimated by replication of measurement for a stable stage. This was undertaken with the same equipment described in this report on a similar stream reach. Two measurements were taken over a relatively stable stage using the velocity-area method. This error propagated to a total error in discharge of ±11%. This indicates that a conservative (over-) estimate of total error in the discharge measurement would be ±15%, which is generally accepted as a reasonable estimate for steep mountain streams. Each discharge measurement has been assigned an uncertainty ranging from 2-30%.

The second source of error is in the development in the rating curve. In steep mountainous streams it is not valid to assume that a line drawn exactly through all calibration points is the most accurate stage-discharge relationship. If the uncertainty in the calibration points allows a smooth line based on hydraulic principles to be drawn within the uncertainty limits, as shown in Figure 2 for the Kwahtum Teeshohsum Falls Gauge site, then we expect that the assumption of this relationship actually reduces the uncertainty associated with the calibration points' average error.

This more valid estimate of discharge error can be quantified from the range of possible rating curves that can be drawn through the error bars of the calibration points. Uncertainty in the stage measurement, ~1 cm due to wave action and measurement error, is generally insignificant compared to the uncertainty in the streambed consistency, and reliance on a smooth discharge-stage relation. Keeping in mind that there is ~15% error in the discharge measurements, and assuming the stage-discharge relationship is smooth, we can estimate the error in estimated discharge by comparing the uncertainty in possible rating curves, as shown in Figure 4. These curves define a 95% confidence envelope around the measured data points. The resulting hydrograph with uncertainty is shown in Figure 5 for the Kwahtum Teeshohsum 125mASL Gauge site. The hydrographs from these bounding curves are used in estimates of uncertainty in the final estimate of MAD at each site and energy production numbers. The three rating curves are developed in order to estimate the hydrometric uncertainty. The 2-sigma coefficient of variation between the MADs from the gauge daily average flows is ±17%. This is considered good.

This implies that **the 2-sigma error (95% confidence interval) is 17% in the estimation of discharge at the Kwahtum Teeshohsum Gauge site.**

4 CONCLUSIONS AND RECOMMENDATIONS

The hydrometric program for Kwahtum Teeshohsum is considered successful so far and the quality of data is good. The average estimated discharge for the gauge over the period of record is 1.34 m^3/s, which equates to a unit runoff of 31 $l/s/km^2$ for a drainage area of 43.6 km^2. The 2-sigma (95% confidence) uncertainty in the MAD is estimated at ± 17%.

The installation of the gauge, and the hydraulic control for the site meet RISC Grade A Standards, as does the resulting rating curve.

We recommend continuing the flow monitoring program at the Kwahtum Teeshohsum 125mASL gauge site until 5 years of data is collected to reduce the uncertainty in the final hydrograph.

In general, the Kwahtum Teeshohsum hydrometric program to date is considered adequate, within the stated uncertainty, for use in determining the potential environmental impact and economic viability of the project.

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TABLES

Table 1: Kwahtum Teeshohsum nearby Hydro-Meteorological Stations

C:\Users\FATHOM\Desktop\DK\Sliammon\data\[Sliammon_RC_v0.3.xlsx]QRecord (AQU-05) printedMay 31, 2017

	Hydrometric Stations	Stn ID	Years	# Complete Years	Agency	DA[F] (km^2)	%Glacier	%Lake	MAD [E,F,G] (m^3/s)	MAR [E,F,G] ($l/s/km^2$)	Precip[D] (mm/year)	Min Elev (m ASL)	Max Elev (m ASL)	Mean (m ASL)	Median (m ASL)
WSC HYDRO	HORSESHOE RIVER ABOVE LOIS LAKE	08GB014	2007 - 2016	5	WSC	133.2	0.0%	11.6%	6.4	48	*1521*	163	1654	453	414
	THEODOSIA RIVER ABOVE SCOTTY CREEK	08GC008	2003 - 2016	8	WSC	94.9	0.0%	0.2%	4.5	48	*1499*	38	1818	826	858
	LANG CREEK NEAR POWELL RIVER	08GB007	1959-1995	36	WSC	127.5	0.0%	10.5%	4.2	33	*1048*	102	975	417	322
	TSOLUM RIVER NEAR COURTENAY	08HB011	1912-2016	54	WSC	264	0.0%	0.8%	10.5	40	*1260*	15	1410	330	224
	OYSTER RIVER BELOW WOODHUS CREEK	08HD011	1973-2010	37	WSC	297	0.0%	1.5%	14.0	47	*1483*	100	1844	921	950
	ROBERTS CREEK AT ROBERTS CREEK	08GA047	1959-2016	57	WSC	32.6	0.0%	0.0%	1.06	33	*1026*	75	1079	591	621
	SLIAMMON CREEK NEAR POWELL RIVER	08GB005	1949-1951	3	WSC	57.4	0.0%	4.5%	1.7	30	*940*	9	1115	515	501
KAWA	KWAHTUM TEESHOHSUM GAUGE AT 125M		2015-2016	1	KAWA	43.6	0.0%	5.9%	1.36	31	*984*	125	1115	592	612
	KWAHTUM TEESHOHSUM LAKE/INTAKE					43.6	0.0%	5.9%	1.36	31	*985*	130	1115	593	613
	KWAHTUM TEESHOHSUM PH					55.1	0.0%	4.7%	1.72	31	*985*	35	1115	515	501
	Climate Stations					--	--	--				**Min T ^oC**	**Max T ^oC**	**Avg T ^oC**	--
MSC	POWELL RIVER	1046390	1924-2004	59	MSC					32	1004	7.1	13.9	10.6	
	POWELL RIVER A	1046391	1954-2004	34	MSC					39	1233	5.2	13.3	9.3	
	COMOX A	1021830	1960-2004	57	MSC					37	1179	5.8	13.6	9.7	

NOTES:

[D] Precip at Hydrometric stations is based on Runoff less a glacier contribution of 90 l/s/km^2 and orographic enhancement assumed to be equal to evapotranspiration

[E] Runoff at Climate stations is simply the algabraic conversion of Precip. values to Runoff.

[F] Where available, DA values and Runoff values are taken from Obedkoff, 2003.

[G] LT MAR is the estimated Long-Term Mean Annual unit-Runoff derived in this Report.

Ver 0.2.1

Table 2: Chronological Record of Kwahtum Teeshohsum 125mASL Gauge Site Measurements (AQU-06)

E:\users\gsentlin\AQUARIUS_R&D\BBA\Projects\Sliammon\Data\[Sliammon_RC_v0.3.xlsx]StageRecord (AQU-06)   Print Mar/28/17 5:57:07

				Start			End							
Date	Measurement Time Zone	Logger Time Zone	Logger Offset (hrs)	Measurement Time	Logger Time	Logger Depth (m)	Watch Time	Logger Time	Logger Depth (m)	Avg. Depth (m)	Party	Rising, Falling, or Stable	Depth Error	Notes
12-Mar-15	PST	PST	0.0	14:21	3/12/15 14:20	0.84	14:45	3/12/15 14:45	0.84	0.84	DK/MS	R	0.01	
30-Apr-15	PST	PST	0.0	13:27	4/30/15 13:25	0.93	14:00	4/30/15 14:00	0.93	0.93	DK/MS	F	0.01	
30-Apr-15	PST	PST	0.0	13:06	4/30/15 13:05	0.92	13:20	4/30/15 13:20	0.93	0.92	DK/MS	R	0.01	
8-Jul-15	PST	PST	0.0	10:05	7/8/15 10:05	0.65	10:26	7/8/15 10:25	0.65	0.65	MS	F	0.01	
8-Jul-15	PST	PST	0.0	10:35	7/8/15 10:35	0.65	10:52	7/8/15 10:50	0.65	0.65	MS	R	0.01	
9-Sep-15	PST	PST	0.0	12:25	9/9/15 12:15	0.70	13:00	9/9/15 13:00	0.71	0.70	MS	R	0.01	
16-Nov-15	PST	PST	0.0	12:13	11/16/15 12:00	1.13	12:45	11/16/15 12:45	1.14	1.14	MS	R	0.01	
16-Nov-15	PST	PST	0.0	13:30	11/16/15 13:30	1.14	13:45	11/16/15 13:45	1.12	1.13	CW	F	0.01	
24-Feb-16	PST	PST	0.0	12:30	2/24/16 12:30	1.08	13:00	2/24/16 13:00	1.08	1.08	CW	F	0.01	
26-Feb-16	PST	PST	0.0	9:00	2/26/16 9:00	1.03	9:30	2/26/16 9:30	1.03	1.03	CW	F	0.01	
14-Apr-16	PST	PST	0.0	10:30	4/14/16 10:30	0.98	11:00	4/14/16 11:00	0.98	0.98	CW	F	0.01	
27-May-16	PST	PST	0.0	12:58	5/27/16 12:45	0.71	13:30	5/27/16 13:30	0.71	0.71	CW	R	0.01	
18-Nov-16	PST	PST	0.0	8:11			8:11			1.51			0.07	Levellogger Memory Full
22-Nov-16	PST	PST	0.0	14:03			14:03			1.63			0.07	Levellogger Memory Full
22-Nov-16	PST	PST	0.0	14:16			14:16			1.63			0.07	Levellogger Memory Full
19-Dec-16	PST	PST	0.0	10:54			10:54			0.97			0.07	Levellogger Memory Full
20-Dec-16	PST	PST	0.0	11:14			11:05			0.96			0.07	Levellogger Memory Full
21-Dec-16	PST	PST	0.0	11:46			10:54			0.94			0.07	Levellogger Memory Full
20-Jan-17	PST	PST	0.0	10:20	1/20/17 10:08	1.61	10:38	1/20/17 10:23	1.61	1.61	CW	F	0.01	
20-Jan-17	PST	PST	0.0	10:37	1/20/17 10:23	1.61	11:22	1/20/17 11:08	1.59	1.60	CW	F	0.02	
20-Jan-17	PST	PST	0.0	14:49	1/20/17 14:40	1.58	15:11	1/20/17 15:10	1.58	1.58	CW	F	0.01	
20-Jan-17	PST	PST	0.0	10:19	1/20/17 10:08	1.61	10:36	1/20/17 10:23	1.61	1.61	CW	F	0.01	
20-Jan-17	PST	PST	0.0	10:35	1/20/17 10:23	1.61	11:07	1/20/17 10:53	1.60	1.60	CW	F	0.02	
20-Jan-17	PST	PST	0.0	14:49	1/20/17 14:40	1.58	15:11	1/20/17 15:10	1.58	1.58	CW	F	0.01	
22-Jan-17	PST	PST	0.0	11:24	1/22/17 11:10	1.31	11:40	1/22/17 11:40	1.31	1.31	CW	F	0.01	
22-Jan-17	PST	PST	0.0	11:24	1/22/17 11:10	1.31	11:41	1/22/17 11:40	1.31	1.31	CW	F	0.01	
24-Jan-17	PST	PST	0.0	15:45	1/24/17 15:40	1.18	16:04	1/24/17 15:55	1.18	1.18	CW	F	0.01	
24-Jan-17	PST	PST	0.0	16:07	1/24/17 15:55	1.18	16:26	1/24/17 16:25	1.18	1.18	CW	F	0.01	
24-Jan-17	PST	PST	0.0	15:45	1/24/17 15:40	1.18	16:08	1/24/17 15:55	1.18	1.18	CW	F	0.01	
24-Jan-17	PST	PST	0.0	16:07	1/24/17 15:55	1.18	16:26	1/24/17 16:25	1.18	1.18	CW	F	0.01	

Table 3: Summary of Kwahtum Teeshohsum 125mASL Gauge Discharge Measurements (AQU-05)

E:\users\gsentlin\AQUARIUS_R&D\BBA\Projects\Sliammon\Data\[Sliammon_RC_v0.3.xlsx]QRecord (AQU-05) Print Mar/26/17 19:22

								From Rating Curve			
Date	Metered by	Meter Type	%MAD	Discharge (m^3/s)	Mean Depth (m)	Notes	Measurement Uncertainty (%)	RC Q (m^3/s)	RC Err (m^3/s)	RC %Err	RC Abs %Err
12-Mar-15	KAWA	CM	13%	0.19	0.84		20%	0.18	0.01	3%	3.1%
30-Apr-15	KAWA	CM	27%	0.40	0.93		20%	0.44	-0.04	-8%	8.5%
30-Apr-15	KAWA	SD	35%	0.52	0.92		5%	0.43	0.09	21%	20.9%
8-Jul-15	KAWA	SD	1%	0.015	0.65		11%	0.02	0.00	-4%	4.3%
8-Jul-15	KAWA	SD	1%	0.015	0.65		5%	0.01	0.00	1%	1.0%
9-Sep-15	KAWA					no measurement	15%	#NUM!	#NUM!		
16-Nov-15	KAWA	SD	117%	1.75	1.14		12%	1.53	0.22	14%	14.1%
16-Nov-15	KAWA	SD	104%	1.56	1.13		15%	1.49	0.07	5%	4.6%
24-Feb-16	KAWA	CM	107%	1.60	1.08	Anom	15%	1.20			
26-Feb-16	KAWA	CM	60%	0.90	1.03		15%	0.91	-0.01	-1%	0.9%
14-Apr-16	KAWA	CM	44%	0.66	0.98		15%	0.65	0.01	2%	2.1%
27-May-16	KAWA	SD	3%	0.048	0.71		15%	0.05	0.00	-3%	3.2%
18-Nov-16	SOLEO	SD	188%	2.8	1.51	Anom	15%	5.13			
22-Nov-16	SOLEO	SD	393%	5.9	1.63	Rising Limb?	15%	6.59	-0.69	-10%	10.5%
22-Nov-16	SOLEO	SD	387%	5.8	1.63	from BM-WL	15%	6.59	-0.79	-12%	12.0%
19-Dec-16	SOLEO	SD	36%	0.5	0.97	from BM-WL	15%	0.61	-0.07	-11%	11.5%
20-Dec-16	SOLEO	SD	33%	0.5	0.96	from BM-WL	15%	0.57	-0.08	-14%	14.4%
21-Dec-16	SOLEO	SD	29%	0.4	0.94	from BM-WL	15%	0.47	-0.04	-8%	7.8%
20-Jan-17	GS	SD	403%	6.0	1.61		9%	6.39	-0.35	-5%	5.5%
20-Jan-17	GS	SD	400%	6.0	1.60		15%	6.23	-0.24	-4%	3.8%
20-Jan-17	GS	SD	404%	6.1	1.58		11%	5.95	0.11	2%	1.8%
20-Jan-17	GS	SD	408%	6.1	1.61		10%	6.39	-0.27	-4%	4.2%
20-Jan-17	GS	SD	411%	6.2	1.60		17%	6.28	-0.11	-2%	1.8%
20-Jan-17	GS	SD	301%	4.5	1.58	Anom	37%	5.95			
22-Jan-17	SOLEO	SD	200%	3.0	1.31		4%	2.97	0.02	1%	0.7%
22-Jan-17	SOLEO	SD	203%	3.0	1.31		5%	2.97	0.07	2%	2.4%
24-Jan-17	SOLEO	SD	108%	1.6	1.18		12%	1.87	-0.25	-13%	13.4%
24-Jan-17	SOLEO	SD	115%	1.7	1.18		7%	1.85	-0.13	-7%	6.9%
24-Jan-17	SOLEO	SD	114%	1.7	1.18		4%	1.87	-0.16	-9%	8.7%
24-Jan-17	SOLEO	SD	112%	1.7	1.18		3%	1.85	-0.17	-9%	9.1%

Table 4: Summary of Kwahtum Teeshohsum 125mASL Gauge Level Checks (AQU-04)

E:\users\gsentlin\AQUARIUS_R&D\BBA\Projects\Sliammon\Data\[Sliammon_RC_v0.3.xlsx]GaugeLevelChecks(AQU-04) Print Mar/28/17 5:39:01

Solinst Levelogger												
Date	Watch Time Zone	Watch Time	Logger Time	Time Offset (mins)	Stage (m)	DP to WL (m)	DP Corr (m)	DP to PT (m)	Gauge Corr. (m)	Stage after Corr. (m)	Corrected DP-PT (m)	Notes
12-Mar-15	PST	14:10	14:00	-10	0.84	0.35		1.19		0.84	1.19	
30-Apr-15	PST	13:27	13:30	3	0.93	0.26		1.19		0.93	1.19	
08-Jul-15	PST	10:05	10:00	-5	0.66	0.54		1.20		0.66	1.20	
09-Sep-15	PST	12:25	12:30	5						0.00		
16-Nov-15	PST	13:26	13:30	4	1.15	0.03		1.18		1.15	1.18	
24-Feb-16	PST	12:30	12:30	0						0.00		
26-Feb-16	PST	12:00	12:00	0	1.03	0.16		1.19		1.03	1.19	was 1.09 before download?
14-Apr-16	PST	10:30	10:30	0	0.98	0.21		1.19		0.98	1.19	
27-May-16	PST	12:58	13:00	2	0.71	0.49		1.20		0.71	1.20	
18-Nov-16	PST	8:00	8:00	0	1.51	-0.32	-0.74	1.19		1.51	1.19	No PT Record, Stage from BM-WL considering angle and wrong BM
22-Nov-16	PST	13:30	13:30	0	1.63	-0.44	-0.74	1.19		1.63	1.19	No PT Record, Stage from BM-WL considering angle and wrong BM
19-Dec-16	PST	10:54			0.97	0.22	-0.74	1.19		0.97	1.19	No PT Record, Stage from BM-WL considering angle and wrong BM
20-Dec-16	PST	11:14			0.96	0.23	-0.74	1.19		0.96	1.19	No PT Record, Stage from BM-WL considering angle and wrong BM
21-Dec-16	PST	11:46			0.94	0.25	-0.74	1.19		0.94	1.19	No PT Record, Stage from BM-WL considering angle and wrong BM
06-Jan-17	PST	11:46			0.94	0.25	-0.74	1.19		0.94	1.19	No PT Record, Stage from BM-WL considering angle and wrong BM
11-Jan-17	PST	11:46			0.96	0.23	-0.74	1.19		0.96	1.19	No PT Record, Stage from BM-WL considering angle and wrong BM
12-Jan-17	PST	11:46			0.95	0.24	-0.74	1.19		0.95	1.19	No PT Record, Stage from BM-WL considering angle and wrong BM
20-Jan-17	PST	14:49	14:30	-19	1.58	-0.37	-0.74	1.21		1.58	1.21	
22-Jan-17	PST	11:24	11:30	6	1.37	-0.12		1.25	-0.05	1.32	1.20	
24-Jan-17	PST	16:07	16:00	-8	1.23	0.02		1.25	-0.05	1.18	1.20	
03-Feb-17	PST	16:07	16:00	-8	1.05	0.20		1.25	-0.05	1.00	1.20	
										Average (m)	1.19	
										StdDev (m)	0.006	

FIGURES

Notes:
1) This satellite image is from Google Earth.
2) This image is tilted and therefore does not have a constant scale.

TLA'AMIN CAPITAL ASSETS INC.

KWAHTUM TEESHOHSUM HYDROELECTRIC PROJECT

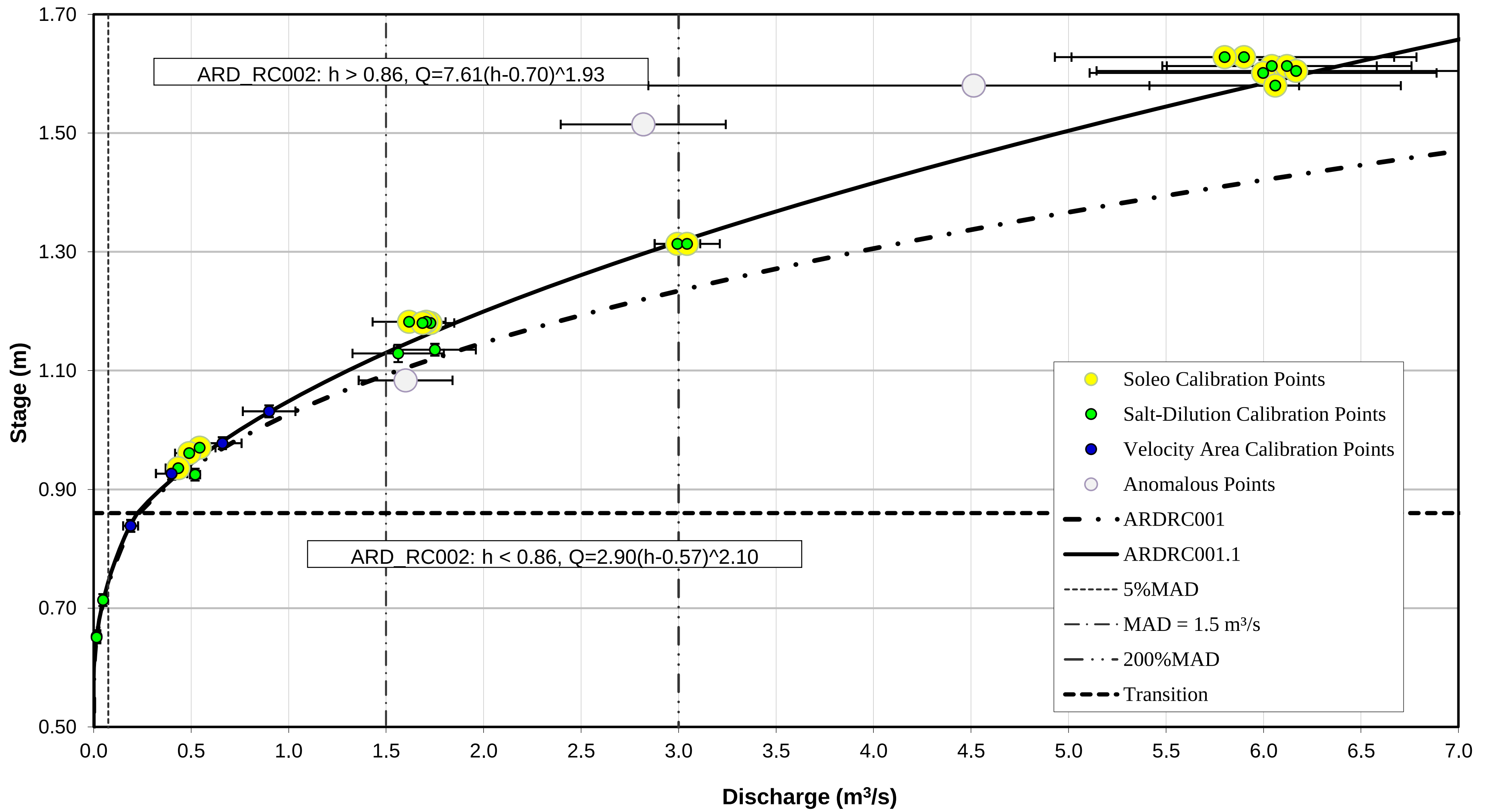
KWAHTUM TEESHOHSUM SATELLITE IMAGE

AQUARIUS Research & Development Inc.

VER 0.6	May 31, 2017	Figure 1

C:\Users\gsentlin\AQUARIUS_R&D\Barkley\Projects\Tranquil Cluster\DATA\Tranquil 2\[Tranquil_2_RatingCurve_v0.2.0.xls]

Figure 1: Kwahtum Teeshohsum Creek Satellite Image



Notes:

1) More high flows are needed at this site.
2) ARDRC001 was used to develop the preliminary synthetic flow series in 2016, without the benefit of the Soleo Calibration Points. Taking these into consideration results in a much different rating curve, ARDRC001.1, which is applied to all stage data from installation to present.

TLA'AMIN CAPITAL ASSETS INC.

KWAHTUM TEESHOHSUM HYDROELECTRIC

KWAHTUM TEESHOHSUM AT 125M GAUGE RATING CURVE

AQUARIUS Research & Development Inc.

FIGURE 2

VER 0.6 | May 31, 2017

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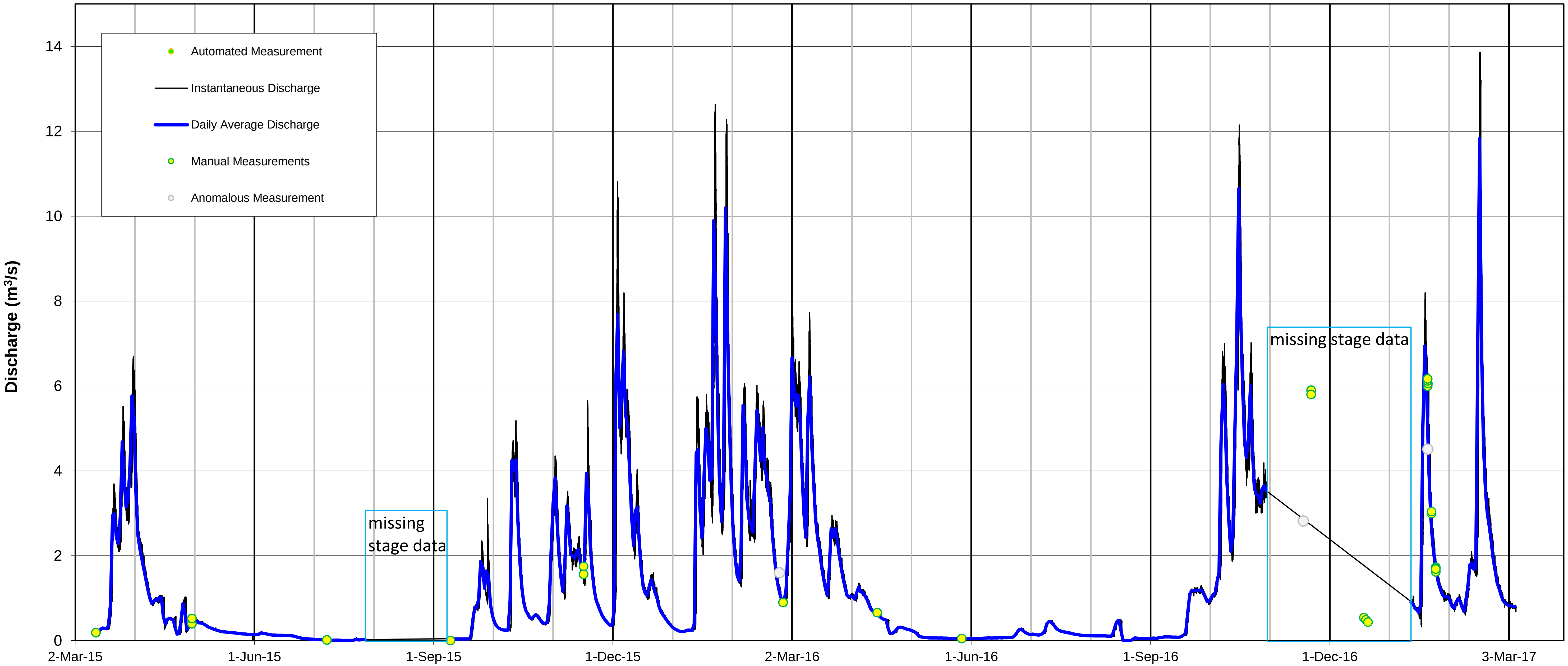
Figure 2: Kwahtum Teeshohsum at 125M Gauge Rating Curve



Notes:
1) Data missing from Jul 28, 2015 to Sep 9, 2016. and from Oct 30, 2016 to Jan 10, 2017.
2) Small abrupt changes in water level are due to short term regulation of the upstream lake, but should not affect monthly flows. significantly.

TLA'AMIN CAPITAL ASSETS INC.

KWAHTUM TEESHOHSUM HYDROELECTRIC PROJECT

KWAHTUM TEESHOHSUM AT 125M GAUGE HYDROGRAPH

AQUARIUS Research & Development Inc.

VER 0.6 | May 31, 2017

FIGURE 3

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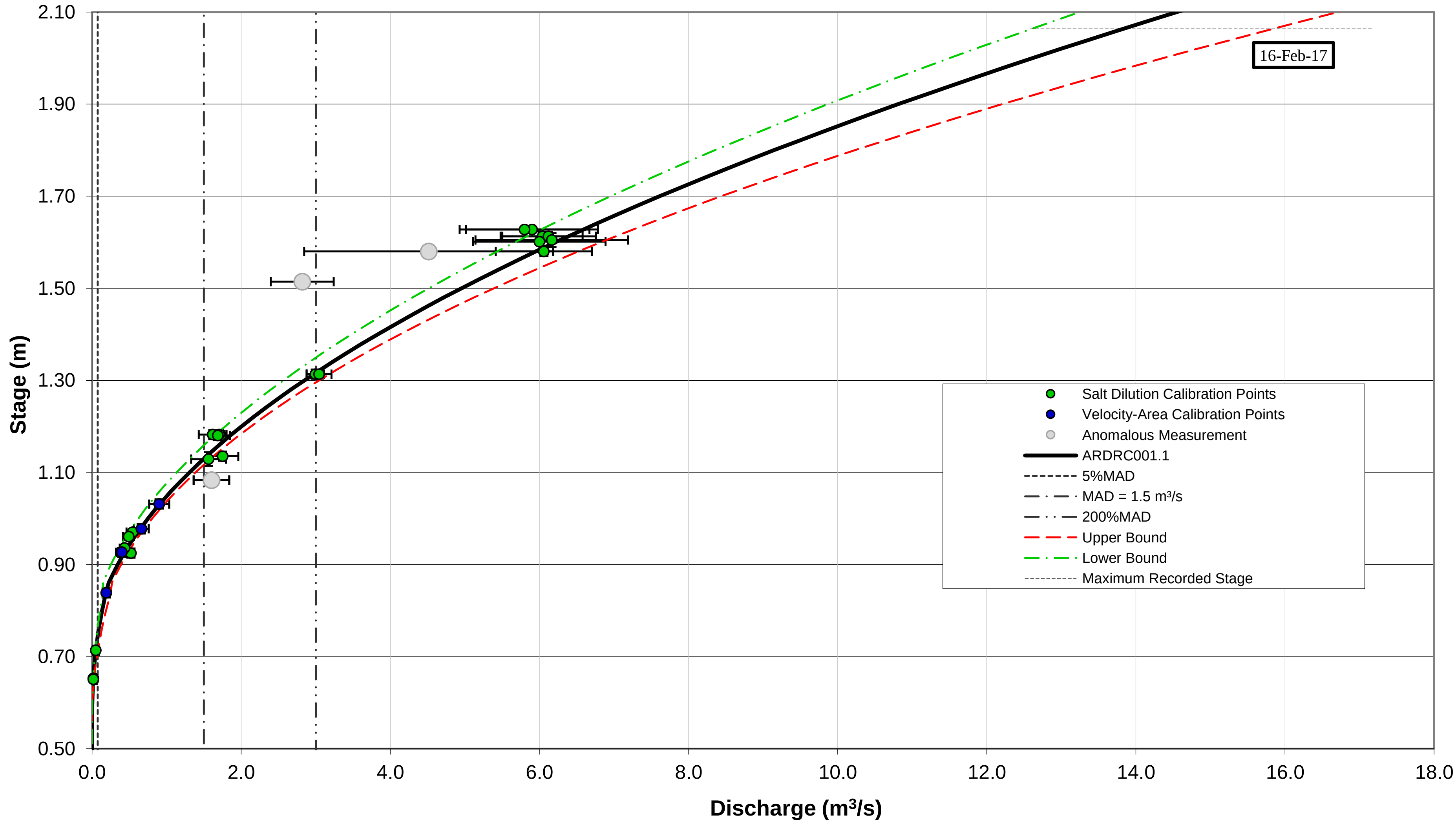
Figure 3: Kwahtum Teeshohsum 125mASL Gauge Hydrograph



Notes:
1) There is not significant uncertainty in high flows at this site due to a several high flow measurements.

TLA'AMIN CAPITAL ASSETS INC.
TLA'AMIN CREEK HYDROELECTRIC PROJECT
TLA'AMIN AT 125M GAUGE RATING CURVE: UNCERTAINTY

AQUARIUS Research & Development Inc.

FIGURE 4

VER 0.6 | Mar 26, 2017

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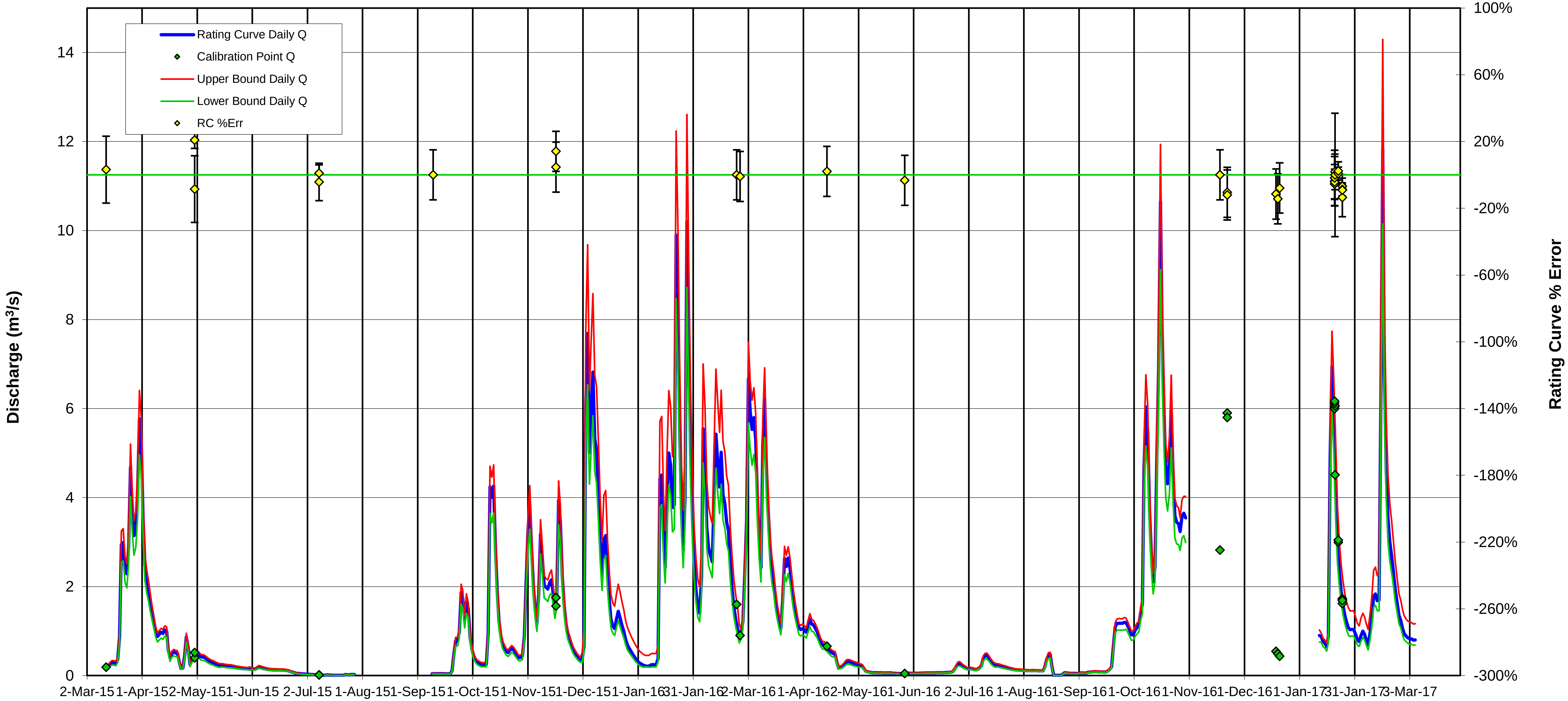
Figure 4: Kwahtum Teeshohsum Gauge Rating Curve Uncertainty



Notes:
1) The Upper Bound and Lower Bounds represent the 95% confidence uncertainty bounds on both the Rating Curve and the Stage Record.
2) The uncertainty in average Q is +/-17% over this period.

TLA'AMIN CAPITAL ASSETS INC.	
KWAHTUM TEESHOHSUM HYDROELECTRIC	
KWAHTUM TEESHOHSUM AT 125M GAUGE HYDROGRAPH: UNCERTAINTY	
AQUARIUS Research & Development Inc. — VER — Feb 17, 2014	**FIGURE 5**

C:\Users\FATHOM\Desktop\DK\Sliammon\data\[Sliammon_RC_v0.3.xlsx]

Figure 5: Kwahtum Teeshohsum at 125M Gauge Hydrograph: Uncertainty

APPENDIX A: DESCRIPTION OF HYDROMETRIC STATION

This section is intended to be the equivalent of the RISC form AQU-01

Gauge Site Location with reference to roads, bridges, towns.

Equipment Description
Solinst Levelogger and Barologger

Control Description
Boulder - bedrock.

Metering Site Description
Current metering about 1m below gauge site. Salt Dilution with salt injected at lake weir and EC probes just below footbridge.

BM Descriptions

DP	Dipping Point: Left side of river at pool outlet
WL	Water Level
CP1	Control Point 1: top-most rock bolt securing the steel pipe
CP2	Control Point 2: right bank on top of boulder next to tree (opposite and slightly upstream of the steel pipe)
Sensor	Elevation of Depth Sensor = 10.0m - 1.17m (artificial offset in logger minus logger depth reading)

Note: it's a coincidence that the DP datum and the logger offset are both 10.0m

Date:	12-Mar	**Start Time:**	14:10	**End Time:**	14:21	**Time Zone**	PST
Hydrometric Leveling Survey							
Stn	**BS**	**HI**	**FS**	**Elevation**	**Notes**		
DP	1.846	3.036		1.190	Dipping Point: Left side of river at pool outlet		
CP1				-			
CP2				-			
Bottom Stilling Well				-			
WL			2.131	0.905			
CP 1	1.307	2.911	1.432	1.604	Control Point 1: top-most rock bolt securing the steel pipe		
WL			2.068	0.843			
Bottom Stilling Well				-			
CP2			1.007	1.904	2: right bank on top of boulder next to tree (opposite and slightly upstream of t		
BM 2				-			
BM 1				-			
PT Reading (m)			0.840	0.00	of Depth Sensor = 10.0m - 1.17m (artificial offset in logger minus logger depth		
ALT			0.350		Manual DP Msmt		

Stn	**Pos 1 - Pos 2**	**Mean Elev. (m)**	**Established Elev. (m)**	**Difference (m)**	**Notes**
DP	#VALUE!	1.190	1.190	0.000	
CP1	-	1.604	1.604	0.000	established this date, mean elev.
CP2	-	1.904	1.904	0.000	established this date, mean elev.
Bottom Stilling Well	-	-	-	-	established this date, mean elev.
WL	0.062	0.874	-	-	

Date:	20-Jan	**Start Time:**	11:10	**End Time:**	11:30	**Time Zone**	PST
Hydrometric Leveling Survey							
Stn	**BS**	**HI**	**FS**	**Elevation**	**Notes**		
CP1	1.660	3.264		1.604			
CP2			1.360	1.904			
CP3			1.820	1.444			
WL Near Gauge (LB)			1.690	**1.574**			
WL Near CP2 (RB)			1.740	**1.524**			
CP3	1.730	3.174		1.444			
WL Near CP2 (RB)			1.650	**1.524**			
WL Near Gauge (LB)			1.560	**1.614**			
CP2			1.270	1.904			
CP1			1.560	1.614			
				-			
PT Reading (m)			**1.580**	-0.02			
ALT							

Stn	**Pos 1 - Pos 2**	**Mean Elev. (m)**	**Established Elev. (m)**	**Difference (m)**	**Notes**
DP	#VALUE!		1.190	1.190	Didn't survey
CP1	-0.010	1.444	1.444	0.000	
CP2	0.000	1.904	1.904	0.000	
CP3	0.000	1.594	1.594	0.000	
WL	0.000	1.594	-	-	

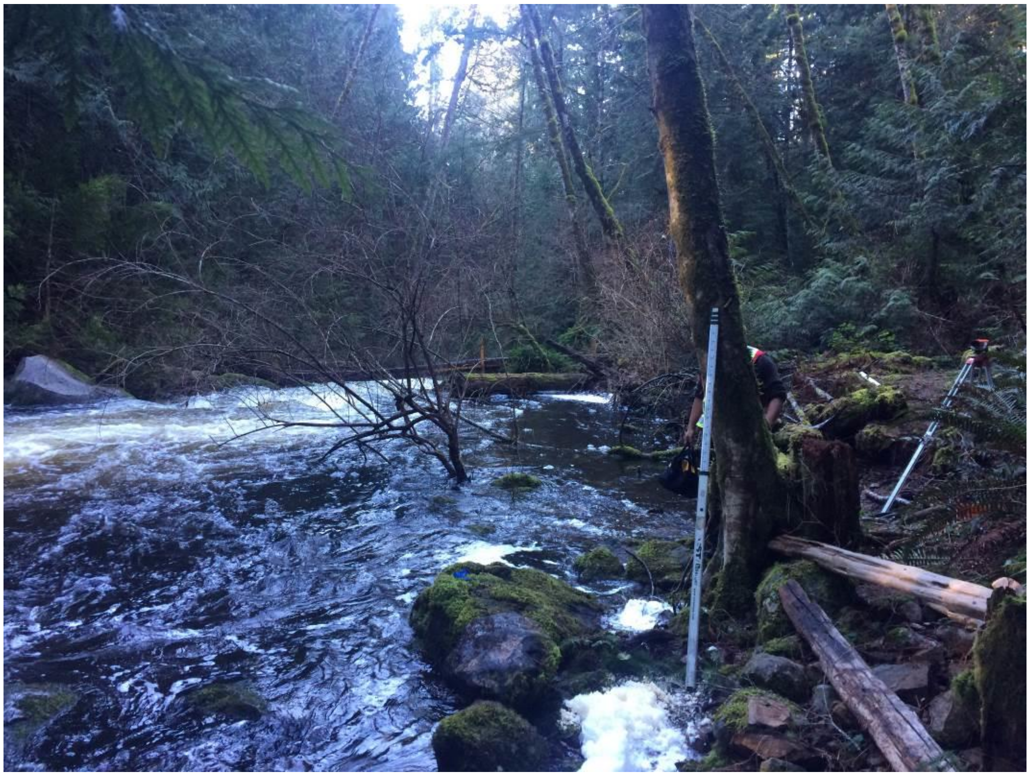


Photo 1: Kwahtum Teeshohsum 125mASL site gauge control looking downstream Jan 20, 2017 at 1110 PST. Q=6.0 m³/s, Stage = 1.58 m

Photo 2: Kwahtum Teeshohsum 125mASL site gauge control looking from RB to LB Jan 20, 2017 at 1110 PST. Q=6.0 m³/s, Stage = 1.58 m

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MEMORANDUM

Client:	Sliammon Development Corporation	Ref. No.:	16.80553-SL.03.K010
Project Name:	Sliammon Creek Hydroelectric Project	Date:	January 22, 2016
Project No.:	80553-SL	Revision:	A
Recipient:	Kelly Rankin, B.Sc., B.Com., RI	Prepared by:	Dan Kovacek, P.Eng.
		Reviewed by:	Chad Wilkinson, RPBio
Subject:	Hydrology Update Memo – January 2016		
Attachments:			

1.0 BACKGROUND

Kawa Engineering (Kawa) is currently conducting the Sliammon Creek Hpydroelectric Project's (the Project) hydrometric program on behalf of the Sliammon Development Corporation (SDC or the Proponent) for the purpose of supporting baseline studies and other technical inputs for a multi-purpose water use development on Sliammon Creek. The program was initiated on 12 March 2015 with the installation of a hydrometric station to provide long-term, continuous monitoring of water level (stage), barometric pressure, and stream temperature. This memo is intended to provide a summary of the data collected to date and presents a regionally-based, preliminary estimate of annual flow averages in Sliammon Creek that can be used for preliminary estimation of the potential for energy generation to support the Project Description for a clean energy project (CEP) Development Plan (DP).

2.0 SUMMARY OF HYDROMETRIC DATA COLLECTION

Since installation of the gauging station, Kawa staff have visited the site six times for hydrometric station equipment servicing and data collection. Activities generally include periodic assessment of the condition of the station equipment, photographing the creek bed surrounding the station for tracking creek morphology, surveying, and ongoing collection of discharge measurements. Hydrometric data collection procedures follow published industry standards in BC (RIC 1988).

2.1 Stage Record

To date, stage records have been retrieved from the station over an eight month period. At the time of writing this report, two additional months will have been recorded, though these data have not yet been retrieved.

A five-week gap in the stage record occurred due to an error in the memory storage settings on the datalogger (**Figure 1**). In the process of performing a detailed hydrological analysis, the gap may be infilled with estimated values by "training" the dataset to the most appropriate regional station.

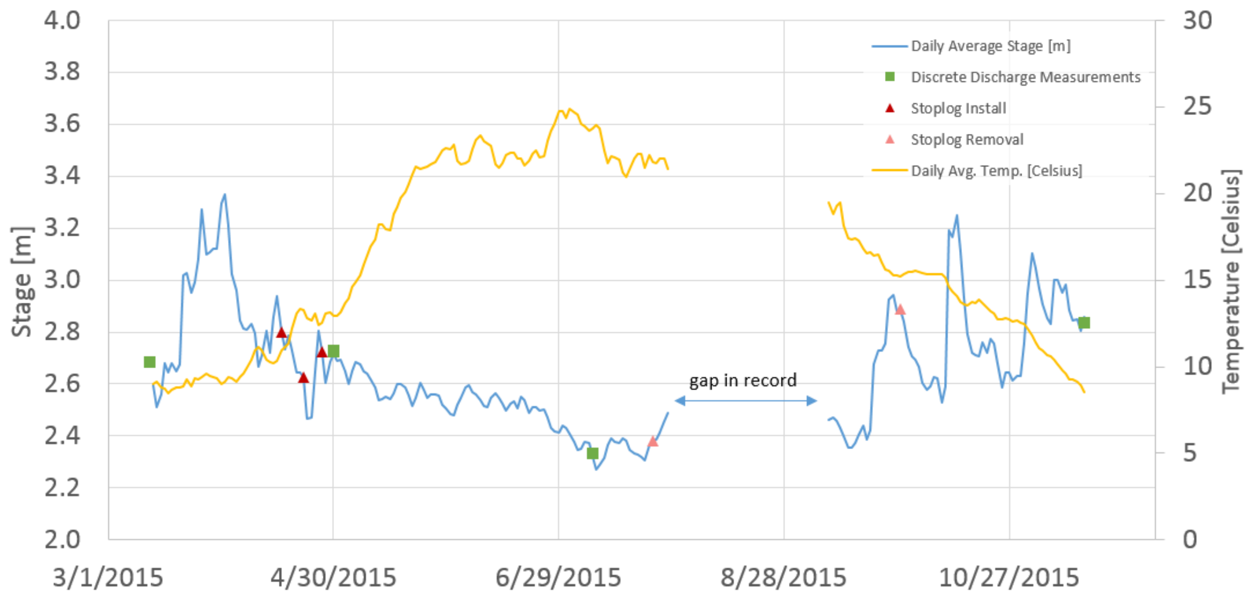

Figure 1 Daily average water level and water temperature in Sliammon Creek (12 March – 16 November 2015).

As shown in **Figure 1**, there are three visibly noticeable rapid fluctuations (i.e., draw-downs) in stage record. These anomalies correspond to the three days when stop logs were placed at the existing intake weir by Sliammon Fisheries (George pers. comm.).

2.2 Discharge measurements

To date, six independent discharge measurements have been collected at the hydrometric station. The techniques used to measure instantaneous flow include area-velocity method (i.e., using a 'swoffer' current meter) and electrical conductivity (i.e., salt-dilution mass balance) methods. A summary of discharge measurements is shown in **Table 1** below.

Table 1 Summary of discharge measurements at the Sliammon Creek Station.

Msmt. No.	Date	Method	Logger Stage [m]	Measured Discharge [cms]
1	3/12/2015	Area-Velocity	2.682	0.19
2	4/30/2015	Area-Velocity	2.726	0.38
3	4/30/2015	Salt Dilution	2.727	0.52
4	7/8/2015	Salt Dilution	2.335	0.05
5	7/8/2015	Salt Dilution	2.335	0.08
6	11/16/2015	Salt Dilution	2.835	0.98

NOTES: 1. SALT DILUTION IS MEASURED IMMEDIATELY UPSTREAM OF THE STATION POOL.
2. THE AREA-VELOCITY TRANSECT IS AT THE OUTLET OF THE STATION POOL.

A preliminary stage-discharge curve has been fitted to these six measurements. It should be noted that industry standard hydrometric practices suggest a minimum of ten independent measurements should comprise a rating curve. As such, it is not recommended to use this rating curve equation for development of other project engineering or financing at this time. Additional visits are planned for 2016 to obtain the remaining discharge measurement across a range of flows.

The plot of measured stage-discharge shown above in **Figure 2** indicates a discrepancy between datalogger readings and manual dipping point measurements that appears to have occurred between 30 April and 8 July, 2015. Further discussion of this anomaly is provided in Section 2.3 below.

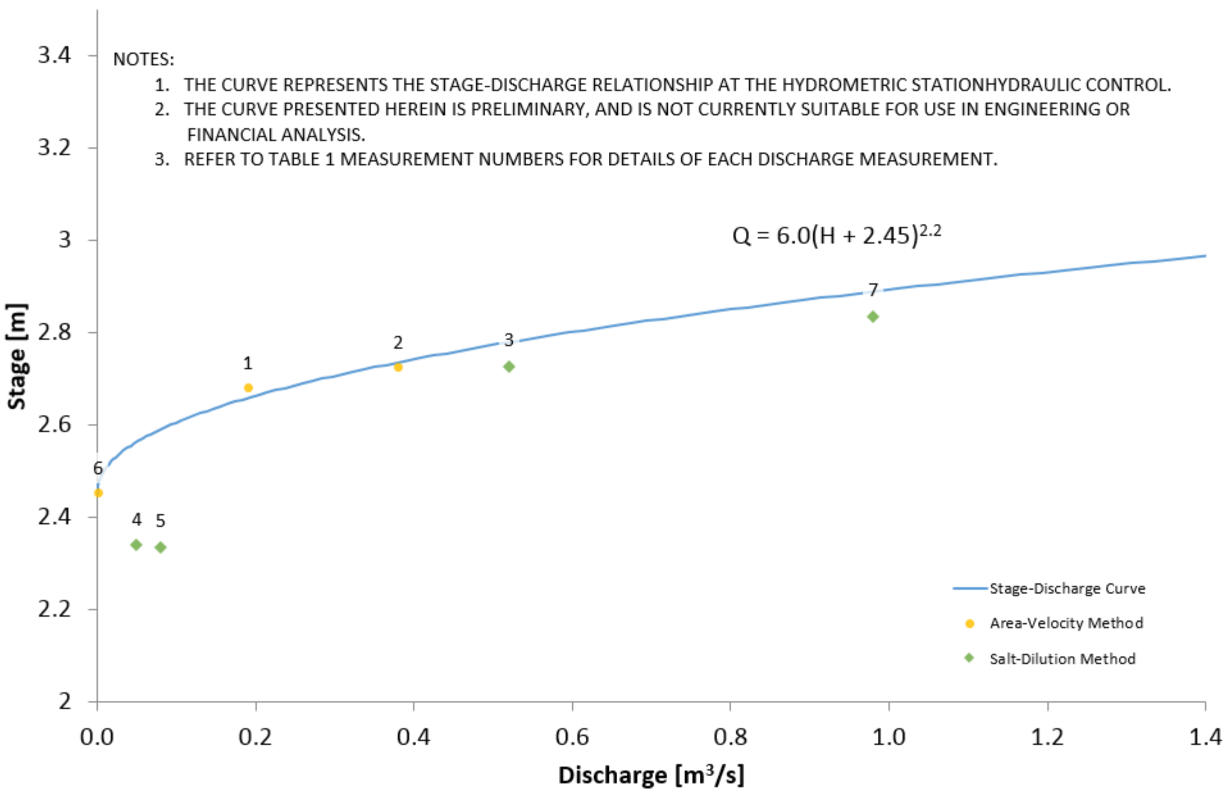

Figure 2 The preliminary stage-discharge curve for the Sliammon Creek Hydrometric Station.

2.3 Quality Review Notes

The data collected to date have undergone a preliminary quality review, including the following:

i. Review of the stage record for anomalous phenomena,
ii. Review of field notes,
iii. Review of discharge measurement files, and
iv. Review of control section photos to identify changes in the geometry of creek bed and banks.

Several anomalous shifts in the stage record were identified, almost all of which correspond to days when stop logs were added or removed from the spillway at the outlet of Sliammon Lake. The stage record in these instances will be adjusted for the shift in stage caused by the sudden flow reduction or surge. An example of a stage shift due to placement of a stoplog is shown below in **Figure 3**.

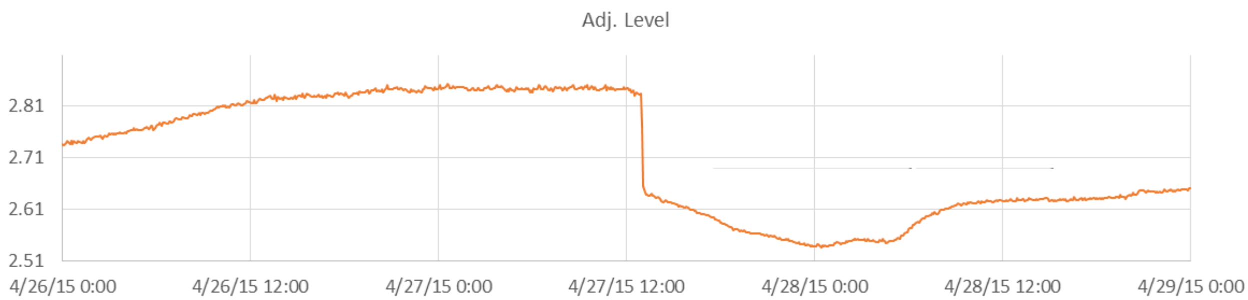

Figure 3 Example of a dramatic stage shift following placement of a stoplog layer at the outlet of Sliammon Lake.

During each site visit, a manual measurement is taken from the water surface to a permanent benchmark identified as a 3/8" bolt installed in the rock face on the stream's left bank. This is referred to as the "dipping point"). The offset measurement can be compared to the stage recorded by the datalogger and tracked over time. The offset value should remain consistent over time, with reasonable variation based on measurement error due to wave action in the gauge pool. Reviewing the record, it is apparent that a shift occurred between 30 April and 8 July 2015. Shifts of this nature could be the result of scouring of the creek bottom at the hydraulic control (gauge pool outlet) or deposition of fine materials after a high flow event; it is not immediately apparent from photographic records if either scouring or deposition is the case. Given the timing and magnitude of flows over the period in question, both scour and deposition are considered unlikely. At the time of writing this report, the full schedule of stop log removals was not available to Kawa, although stop log installation and removal information has been requested from Sliammon Fisheries (19 January 2016). It is not possible to determine the cause of the stage shift or correct for it at this time, but it may be possible to make a correction with more information. Comparing the general pattern of stage data to historical hydrometric data from nearby Water Survey of Canada (WSC) stations, the punctuated stage shift recorded in the order of 10cm is inconclusive.

In order to maintain a high quality stage record, it is important to monitor the hydraulic control section at the gauging station. Below is a comparison of photos from site visits six months apart. From the photo comparison shown in **Figure 4** below, a major change in the hydraulic control is not evident.

Figure 4 Comparison of outlet control at the Sliammon Creek hydrometric station at installation (12 March 2015, top) and during a site visit six months later (9 September 2015, bottom).

3.0 REGIONAL HYDROLOGY

Kawa undertook a literature review of regional hydrology to determine basic hydrological characteristics of the watershed. For the Project's DP, a detailed hydrometric analysis is required; however, some basic parameters can at minimum contribute to a high-level "show stopper" analysis, or at best provide enough detail for project input parameters to a Class 4 estimation level, based on Association for the Advancement of Cost Estimation (AACE) classification.

Obedkoff (2003) classifies the location of the Sliammon Creek watershed in Zone 27, and suggests an average annual runoff of 36 L/s/km^2 for an estimated drainage area of 42 km^2. Translated to the Sliammon Creek watershed, this suggests an mean annual discharge (MAD) of 1.5 m^3/s, however; the actual value is expected to be lower due to evaporation on the large area of lake within the catchment, coupled with the low-level terrain of the watershed (orographic effects: precipitation increases with elevation).

4.0 RECOMMENDATIONS

Based on a review of all of the existing data for the Sliammon Creek hydrometric station, Kawa recommends the following:

i. Perform a cross section survey at the station hydraulic control during the next site visit scheduled for February 2016 and following any major flow events, which should occur approximately twice annually;
ii. Replace the existing pressure transducer and send the current transducer to the equipment supplier for calibration at the end of two years;
iii. Continue conducting site visits on approximately a quarterly basis at minimum. Visits should be scheduled such that the greatest range of flow conditions may be captured by discharge measurements;
iv. Use the recently acquired Lidar data to accurately determine watershed characteristics such as drainage area, median basin elevation, percent lake coverage, etc.
v. Collect six additional independent discharge measurements for use in rating curve development, and
vi. Complete one full year of uninterrupted stage data collection for the development of a preliminary long-term streamflow series. A total of two years of data collection are required for the purpose of conducting a full hydrological analysis that supports the DP.

5.0 REFERENCES

i. Resources Inventory Committee (RIC). 1998. *Manual of Standard Operating Procedures for Hydrometric Surveys in BC*; Prepared by Ministry of Environment, Lands and Parks, Resources Inventory Branch for the Aquatic Inventory Task Force Resources Inventory Committee. Version 1.1.
ii. George, L. 2015. Manager, Sliammon Fisheries. Personal communication.
iii. Obedkoff, W. (2003). *Streamflow in the Lower Mainland and Vancouver Island.* Ministry of Sustainable Resource Management, British Columbia. Aquatic Information Branch.

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MEMORANDUM

Client:	Sliammon Development Corporation	Ref. No.:	15.80553-SL.03.K043
Project Name:	Sliammon Creek Hydroelectric Project	Date:	May 6, 2015
Project No.:	80553-SL	Revision:	0
Recipient:	Kelly Rankin, B.Sc., B.Com., RI	Prepared by:	Dan Kovacek, P.Eng.
		Reviewed by:	Glen Ichikawa, P.Eng.
Subject:	Hydrometric Site Visit to Sliammon Creek		
Attachments:	6 May 2015 Site Visit Photo Report.pdf		

1.0 INTRODUCTION

A site visit to Sliammon Creek was conducted by Dan Kovacek and Micah Smith of Kawa Engineering (Kawa) on behalf of the Sliammon Development Corporation (SDC) on 30 April 2015. Kawa were met on site by Kelly Rankin and Zach Nelson, with Zach providing assistance in accompanying the team for the field visit, which included high-accuracy surveying of the existing concrete structure, assessment of the hydrometric station equipment, station data download, and volumetric flow discharge measurements. The purpose of the hydrometric station (installed 12 March 2015) is to provide for long-term, continuous monitoring of water level in support of baseline studies and permitting for a multi-purpose water-use development on Sliammon Creek.

2.0 SLIAMMON CREEK HYDROMETRIC STATION

2.1 Station assessment and data acquisition

The flow in Sliammon Creek at the time of the site visit was noticeably higher than the previous visit due to recent rainfall. Stop logs have been added to the existing concrete weir in three stages since the previous visit, as shown in **Photo 1**. Detailed site survey was taken of the existing concrete weir structure, the adjacent natural banks, and the creekbed immediately downstream of the structure for the purpose of establishing basic project parameters.

The hydrometric station, shown in **Photo 2**, was operating and in good condition at the time of the site visit. Minor changes were noted in debris downstream of the station, where it appears as though higher flows have removed some woody debris from the river right bank. The hydraulic control, shown in **Photo 3**, appeared stable and consistent. **Figure 1** shows the recorded stage (water level) and temperature since the station was installed.

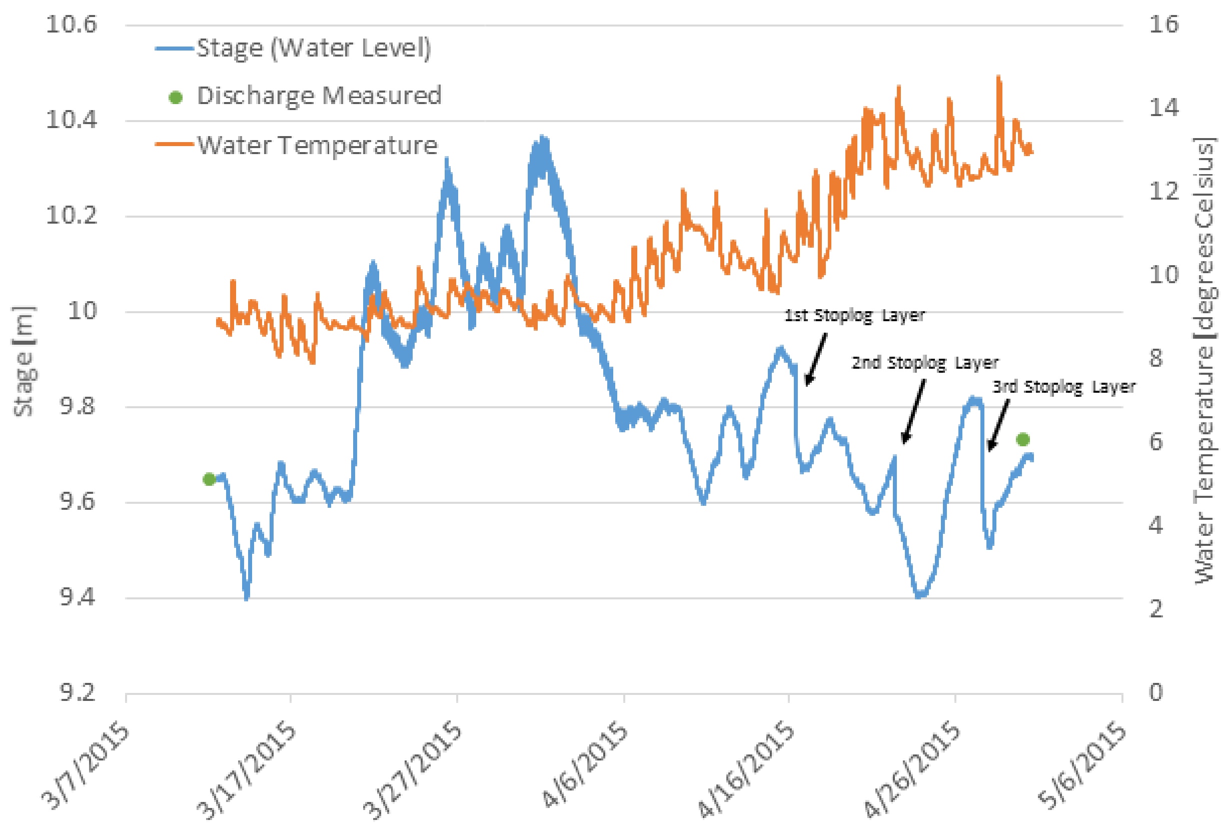

Figure 1 – Daily average water level and water temperature in Sliammon Creek (12 March – 30 April 2015).

As shown in **Figure 1**, there are three noticeably rapid fluctuations (draw-downs) visible in the stage record. These anomalies correspond to the three days when stoplogs were placed at the existing intake weir. The dates the modifications took place were confirmed by e-mail correpondence with the SDC as the 16th, 22nd, and 27th of April.

2.2 Discharge measurements

Three discharge measurements were taken during the site visit, employing two different measurement methods. One salt-dilution measurement was taken (using two independent sensors for quality control), and two independent measurements were taken using a flow-meter (Swoffer). The measured flows ranged from 0.4 to 0.5 m3/s, with an average of 0.45 m^3/s. The cross section used for the current meter measurement are shown in **Photos 4 and 5**.

2.3 Recommendations

It is recommended that site visits continue on approximately a quarterly basis at minimum. Visits should be scheduled such that the greatest range of flow conditions may be captured by discharge measurements.

Photo 1 – Sliammon Lake outlet and old concrete weir. Three stages of stoplogs have been installed.

Photo 2 – The pool at the hydrometric station.

Photo 3 – View towards the river right bank at the hydraulic control outlet for the hydrometric station.

Photo 4 – Upstream view from the cross section used for the current meter flow measurement. (1 of 2)

Photo 5 – Upstream view from the cross section used for the current meter flow measurement. (2 of 2)

Hydrological Analysis of Kwahtum Teeshohsum

Version 0.5

(Jun 11, 2017)

Prepared By: Gabe Sentlinger, M.A.Sc., P.Eng.

PROFESSIONAL ENGINEER G. P. SENTLINGER # 33679 Oct 19 2018

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ABSTRACT

This report summarizes the results of the hydrological analysis for the proposed water power project on Kwahtum Teeshohsum, near Powell River, B.C. as shown on MAP 202. Kwahtum Teeshohsum drains into Georgia Strait. **Based on the analysis presented herein, the long-term Mean Annual Discharge (MAD) for the catchment corresponding to the proposed intake location is 1.36 m^3/s, which is equivalent to a Mean Annual Runoff (MAR) of 31 l/s/km^2 for the proposed intake drainage of 43.6 km^2. The long-term MAD for the catchment corresponding to the proposed powerhouse location is 1.72 m^3/s, which is equivalent to a Mean Annual Runoff (MAR) of 31 l/s/km^2 for the proposed powerhouse drainage of 55.1 km^2.** These estimates of MAR are in agreement with regional expectations. The estimated long-term average and median daily flows within each month and annually for the proposed intake catchment are detailed in Table 1 and depicted graphically in Figure 1. **The 2-sigma (95% confidence) uncertainty in MAD at the intake site is estimated to be ±13%. The 2-sigma uncertainty in the potential energy generation due to hydrological uncertainty is ±9%.**

Table 1: Summary of Monthly Average and Median Daily Discharges for the Intake

E:\users\gsentlin\AQUARIUS_R&D\BBA\Projects\Sliammon\Data\[sliammon_summary_v0.2.1.xlsx]LT_Q

	Average	Median[A]
Jan	2.20	1.69
Feb	2.06	1.54
Mar	1.87	1.28
Apr	1.84	1.48
May	1.20	0.79
Jun	0.55	0.36
Jul	0.24	0.18
Aug	0.16	0.12
Sep	0.46	0.29
Oct	1.44	0.64
Nov	2.44	1.78
Dec	1.86	1.21
Annual	1.36	0.83

NOTES

A) This is the median of all daily flows within a month (or a year for "Annual")

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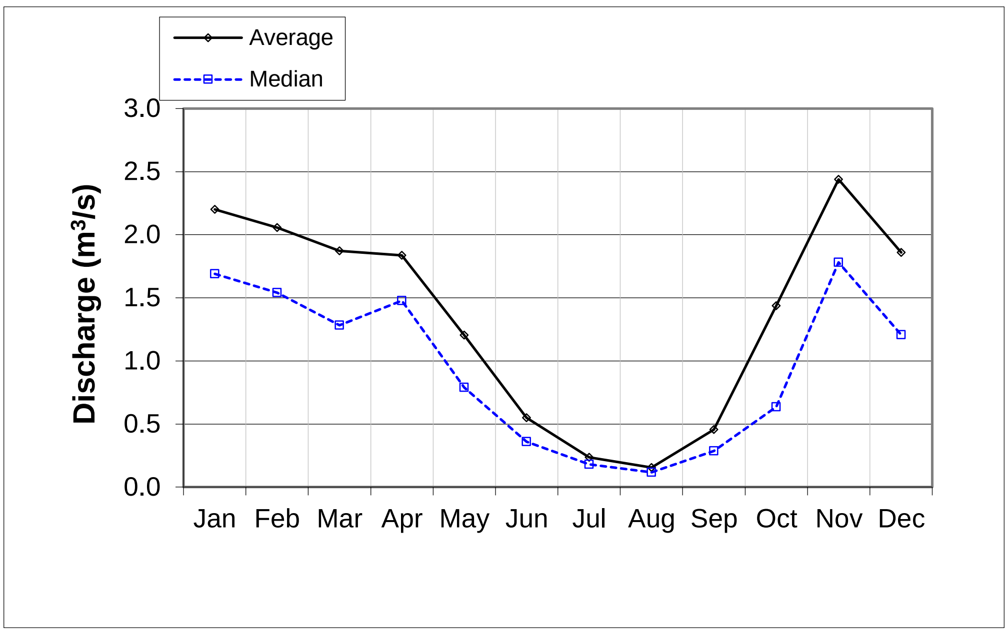

Figure 1: Estimated Monthly Average and Median Discharge for the Proposed Kwahtum Teeshohsum Intake Catchment

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ACRONYMS AND ABBREVIATIONS

DA	Drainage Area
DEM	Digital Elevation Model
FDC	Flow Duration Curve
GIS	Geographical Information System
IFR	Instream Flow Requirements
MAD	Mean Annual Discharge
MAR	Mean Annual Runoff
MSC	Meteorological Services of Canada
MMR	Monthly Multiple Regression
MMR	Monthly Single Regression
UBCWM	University of British Columbia Watershed Model
WSC	Water Survey of Canada
WY	Water Year

1 INTRODUCTION

A hydropower project is proposed on Kwahtum Teeshohsum , located ~10km north of Power River on the west coast of British Columbia. Kwahtum Teeshohsum flows directly into Georgia Strait. Aquarius R&D Inc. (ARD) has been asked to review and assess the existing hydrometric and hydrological information that is being used as the basis for the design and economic feasibility analysis of the project, and to generate a synthetic dataset based on regional expectations

A gauge was installed on Kwahtum Teeshohsum by WSC in 1949 and deactivated in 1951. Unfortunately, there are no other relevant and concurrent long-term WSC records with which to derive a long-term synthetic series from this series. Key catchment parameters of this gauge site are included in Table 2. The location of this gauge, and other regional gauges, is shown in MAP202. The Kwahtum Teeshohsum gauge sites are shown in MAP100.

Sliammon First Nation engaged FSCI Biological Consultants to conduct a water volume study in 2004. The results are summarized in "Sliammon Traditional Territory Water Volume Study A Summary" (Bates and Paul 2005). The derived daily flow series is available from this study, however, the manual discharge measurements do not have an associated date and time. This data is therefore considered anecdotally.

In 2015, Sliammon Development Corp. engaged Kawa Engineering Ltd. (now BBA Engineering Ltd.) to instantiate a new hydrometric program. A gauge was installed on Mar 12, 2015. A satellite image of the gauge location is shown in on Figure 2. The hydrometric program is described in the companion document "Hydrometric Program for Kwahtum Teeshohsum v0.4" (Sentlinger, 2017) for the gauge installed in March of 2015.

This report integrates the hydrometric results from Sentlinger (2017) with the regional hydrological analysis from nearby Water Survey of Canada (WSC) gauges, in order to generate a long-term synthetic dataset representative of the proposed project location. The "Hydrological Guidelines for Water Power Projects, October 2005" published by LWBC have been followed throughout this analysis.

No analysis of sediment transport is performed or presented in this report. ARD accepts no liability for hydrological or other processes not presented in this report.

2 REGIONAL ANALYSIS

Kwahtum Teeshohsum is located near Powell River on the west coast of British Columbia. There are no long-term (>20 years) hydrological records for Kwahtum Teeshohsum itself. A summary of regional station information is provided in **Table 2**.

There is considerable variability in annual average unit runoff in the region due to several factors:

- area/elevation relationships: a catchment with a large high elevation basin will have more unit runoff in the summer than a catchment with much of its area at lower elevations. This relationship is captured in the mean and median elevation.
- local weather patterns: local weather patterns can vary significantly over a distance of 10s of km due to the interaction of moist air masses with the diverse and extreme topography of the BC Coast.
- orographic effects: precipitation, and runoff, increases with elevation as warm and moist air masses are lifted up mountain slopes causing condensation and precipitation.
- aspect: the cardinal direction that the catchment faces will determine if it is on the lee or weather side of dominant weather patterns. Lee side catchments will have a much stronger orographic effect due to spillover of precipitation into the higher elevations, yet generally have less unit runoff overall. South-facing catchments will tend to have more dramatic spring freshets that don't last as long as a catchment facing north.
- size: larger catchments have more ground storage and therefore a smoother hydrograph than smaller catchments which tend to be more reactive to precipitation (flashy). Significant Lake storage (>5%of catchment) can also dampen a catchments runoff signal.

These factors affect three main characteristics of a catchment's hydrograph:

- Mean Annual Discharge (MAD): this is the long-term (> 20 years) average discharge at the intake. It is often expressed as the Mean Annual Runoff (MAR), or unit area runoff, over the drainage area expressed in l/s/km² or mm/yr[1]. This latter measure casts the volume of runoff into a regional context.
- Monthly runoff variation: colder catchments farther from the coast store winter precipitation as snow which is released in the summer.
- Daily streamflow and Flow Duration Curve (FDC): this measure captures the above characteristics as well as how a catchment reacts to a storm event or to snowmelt.

In attempting to estimate these three characteristics for Kwahtum Teeshohsum, we compare short term flows in Kwahtum Teeshohsum with long-term records from relevant WSC gauges. In the process, the most suitable regional WSC station is identified and used as a 'surrogate' in

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[1] These units are dimensionally equivalent: $\frac{1.0l}{s\cdot km^2}\cdot\frac{m^3}{10^3 l}\cdot\frac{km^2}{10^6 m^2}\cdot\frac{3600\cdot 24\cdot 365s}{yr}\cdot\frac{10^3 mm}{m}=31.54\frac{mm}{yr}$

so 100 l/s/km² would be equivalent to 3154mm/yr.

order to generate a synthetic streamflow record. It is also possible for more than one surrogate station to be selected based on the mechanisms which predominantly affect runoff throughout the year at each regional station compared to the watershed of interest.

2.1 Selection of Candidate Regional Stations

The west coast of British Columbia is subject to a very wet maritime climate with moderate summers and mild winters during which the area receives heavy precipitation from Pacific storms. In the lower and middle elevation bands of the drainage basins the winter precipitation falls as rain while at the higher elevations it falls as snow, to be stored until the spring and summer.

Kwahtum Teeshohsum is in the Western South Coast Mountains (Zone 27) hydrologic zone, according to Obedkoff (2003). This region is subject to intense winter storms from the Pacific Ocean. This region is "similar to that of the Coast Mountains, but due to the low altitude and maritime influence of the zone, most of this precipitation falls in the form of rain." (Obedkoff, 1998).

The relevant hydrometric and climate stations are shown on **MAP 202** with relevant parameters tabulated in **Table 2**. Candidate climate and flow gauges were chosen based on proximity of the gauge to the proposed intake site, similarity of catchment parameters, and length, quality, and concurrency of hydrometric record.

MAP 202 shows lines of constant unit runoff as drawn in Obedkoff (2003) which are based on interpolation between long-term hydrometric stations. These lines do not capture the fine detail such as orographic enhancements and rain shadows within individual watersheds, but provide an overview of the changing unit runoff values at approximately the elevation of the nearest hydrometric station. The Obedkoff analysis suggests Kwahtum Teeshohsum is in a region generating approximately 32 $l/s/km^2$ runoff.

This relatively dry region is corroborated by the PRISM model (Parameter-elevation Regressions on Independent Slopes Model), developed by the Spatial Climate Analysis Service at Oregon State University (Daly, 1994, Env. Can. 2006). The results of this model for the area around Kwahtum Teeshohsum are shown MAP 202[2]. MAP 202 shows precipitation at Kwahtum Teeshohsum is much lower than Theodosia to the north. Table 3 shows the average annual precipitation from PRISM averaged over the drainage area for the regional catchments. Note that the PRISM model uses a 1961-1990 climate normal, while the climate stations use a 1971-2000 climate normal. The PRISM is trained on regional precipitation stations. In this area, the PRISM estimate appears to be overestimating precipitation by 8.0% on average.

The PRISM estimates when converted directly to runoff are 45% larger on average. This discrepancy includes both model error and evapotranspiration losses. The nearest WSC station used as a surrogate for the PRISM analysis is Theodosia River. The difference of –68.2% when applied to the PRISM estimate over Kwahtum Teeshohsum results in a MAR of 35 $l/s/km^2$.

[2] This map was created by interpolating between 4 km resolution 1961-1990 climate normal precipitation maps obtained from Environment Canada to 1 km resolution. The PRISM model is based on local regression analysis between long-term stations at different elevations to account for aspect, elevation, local weather patterns, etc.

There is a short term WSC record on Sliammon Creek near the Mouth from 1949-1951. However there is no relevant long-term record to regress against. We have a measured short term record from 2015-2016, but there is no ideal long-term WSC concurrent record. A review of nearby WSC stations is as follows:

-LANG CREEK NEAR POWELL RIVER (08GB007) is the most relevant station but only has record from 1959-1995.

-HORSESHOE RIVER ABOVE LOIS LAKE (08GB014) is also nearby and concurrent, but as shown in Figure 4, this station exhibits a strongly regulated signal due to the influence of the upstream lake.

-THEODOSIA RIVER ABOVE SCOTTY CREEK (08GC008) is nearby and concurrent, but has a significantly higher mean elevation than Kwahtum Teeshohsum (826 mASL vs 592 mASL). It is also a shorter term record, running from 2003 to 2016.

-TSOLUM RIVER NEAR COURTENAY (08HB011) is concurrent and long-term, but is on Vancouver Island and east facing. It was considered as the primary proxy gauge for Kwahtum Teeshohsum, but resulted in unacceptably low R^2 values due to its distance from Kwahtum Teeshohsum.

-OYSTER RIVER BELOW WOODHUS CREEK(08HD011) is discontinued far away, and with a higher mean elevation.

-ROBERTS CREEK AT ROBERTS CREEK(08GA047) is concurrent and long-term. It has a low mean elevation comparable to Kwahtum Teeshohsum (591 mASL vs 592 mASL). It reacts slightly different to storms than Kwahtum Teeshohsum.

Based on this review, and daily regression analysis, we've chosen to use a monthly multiple regression model with Theodosia and Roberts to generate a daily synthetic flow series. Unfortunately this series only goes from 2003-2016, a 13 year record. In order to extend the series to 20 years, we've appended a slightly scaled Lang Creek synthetic series from 1988-1995.

Figure 3 plots the average monthly unit-runoff for the real-time stations, and Figure 5 shows the daily unit runoff for the stations. Both figures represent the period of record concurrent with Kwahtum Teeshohsum (2015-2017). Theodosia has the most unit-runoff overall while Roberts Creek is highly correlated with Kwahtum Teeshohsum. It's clear some storms occur at Roberts Creek, but not at Kwahtum Teeshohsum, but this is likely due to storage regulation at Kwahtum Teeshohsum Lake.

3 LONG TERM SYNTHETIC DATASET

In order to determine the long-term unit area runoff, monthly distribution, and synthetic daily flows, concurrent daily discharge records are regressed against regional stations.

3.1 Results of Regression Analysis

A Monthly Multiple Regression (MMR) of daily discharge values is used to generate a long-term synthetic flow series at the Kwahtum Teeshohsum Gauge site. For each calendar month, a coefficient for River discharge is calculated as well as an intercept.

The MMR Model results in 12 sets of 3 values, as detailed Table 4 for Kwahtum Teeshohsum. This table also lists the coefficients of the regression as "Slope UR", which is the ratio of the unit-runoff at Roberts or Theodosia to the Kwahtum Teeshohsum gauge for that month. To determine the daily simulated discharge at the Kwahtum Teeshohsum Gauge, the discharge at Roberts is multiplied by "slope Q" for the appropriate month and added to the product of the Theodosia Q and slopeQ for Theodosia, which in turn is added to the intercept for that month.

This table shows the regression coefficient of determination (R^2) values between Kwahtum Teeshohsum gauge site, Roberts Creek, and Theodosia. R^2 is a measure of the strength of the relationship between concurrent daily flows at the two sites. An R^2 of zero indicates no relationship, while a value of 1 is a perfectly correlated relationship. R^2 can be interpreted as the % of the total variation in the observed data points that can be explained by the regression equation. It is analogous to the Nash-Sutcliffe (NS) efficiency measure, although NS takes into account any offset (bias) in the relationship.

This regression shows relatively low R2 values. This is likely due to regulation of the Kwahtum Teeshohsum Lake regulation. The DeltaRSQ column describes the increase in RSQ when the 2nd independent variable, Theodosia, is added.

The regression approach avoids any error introduced by scaling of regional data by drainage area as the regression is performed solely on the relationship between measured discharges. As a diagnostic check of the regression model, the slope of the unit runoff was also calculated by multiplying the slope of the discharge by the ratio of the estimated drainage areas. The regression coefficients expressed as a slope-unit runoff, and intercepts as m^3/s, are shown in Figure 6 for Kwahtum Teeshohsum. A slope-unit-runoff value of 100% indicates the same unit-runoff in that month as the source WSC record. Based on this analysis, Kwahtum Teeshohsum is most highly correlated with Robert's Creek, which is much further south than Theodosia, but is more similar in catchment characteristics. Storms in November and March better match those from Theodosia due to proximity and the transitional nature of the Theodosia hydrograph at these times.

When SimKwahtum_TeeshohsumQ (simulated Kwahtum Teeshohsum daily average flow) is less than MinKwahtum TeeshohsumQ (minimum measured flow at Kwahtum Teeshohsum), we are in an area of extrapolation to very low values. To avoid negative results, we simply scale the Roberts flows by a "Scaling Factor", which essentially forces the lowest portion of the regression line through the origin. Figure 7 shows the results of a single regression between Roberts Creek and Kwahtum Teeshohsum gauge, along with the low flow scaling line.

The concurrent long term Roberts Creek record and Theodosia River is processed using the regression equation from Table 4 to generate the Kwahtum Teeshohsum synthetic flow series. A comparison of the measured and synthetic daily flows for Kwahtum Teeshohsum is shown on Figure 8. From this figure, it is evident that the synthetic series is sometimes higher and sometimes lower than the measured, as expected.

The corresponding Flow Duration Curves (FDCs) for Kwahtum Teeshohsum are shown in Figure 9:. The FDCs compared in these figures are for the entire concurrent period of record.

A scatter plot of the daily synthetic dataset and the measured data is shown for Kwahtum Teeshohsum in Figure 10, which shows more scatter than desirable, and an R^2 value of 0.59 is lower than desirable. The slope of 0.83 for flows below 200%MAD is not very meaningful given the low R^2. The average discharge for the measured dataset for the period of record shown is 1.3 m^3/s while it is 1.4 m^3/s for the simulated dataset.

The Nash-Sutcliffe efficiency for the entire 12 month record of observed data at the site is 21%, which is considered poor.

3.2 Validation of Synthetic Dataset

The long-term average monthly unit runoff at the Kwahtum Teeshohsum gauge site is shown on Figure 12 compared with other regional stations. This hydrograph shows that Kwahtum Teeshohsum has a slightly larger freshet peak, but lower summer flows, than Roberts Creek. Table 2 shows that Kwahtum Teeshohsum intake gauge catchment has about the same mean elevation as Roberts.

In terms of daily flow patterns, the FDCs for concurrent periods (2015-2017), expressed as % MAD for the Kwahtum Teeshohsum and regional WSC watersheds, are shown in Figure 11. The Kwahtum Teeshohsum FDC appears almost identical to Roberts Creek.

As validation of the average annual unit runoff at the Kwahtum Teeshohsum gauge, it is common practice to compare concurrent periods of record with long-term WSC stations and adjust the short-term unit runoff to long-term trends. The concurrent Period of Record (PoR) comparison is shown in Table 5, which compares the short term Kwahtum Teeshohsum record to two longer term records at Theodosia (2003-2017) and Roberts (1971-2000). We use the 1971-2000 normal from Obedkoff (2003) as the Roberts normal runoff. Using the concurrent period of records for Roberts and Theodosia, we arrive at estimates of MAR at Kwahtum Teeshohsum of 32 $l/s/km^2$ and 37 $l/s/km^2$ respectively.

Based on the concurrent comparison between Kwahtum Teeshohsum, Roberts, and Theodosia, the average estimated LT MAR at the Kwahtum Teeshohsum intake site is 35 $l/s/km^2 \pm 10\%$. This estimate falls within the uncertainty limits of 31 ± 13% derived in Section 3.4 for the Kwahtum Teeshohsum intake gauge.

3.3 Transposition of Gauge Flow Series to Powerhouse Site

The Kwahtum Teeshohsum intake gauge is located near the proposed intake site at an elevation of 125mASL. The powerhouse is currently proposed at an elevation of approximately 35 mASL.

An estimated flow series for the powerhouse is generated from transforming the synthetic flow series at the intake site. To take into account elevation effects between the sites, the flows in each month are scaled by the monthly transposition vectors shown in Table 6. These scaling factors are the results of the UBC Watershed Model. **After the monthly transposition vector is applied, the resulting MAD is 1.72 m^3/s at the PH Site. This corresponds to a MAR of 31 $l/s/km^2$ for a DA of 55.1 km^2.**

3.4 Uncertainty in Synthetic Results

The total uncertainty associated with the long-term average unit-area runoff at the Intake has two sources: 1) the uncertainty associated with the measured runoff, which is ±17% (2-sigma) at the intake site based on the analysis in the companion document "Kwahtum Teeshohsum Hydrometric Program: V0.1" (Sentlinger, 2017), and 2) the uncertainty associated with transposing the short-term record to long-term trends. In the hydrometric program description document, three rating curves were developed for the gauge: the most likely, an upper bound, and a lower bound. These three rating curves formed what was expected to be the two-sigma (95% confidence interval) range of possible rating curves. That is, we are 95% confident that the true rating curve falls between the upper and lower bound rating curves, while the most likely rating curve was used to generate the measured Kwahtum Teeshohsum daily hydrograph.

In order to determine the impact of each of these curves on the final MAR and MAD, the upper and lower bound rating curves have been entered into the single regression model and coefficients have been adjusted accordingly. Using the Upper Bound hydrograph, we arrive at a MAD of 1.53 m^3/s, which equates to a MAR of 35 $l/s/km^2$ at the gauge site. Using the Lower Bound hydrograph, we arrive at a MAD of 1.25 m^3/s, which equates to a MAR of 29 $l/s/km^2$, at the gauge site. The coefficient of variation between these three estimates of MAR at the gauge, including the most likely, is ±10% or ± 3 $l/s/km^2$ at the 2-sigma level. For purposes of energy modeling and environmental impact, the uncertainty in flows below 200%MAD will be more relevant and are discussed below.

In order to determine the uncertainty of transposing the short term record to expected future long-term trends, two alternative regression models were considered. The first uses a Monthly Ranged Regression (MRR) model trained with Roberts between 1988 and 2017. The second is the MMR synthetic dataset using Roberts, but only the years 2004-2017, which is the MMR model results alone. The MAD at the intake gauge site using the 1988-2017 MRR series is 1.45 m^3/s, which equates to a MAR of 33 $l/s/km^2$. The MAD using the 2002-2017 MMR dataset is 1.45 m^3/s, which equates to a MAR of 33 $l/s/km^2$. The coefficient of variation between these three estimates of MAR, including the most likely of 31 $l/s/km^2$, is ±4% or ±1 $l/s/km^2$ at the one sigma level.

Summing these two independent estimates of uncertainty in quadrature, the total error is 13% in the MAD at 2-sigma (95% confidence) level. This gives a probable range of 31 ± 3 $l/s/km^2$ at the Kwahtum Teeshohsum Gauge site. Note that this is simply the uncertainty in MAD and not applicable to uncertainty in energy production or other measures which generally concern the range of flows below 200% MAD. This uncertainty estimate is expected to be reduced as additional years of high quality instream flow measurement data are collected.

A monthly hydrograph of the average discharge from these five alternate training sets have been plotted in Figure 13. It can be seen in this figure, that the uncertainty in the rating curve creates the largest variation from the most-likely, the MRR results are generally higher in the summer. The average error (1-sigma) between mean monthly flows is ±14%, shown in Table 7. Note that this is only the error in the distribution of flows, and is independent of the error in MAD and MAR.

Figure 14 compares the daily average discharge FDCs derived from the five alternate training sets. For the purpose of estimating the uncertainty in energy potential, the area under each FDC and 200% MAD is compared. The error in potential energy generation due to uncertainty in the hydrometric program is ±6% at 2-sigma; the uncertainty due to the regression analysis is ±6% at 2-sigma. Added in quadrature, the total uncertainty in energy potential is ±9% at 2-sigma (95% confidence).

In summary, this analysis suggests that there is a 2-sigma uncertainty of ±13% in the estimate of MAD and MAR (±3 l/s/km²). The uncertainty in the distribution of monthly flows is ±14% on average, which is independent from the energy and MAD uncertainty. The 2-sigma uncertainty in the potential energy generation due to hydrological uncertainty is ±9%.

3.5 Frequency Analysis and Extreme Flow Statistics

The frequency analysis results are summarized in Table 8 for the intake gauge site. The return period statistics for mean monthly and annual discharges are depicted graphically in Figure 15, which shows that the most runoff variability occurs in the spring and fall, as the October - March rainfall is highly variable and runoff is temperature dependent.

The median of daily flows for the proposed intake catchment are compared with the average in Table 9 and on Figure 16. Because of the skew in the dataset towards lower flows, the median daily flows for all months are lower than the average. A "Spaghetti" diagram showing all synthetic flow years for the proposed Kwahtum Teeshohsum intake catchment is shown in Figure 17.

The peak flood and 7-day low flow statistics for the intake site and powerhouse site are shown in Table 10. The values under "Sim Intake" and "Sim PH" are those chosen for this analysis, while the values under "Obedkoff" are shown for comparison only. The Peak values were derived from the synthetic datasets' mean daily discharge input to Environment Canada's CFA_3 package and fit to a LPIII distribution. The peak daily discharge was then multiplied by the estimated ratio of peak instantaneous discharge (Qi) to daily average discharge (Qd). **A Qi:Qd ratio of 2.4 was used based on several factors:**

1. The average ratio of Qi:Qd for Roberts Creek was 2.2, as shown in Table 11, and in Figure 18. There is a positive relationship between the ratio and the instantaneous discharge. The largest measured Qi has a ratio of 2.8 in 1998. The largest ratio of 3.6 is for the second smallest event.
2. Looking at the Qi:Qd ratio in the hydrometric record at Kwahtum Teeshohsum Intake for several storm events, the average ratio was 1.2, as shown in Table 12. This is much lower than 2.4, and may be due to the attenuating ability of Kwahtum Teeshohsum Lake. However, the rating curve is only defined up to 6 m^3/s, therefore a Qi:Qd ratio of 2.4 is considered conservative until larger flows are measured.
3. Climate change over the next 40 years is expected to result in larger fall and winter storms, discussed in Section 3.6. **Using a climate change contingency factor of 110% and a conservative estimate of 2.2 results in a Qi:Qd ratio of 2.4.**

We recommend this ratio, and flood frequency analysis, be revisited once more large flow measurements are made at the gauge site, and a longer record is available.

For comparison purposes, flood estimates were derived from the methods described by Obedkoff (2003), for the intake gauge site only. Based on this method, the 10-year return period for instantaneous peak flows were derived using a graphical interpolation from Roberts Creek and for Tsolum River near Courtenay to the drainage area of 43.6 km² at the intake. The graphical interpolation runs parallel to the Zone 27 Western South Coast Mountains regression line.

Flood statistics derived from the synthetic dataset at the intake site (using a LPIII distribution) are generally in agreement with Roberts Creek flood values, except the Kwahtum Teeshohsum 200 year flood event is larger. This seems unlikely due to lake attenuation and should be revisited in order to avoid oversizing the intake or dam structure.

Because this potential dam site is above a residential area, 500 and 1000 year return flood estimates are required, as well as the Probable Maximum Flood. The 500 and 1000 year floods are estimated by extrapolation from the above method using a LPIII distribution. The PMF is taken from the letter report titled "PMF Hydrograph for the Kwahtum Teeshohsum Hydroelectric Project" (Cathcart, 2017).

The estimates derived from this analysis are presented in Table 10. There is a high degree of uncertainty on these estimates as they are based on extrapolation of the rating curve at all sites, and extrapolation of the flood distribution curve to recurrence intervals far beyond any measured record.

The maximum "measured"[3] instantaneous discharge recorded at Kwahtum Teeshohsum site occurred on Feb 16, 2017 and is estimated to be 13.9 m^3/s, which is less than the estimated 2-year return period flood. Peak flood values will typically occur in Nov-Feb.

The minimum annual average 7-day low flow values were entered into the Low Flow Analysis (LFA) package from Environment Canada. Using a Gumbel III distribution, Table 10 shows the estimated low flow values compared with values derived from methods described in Obedkoff (2003). Roberts and Tsolum estimates flank the Kwahtum Teeshohsum estimates. The minimum measured 7 day low flow occurred Jun 22, 2015 and was 0.005 m^3/s. This corresponds to an approximately 20 year low flow, which corresponds with expectations. This measurement followed a site visit on Jun 8, 0215 when 0.015 m^3/s was measured, lending credibility to this low flow estimate.

The Long-Term FDCs for the Kwahtum Teeshohsum intake site and the powerhouse site are shown in Figure 19.

3.6 Climate Change

There is consensus amongst climate scientists that the climate is changing. It is reasonable to question if a synthetic dataset based on the previous 20 years will resemble the next 20+ years. General Circulation Models (GCM) are often run to determine the effect of global warming on climate. It is not possible to make blanket statements regarding climate change as it tends to have local influences that can vary from place to place. Environment Canada has published a version of the PRISM climate maps based on the 1961-1990 and 1971-2000 Normal periods but adjusted for three future slices using the CGM2 ensemble mean for greenhouse gases plus aerosols. Details of this model can be found at the Environment Canada website (Environment Canada, 2006). It should be noted that there is substantial uncertainty in a GCM given the number of unknowns and assumptions, and downscaling of these models to a small

[3]"Measured" may not be an accurate adjective as only the stage was measured and the discharge is estimated based on an extrapolation of the rating curve.

catchment such as Kwahtum Teeshohsum will introduce more uncertainty. However, given that this model is the smallest scale model currently available, it was considered a suitable starting point.

Figure 20 shows the change in mean monthly temperature and total monthly precipitation for the west coast of B.C. near the Kwahtum Teeshohsum catchment. These values are detailed in Table 13. This data is based on data CanESM2 / CGCM4 and PRISM model data using ClimateBCV5.02comparing climate normals (1961-1990 and 1971-2000) and predicted climate change in 2055 for a worst case (RCP8.5) and best case (RCP4.5) climate scenario. These climate change scenarios are described in Figure 21

Figure 20 shows temperatures increasing by 3.1˚C (RCP4.5) to 4.0˚C (RCP8.5) degrees on average, and precipitation increasing by 6% (RCP4.5) to 7% (RCP8.5) on average, with more winter precipitation and less precipitation in May-June. The increased temperatures are expected to exacerbate the seasonal wet and dry extremes seen in Kwahtum Teeshohsum. The increase in precipitation is expected to predominantly occur in the winter as large storms. Neither of these impacts is expected to increase the capacity factor of a hydro-power project for a synoptically dominated system such as Kwahtum Teeshohsum. The increased precipitation may result in larger baseflows depending on the ground storage capacity of the watershed, but a conservative approach would be to expect lower 7-day low flows over the next 40 years.

4 CONCLUSIONS AND RECOMMENDATIONS

A small hydroelectric power project is proposed for Kwahtum Teeshohsum near Powell River, B.C. **Based on regression analysis of 21 months of in-stream flow measurements on Kwahtum Teeshohsum and concurrent flow records at Roberts Creek and Theodosia River, the Mean Annual Discharge at the intake gauge site (with a DA of 43.6 km²) is estimated to be 1.36 m³/s, which equates to a unit runoff of 31 l/s/km².** This MAR is not significantly different than that of Roberts Creek at 33 m³/s, nor of Lang Creek at 33 l/s/km². The monthly average discharge pattern derived from the synthetic dataset agrees to some extent with expectations based on regional trends and the watershed characteristics of the Kwahtum Teeshohsum location.

The Kwahtum Teeshohsum intake gauge flows are transposed to the powerhouse station catchment with DA of 55.8 km² using area proration and a slight monthly transposition factor. The estimated MAD at the **powerhouse site is estimated to be 1.72 m³/s, which equates to a unit runoff of 31 l/s/km².**

The 2-sigma uncertainty (95% confidence interval)is ±13 % on both of these estimates. The 2-sigma uncertainty in the potential energy generation due to hydrological uncertainty is ±9%

The long term monthly average discharge is summarized in Table 14 for the proposed intake site, and in Table 15 for the proposed powerhouse site.

We recommend continuing the hydrometric program for at least 5 years to reduce the uncertainty associated with this hydrological estimate. Site visits should occur at minimum 4 times per year to maintain data quality.

We recommend revisiting the flood estimates once larger flows (>10 m^3/s) are measured.

This synthetic dataset is considered to be of adequate quality for use in energy and environmental modeling studies, within the limits of the uncertainty derived and presented herein.

5 REFERENCES

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6 TABLES

Table 2: Regional Hydro-Meteorological Stations near Kwahtum Teeshohsum

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	Hydrometric Stations	Stn ID	Years	# Complete Years	Agency	DA[F] (km^2)	%Glacier	%Lake	MAD [E,F,G] (m^3/s)	MAR [E,F,G] (l/s/km^2)	Precip[D] (mm/year)	Min Elev (m ASL)	Max Elev (m ASL)	Mean (m ASL)	Median (m ASL)
WSC HYDRO	HORSESHOE RIVER ABOVE LOIS LAKE	08GB014	2007 - 2016	5	WSC	133.2	0.0%	11.6%	6.4	48	*1521*	163	1654	453	414
	THEODOSIA RIVER ABOVE SCOTTY CREEK	08GC008	2003 - 2016	8	WSC	94.9	0.0%	0.2%	4.5	48	*1499*	38	1818	826	858
	LANG CREEK NEAR POWELL RIVER	08GB007	1959-1995	36	WSC	127.5	0.0%	10.5%	4.2	33	*1048*	102	975	417	322
	TSOLUM RIVER NEAR COURTENAY	08HB011	1912-2016	54	WSC	264	0.0%	0.8%	10.5	40	*1260*	15	1410	330	224
	OYSTER RIVER BELOW WOODHUS CREEK	08HD011	1973-2010	37	WSC	297	0.0%	1.5%	14.0	47	*1483*	100	1844	921	950
	ROBERTS CREEK AT ROBERTS CREEK	08GA047	1959-2016	57	WSC	32.6	0.0%	0.0%	1.06	33	*1026*	75	1079	591	621
	SLIAMMON CREEK NEAR POWELL RIVER	08GB005	1949-1951	3	WSC	57.4	0.0%	4.5%	1.7	30	*940*	9	1115	515	501
KAWA	KWAHTUM TEESHOHSUM GAUGE AT 125M		2015-2016	1	KAWA	43.6	0.0%	5.9%	1.36	31	*984*	125	1115	592	612
	KWAHTUM TEESHOHSUM LAKE/INTAKE					43.6	0.0%	5.9%	1.36	31	*985*	130	1115	593	613
	KWAHTUM TEESHOHSUM PH					55.1	0.0%	4.7%	1.72	31	*985*	35	1115	515	501
	Climate Stations					--	--	--				**Min T °C**	**Max T °C**	**Avg T °C**	--
MSC	POWELL RIVER	1046390	1924-2004	59	MSC					32	1004	7.1	13.9	10.6	
	POWELL RIVER A	1046391	1954-2004	34	MSC					39	1233	5.2	13.3	9.3	
	COMOX A	1021830	1960-2004	57	MSC					37	1179	5.8	13.6	9.7	

NOTES:

[D] Precip at Hydrometric stations is based on Runoff less a glacier contribution of 90 l/s/km^2 and orographic enhancement assumed to be equal to evapotranspiration

[E] Runoff at Climate stations is simply the algabraic conversion of Precip. values to Runoff.

[F] Where available, DA values and Runoff values are taken from Obedkoff, 2003.

[G] LT MAR is the estimated Long-Term Mean Annual unit-Runoff derived in this Report.

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Table 3: Kwahtum Teeshohsum PRISM Analysis

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	PRISM[A]		MAR[C]			%Diff[D]
	mm/year	(l/s/km²)[B]	(l/s/km²)	%Glacier	MAP	
KWAHTUM TEESHOHSUM GAUGE AT 125M	1880	60	35	0.0%	35	-68.2%
KWAHTUM TEESHOHSUM GAUGE AT 130M	1880	60	35	0.0%	35	-68.2%
HORSESHOE RIVER ABOVE LOIS LAKE	1770	56	48	0.0%	48	-16.3%
THEODOSIA RIVER ABOVE SCOTTY CREEK	2546	81	48	0.0%	48	-68.2%
OYSTER RIVER BELOW WOODHUS CREEK	2260	72	47	0.0%	47	-52.5%
TSOLUM RIVER NEAR COURTNEY	1645	52	40	0.0%	40	-30.6%
LANG CREEK NEAR POWELL RIVER	1661	53	33	0.0%	33	-58.7%
					Average	-45.2%
POWELL RIVER	1186	*38*			***32***	-18.1%
POWELL RIVER A	1241	*39*			***39***	-0.7%
COMOX A	1242	*39*			***37***	-5.3%
					Average	-8.0%

Notes:

A) Precipitation values taken from the 1961-1990 climate normal PRISM model

B) These values are PRISM Precip values converted to l/s/km^2 and does not include the effects of evapotranspiration

C) These values taken from long-term WSC record or from hydrological analysis based on long-term WSC records.

D) %Diff Values will include the error in the PRISM model as well as losses due to evapotranspiration.

E) Precip at Hydrometric stations is based on Runoff less a glacier contribution of 30 l/s/km^2.

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Table 4: Monthly Single Regression Results for Kwahtum Teeshohsum Intake Gauge

E:\users\gsentlin\AQUARIUS_R&D\BBA\Projects\Sliammon\Data\[Kwahtum Teeshohsum_Theodosia_Roberts_ARM_v0.1.7.xlsx]RegressionSummary

Date Printed: Jun 11, 2017

Period	Training Years	Multiple Regression						Delta	Low Flow Scaling		
		Intercept	ROBERTS		THEODOSIA		RSQ	Delta	Min_KWAHTUM TEESHOHSUM	Min_ROBERTS	ScalingFactor
			Slope Q	Slope UR	Slope Q	Slope UR		RSQ			
Jan	**2016 2017**	-0.06	1.271	95%	0.034	7%	**78%**	**0.1%**	0.34	0.27	1.24
Feb	**2016 2017**	0.52	1.130	84%	0.005	1%	**73%**	**0.0%**	0.96	0.38	2.54
Mar	**2015 2016**	-0.66	1.111	83%	0.174	38%	**69%**	**6.3%**	0.36	0.23	1.57
Apr	**2016**	0.36	2.129	159%	-0.110	-24%	**84%**	**9.7%**	0.24	0.21	1.18
May	**2016**	-0.07	2.068	155%	-0.028	-6%	**85%**	**5.1%**	0.03	0.09	0.27
Jun	**2016**	-0.079	1.841	138%	-0.003	-1%	**68%**	**13.7%**	0.00	0.00	0.00
Jul	**2015 2016**	-0.09	1.615	121%	0.021	5%	**86%**	**2.9%**	0.00	0.05	0.04
Aug	**2016**	0.00	1.074	80%	0.059	13%	**49%**	**0.3%**	0.00	0.00	0.00
Sep	**2016**	0.000	1.474	110%	0.088	19%	**47%**	**20.1%**	0.00	0.00	0.00
Oct	**2015 2016**	0.00	1.875	140%	0.118	26%	**80%**	**3.0%**	0.00	0.00	0.00
Nov	**2015**	0.00	0.065	5%	0.417	91%	**91%**	**8.3%**	0.00	0.00	0.00
Dec	**2015**	0.00	0.556	42%	0.095	21%	**89%**	**3.6%**	0.00	0.00	0.00

Notes:

*1) The regression equation is SimKWAHTUM TEESHOHSUMQ = Intercept + (SlopeROBERTSQ*ROBERTSQ) + (SlopeTHEODOSIAQ*THEODOSIAQ) when SimKWAHTUM TEESHOHSUMQ > Min_KWAHTUM TEESHOHSUM and SimKWAHTUM TEESHOHSUMQ = ScalingFactor*ROBERTSQ when SimKWAHTUM TEESHOHSUMQ < Min_KWAHTUM TEESHOHSUM*

Ver 0.1.7

Table 5: Concurrent Period of Record Runoff Values for Nearby Active Regional Stations.

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Station	Agency	Period of Record	# of Years	Area	Avg Q	Avg Unit Runoff		%	Est. LT Avg
				(km^2)	(m^3/s)	($l/s/km^2$)	(mm/yr)	LT Avg	($l/s/km^2$)
ROBERTS	OBED	1971-2000[A]	30	32.6	1.07	33	1035	100%	33
	WSC	2015-2017 concurrent KWAHTUM TEESHOHSUM	2	32.6	0.99	30	958	93%	
THEODOSIA	WSC	2003-2017	14	94.9	4.7	50	2870	100%	50
	WSC	2016-2017 concurrent KWAHTUM TEESHOHSUM	1	94.9	4.6	48	1527	97%	
KWAHTUM TEESHOHSUM	BPG	2016-2017 concurrent ROBERTS	1	43.6	1.29	30	936	93%	32
	BPG	2016-2017 concurrent THEODOSIA	1	43.6	1.29	30	936	97%	30
								avg	31
								stdev	4%

Notes

A] Estimated Long Term Average based on Obedkoff normal period 1971-2000.

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Table 6: Monthly Transposition Vector for Powerhouse Site

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Study Site	Source	Source Mean Elev (mASL)	Study SIte Mean Elev (mASL)	Delta Mean Elev	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Orog Eff /100m
KWAHTUM TEESHOHSUM POWERHOUSE	AHTUM TEESHOHSUM GAU	592	515	-77	1.04	1.06	1.06	1.02	0.97	0.94	0.94	0.94	0.95	0.97	1.00	1.04	0.98	5.5%

Notes:

A) These scaling factors are the results of UBC Watershed Model simulations. They include the monthly timing factors as well as orographic enhancement.

B) The correction vector in Jul-Nov have been modified to better agree with measured flows at the tributary gauge.

Ver 0.7

Table 7: Monthly Uncertainty due to Hydrological Uncertainty

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Flow (m^3/s)	SimKwahtum_Teeshohsum MMR MostLikely	SimKwahtum_Teeshohsum MMR Upper	SimKwahtum-Teeshohsum MMR	SimKwahtum_Teeshohsum MRR 1988-2017	SimKwahtum_Teeshohsum MMR 2004-2017	COV
Jan	2.20	2.87	2.12	2.36	2.23	13%
Feb	2.06	2.38	1.92	1.91	1.86	10%
Mar	1.87	1.98	1.73	1.90	1.97	5%
Apr	1.84	1.93	1.67	1.95	2.14	9%
May	1.20	1.38	1.06	1.13	1.40	12%
Jun	0.55	0.61	0.48	0.68	0.61	13%
Jul	0.24	0.26	0.21	0.32	0.24	16%
Aug	0.16	0.18	0.14	0.27	0.20	25%
Sep	0.46	0.49	0.41	0.59	0.53	14%
Oct	1.44	1.55	1.29	2.17	2.06	23%
Nov	2.44	2.60	2.22	2.61	2.70	8%
Dec	1.86	2.08	1.75	1.46	1.41	16%
MAD	1.36	1.53	1.25	1.45	1.45	AVG
MAR($l/s/km^2$)	31	35	29	33	33	14%

Notes

A] These monthly values are for the Kwahtum Teeshohsum Gauge Site with a DA of: 43.6 km^2

Ver 0.2.1

Table 8: Summary Table of Mean Monthly Flows for the 5-, 10-, and 20- year Dry and Wet Return Periods for the Kwahtum Teeshohsum Intake Site

E:\users\gsentlin\AQUARIUS_R&D\BBA\Projects\Sliammon\Data\[sliammon_summary_v0.2.1.xlsx]LT_Q_Synka 3/30/2017 17:08

Years	20	10	5	Median	5	10	20			
Probability wetter	95%	90%	80%	50%	20%	10%	5%	Average	Min	Max
Jan	1.44	1.49	1.59	2.03	2.88	3.52	4.17	2.21	0.99	3.96
Feb	1.17	1.23	1.35	1.82	2.74	3.43	4.13	2.01	1.12	4.42
Mar	1.06	1.13	1.26	1.80	2.85	3.65	4.44	1.90	0.99	3.39
Apr	1.01	1.08	1.21	1.75	2.80	3.60	4.39	1.85	0.62	3.40
May	0.35	0.41	0.55	1.11	2.19	3.02	3.84	1.21	0.28	2.93
Jun	0.16	0.19	0.26	0.50	0.99	1.36	1.72	0.55	0.09	1.26
Jul	0.09	0.10	0.13	0.22	0.40	0.54	0.68	0.24	0.04	0.50
Aug	0.06	0.06	0.08	0.14	0.26	0.35	0.44	0.15	0.05	0.38
Sept	0.18	0.20	0.24	0.41	0.75	1.00	1.25	0.45	0.17	1.05
Oct	0.13	0.23	0.44	1.29	2.95	4.20	5.45	1.45	0.22	4.45
Nov	1.35	1.42	1.59	2.24	3.52	4.49	5.45	2.37	0.58	4.27
Dec	0.86	0.94	1.10	1.77	3.06	4.05	5.03	1.89	0.48	4.34
Annual	1.15	1.17	1.20	1.32	1.56	1.74	1.92	1.37	0.97	1.79
%Median	87%	88%	91%	100%	118%	132%	145%	104%	73%	136%

NOTES:

[1] The "Annual" flows are based on the distribution of mean annual flows. The median "Annual" flow is the median MAD.

[2] The monthly flows are based on the distribution of mean monthly flows.

V1.6

Table 9: Summary of Average and Median Daily Discharge at the Proposed Intake Catchment

E:\users\gsentlin\AQUARIUS_R&D\BBA\Projects\Sliammon\Data\[sliammon_summary_v0.2.1.xlsx]LT_Q

	Average	Median[A]
Jan	2.20	1.69
Feb	2.06	1.54
Mar	1.87	1.28
Apr	1.84	1.48
May	1.20	0.79
Jun	0.55	0.36
Jul	0.24	0.18
Aug	0.16	0.12
Sep	0.46	0.29
Oct	1.44	0.64
Nov	2.44	1.78
Dec	1.86	1.21
Annual	1.36	0.83

NOTES

A) This is the median of all daily flows within a month (or a year for "Annual")

V1.6

Table 10: Peak Flood and Low Flow Statistics at Kwahtum Teeshohsum Compared with Regional Expectations

Flood statistics derived from the synthetic dataset (using a Log Pearson III distribution) generally are close to those from Roberts and Tsolum. The flood estimates at Kwahtum Teeshohsum Intake and PH use a Qi:Qd ratio of 2.4. The QPMF is taken from Cathcart (2017)

E:\users\gsentlin\AQUARIUS_R&D\BBA\Projects\Sliammon\Data\[sliammon_summary_v0.2.2.xlsx]Obedkoff_LowFlow_Peak 6/11/2017 9:32

	INTAKE ANALYSIS					PH ANALYSIS	
	Parameter	Obedkoff[A]		Sliammon In.[B]		Sliammon PH.[C]	
		Roberts	Tsolum	(l/s/km^{2})	(m^3/s)	(l/s/km^{2})	(m^3/s)
Peak Flood	2 yr	815	870	697	30	708	39
	10 yr	1,300	1,200	1,094	48	1,089	60
	50 yr	1,589	1,334	1,516	66	1,452	80
	100 yr	1,681	1,364	1,716	75	1,597	88
	200 yr	1,760	1,391	1,924	84	1,760	97
	500 yr			2,234	97	1,978	109
	1000 yr			2,569	112	2,569	142
	QPMF[G]				**500**		
7-day Low (m^3/s)	1 yr	-	-		0.406		0.535
	2 yr	0.119	0.006		0.063		0.071
	5 yr	0.093	0.003		0.021		0.023
	10 yr	0.080	0.002		0.010		0.010
	20 yr	0.069	0.001		0.004		0.004

Notes:

[A] These Flow statistics are based on the 10 year value derived graphically from Obedkoff (2003) using the WSC Roberts Creek site (08GA047) and Tsolum Creek at the Mouth (08HB011). Peak Flood values are in l/s/km^2 while 7-day low flows are in m^3/s.

[B] These values are at the intake site DA of: 43.6 km²

[C] These values are at the PH site DA of: 55.1 km²

[G] QPMF from taken from "PMF Hydrograph for the Kwahtum Teeshohsum Hydroelectric Project" (Cathcart, 2017)

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Table 11: Ratio of Qi to Qd at Robert's Creek (DA=32.6 km²)

E:\users\gsentlin\AQUARIUS_R&D\BBA\Projects\Sliammon\Data\Stats\[Sliammon_IN Ann Peak_V0.3.xlsx]QiQd_Roberts 3/30/2017 17:13

Year	I-MAX	HH:MM	CODE	MM--DD	DAILY MAX (M^3/S)	Ratio	Freshet	Fall
1986	26.6	21:00:00	PST	01--18	13.0	2.0		2.0
1987	19.5	03:50:00	PST	01--03	11.6	1.7		1.7
1988								
1989	27.1	00:55:00	PST	11--10	9.9	2.7		2.7
1990	34	17:09:00	PST	11--23	14.8	2.3		2.3
1991								
1992	28.1	21:05:00	PST	01--23	10.0	2.8		2.8
1993	25.8	12:03:00	PST	12--13	15.6	1.7		1.7
1994	46.4	19:19:00	PST	12--19	27.4	1.7		1.7
1995	50.3	00:16:00	PST	12--13	14.3	3.5		3.5
1996	10.8	23:38:00	PST	01--14	8.7	1.2		1.2
1997	53.7	23:36:00	PST	10--09	12.2	4.4		4.4
1998	64.1	19:51:00	PST	01--23	22.5	2.8		2.8
1999	38.9	11:11:00	PST	11--09	14.4	2.7		2.7
2000	7.07	07:42:00	PST	06--12	4.7	1.5	1.5	
2001	18.4	21:25:00	PST	12--16	9.6	1.9		1.9
2002								
2003	14.6	18:08:00	PST	10--16	9.9	1.5		1.5
2004	11.3	07:34:00	PST	11--07	7.7	1.5		1.5
2005	14.4	17:30:00	PST	01--19	12.1	1.2		1.2
2006	20.5	17:57:00	PST	11--15	10.6	1.9		1.9
2007	14.5	13:09:00	PST	01--02	8.2	1.8		1.8
2008	7.12	22:20:00	PST	10--04	3.0	2.3		2.3
2009	19.5	04:12:00	PST	11--20	11.3	1.7		1.7
2010	32.9	14:46:00	PST	12--24	18.7	1.8		1.8
2011	13.8	16:06:00	PST	02--14	5.9	2.3		2.3
2012	16	00:36:00	PST	04--26	8.5	1.9		1.9
2013	14.8	21:31:00	PST	09--29	4.9	3.0		3.0
					Average	2.2	1.5	2.2

Notes

[A] Only concurrent storm events are considered

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Table 12: Ratio of Qi to Qd at Kwahtum Teeshohsum Intake Gauge (DA=43.6 km²)

			DA:	43.6
Date	Maximum this date		Daily	
	H	Q	Daily Q	Qi/Qd
1/22/16 0:00	2.001	12.6	9.90	1.3
10/16/16 0:00	1.975	12.1	10.65	1.1
2/16/17 0:00	2.065	13.9	11.83	1.2
			Average	1.2

Table 13: Predicted Climate Change near Kwahtum Teeshohsum from ClimateBC for 2055

E:\users\gsentlin\AQUARIUS_R&D\BBA\Projects\Sliammon\Data\[sliammon_summary_v0.2.1.xlsx]PRISM 4/7/2017 16:48

	Precip (mm)				Mean Temp (oC)				Evapotranspiration			
	Normal		2055		Normal		2055		Normal		2055	
	1961-1990	1971-2000	RCP8.5	RCP4.5	1961-1990	1971 - 2000	RCP8.5	RCP4.5	1961-1990	1971 - 2000	RCP8.5	RCP4.5
1	157	158	149	168	2.4	2.7	6.7	5.2	10	10	13	11
2	124	126	192	148	3.9	4	9.9	7.4	18	18	25	20
3	120	120	156	125	5.5	5.7	9.6	8.6	37	37	45	41
4	74	82	49	77	8.1	8.4	9.8	10.5	59	59	70	63
5	70	75	70	75	11.6	11.9	15.5	14.2	90	88	95	94
6	53	63	51	46	14.7	14.6	17.8	18.3	103	100	119	115
7	41	43	22	22	17.1	17.3	23.4	21.5	114	112	119	138
8	52	52	24	30	17	17.2	25.4	21.2	96	95	107	114
9	70	62	35	63	13.9	14.2	17.4	17.4	60	61	65	70
10	142	135	144	155	9.3	9.4	11.9	11.6	31	30	37	33
11	190	189	230	206	5	5.2	7.5	7.3	13	13	15	14
12	182	175	160	200	2.7	2.9	4.6	5.2	8	8	9	9
Ann	1275	1280	1282	1315	9.3	9.5	13.3	12.4	53.3	52.6	59.9	60.2
Change			7	40			3.9	3.0			7.0	7.2
%Change			1%	3%								

NOTES

A) From CanESM2 / CGCM4 and PRISM model using ClimateBC_v5.10 (desktop version)

Latitude=49.925927° *Longitude=-124.591905°* *Elevation=125m* *Site=Sliammon Gauge 1*

Table 14: Flows at Kwahtum Teeshohsum Proposed Intake Site (43.6 km², 1988-2017)

E:\users\gsentlin\AQUARIUS_R&D\BBA\Projects\Sliammon\Data\[SimSliammonQ_v0.6.xlsx]MMTable printed 3/31/2017 17:17

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1988	1.29	1.65	1.47	2.14	1.57	0.46	0.22	0.08	0.42	0.37	4.22	2.86	1.4
1989	2.11	1.31	1.61	1.55	0.78	0.25	0.18	0.05	0.25	0.48	1.52	1.55	1.0
1990	1.99	2.58	1.59	1.19	0.75	1.26	0.27	0.07	0.27	0.46	2.40	2.80	1.3
1991	2.11	4.42	0.99	1.21	0.47	0.23	0.12	0.13	0.61	0.30	1.91	2.20	1.2
1992	3.96	3.68	1.22	0.83	0.62	0.19	0.20	0.06	0.17	0.46	1.59	1.20	1.2
1993	1.19	1.15	1.08	1.57	1.77	0.62	0.37	0.12	0.39	0.22	0.58	2.97	1.0
1994	2.09	2.17	3.09	1.21	0.52	0.34	0.31	0.08	0.36	0.39	1.55	2.80	1.2
1995	2.44	2.31	2.44	1.05	0.65	0.23	0.12	0.06	0.18	0.67	2.32	4.34	1.4
2004	2.18	1.87	1.49	1.39	0.57	0.23	0.07	0.25	0.83	1.81	3.33	1.40	1.3
2005	3.35	1.15	1.51	3.09	0.93	0.73	0.50	0.18	0.35	3.28	2.24	1.29	1.6
2006	3.00	2.16	1.55	2.18	1.28	0.57	0.11	0.13	0.22	0.51	2.40	1.71	1.3
2007	2.41	2.27	3.32	2.43	1.39	0.54	0.47	0.23	0.59	3.57	2.98	1.36	1.8
2008	1.45	1.26	0.96	1.37	2.93	1.06	0.19	0.38	0.29	1.79	2.12	0.67	1.2
2009	1.78	1.27	0.99	2.61	2.83	0.24	0.05	0.16	0.54	1.87	4.52	0.96	1.5
2010	3.46	1.91	1.66	2.56	0.92	1.13	0.18	0.19	0.88	2.13	2.70	2.78	1.7
2011	2.53	2.00	2.57	1.70	2.44	1.20	0.38	0.33	0.61	1.26	2.29	0.79	1.5
2012	1.71	2.21	1.74	3.07	1.52	1.07	0.53	0.16	0.17	1.57	2.93	1.65	1.5
2013	0.99	1.45	3.04	3.40	2.12	0.76	0.16	0.18	1.05	0.99	0.92	0.46	1.3
2014	1.64	1.12	2.47	2.32	0.89	0.23	0.30	0.15	0.24	3.04	2.57	2.08	1.4
2015	2.05	2.13	1.46	1.10	0.26	0.11	0.02	0.16	0.69	1.05	1.83	2.45	1.1
2016	3.18	2.86	3.08	0.63	0.08	0.10	0.21	0.11	0.45	3.95	4.32	0.72	1.6
2017	1.52	2.33											
Avg	2.20	2.06	1.87	1.84	1.20	0.55	0.24	0.16	0.46	1.44	2.44	1.86	1.36
Min	0.99	1.12	0.96	0.63	0.08	0.10	0.02	0.05	0.17	0.22	0.58	0.46	1.0
Max	3.96	4.42	3.32	3.40	2.93	1.26	0.53	0.38	1.05	3.95	4.52	4.34	1.8
Avg UR (l/s/km^2)	50	47	43	42	28	13	5	4	10	33	56	43	31

Notes:

1) Unit Runoff is based on an intake drainage area of: 43.6 km2

2) Simulated Data from 1988-1995 is from scaled Lang Creek and from 2004-2017 is from MMR results against Theodosia and Robert's Creek.

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Table 15: Flows at Kwahtum Teeshohsum Proposed Powerhouse Site (55.1 km², 1988-2017)

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Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1988	1.69	2.18	1.94	2.75	1.90	0.54	0.26	0.10	0.50	0.45	5.29	3.71	1.8
1989	2.76	1.73	2.12	1.99	0.94	0.29	0.21	0.06	0.30	0.58	1.91	2.02	1.2
1990	2.60	3.42	2.10	1.52	0.90	1.49	0.32	0.08	0.33	0.56	3.01	3.62	1.6
1991	2.75	5.84	1.31	1.55	0.57	0.27	0.14	0.16	0.72	0.36	2.39	2.85	1.5
1992	5.17	4.87	1.62	1.06	0.75	0.23	0.24	0.07	0.20	0.56	1.99	1.55	1.5
1993	1.55	1.52	1.42	2.02	2.14	0.73	0.43	0.14	0.47	0.27	0.73	3.85	1.3
1994	2.73	2.87	4.08	1.54	0.63	0.40	0.37	0.09	0.43	0.48	1.95	3.63	1.6
1995	3.19	3.06	3.23	1.34	0.79	0.27	0.15	0.07	0.22	0.81	2.90	5.62	1.8
2004	2.85	2.47	1.96	1.79	0.69	0.27	0.08	0.30	0.99	2.21	4.17	1.81	1.6
2005	4.38	1.52	2.00	3.96	1.12	0.86	0.59	0.21	0.42	3.99	2.80	1.68	2.0
2006	3.93	2.86	2.05	2.79	1.55	0.67	0.13	0.16	0.26	0.62	3.01	2.22	1.7
2007	3.15	3.00	4.39	3.12	1.68	0.64	0.56	0.27	0.70	4.35	3.73	1.76	2.3
2008	1.89	1.67	1.27	1.75	3.54	1.26	0.22	0.45	0.35	2.18	2.65	0.87	1.5
2009	2.32	1.68	1.31	3.34	3.43	0.28	0.05	0.19	0.65	2.28	5.67	1.24	1.9
2010	4.52	2.53	2.19	3.28	1.11	1.33	0.21	0.22	1.06	2.60	3.38	3.61	2.2
2011	3.31	2.64	3.40	2.17	2.96	1.41	0.45	0.39	0.73	1.53	2.87	1.03	1.9
2012	2.23	2.92	2.30	3.93	1.84	1.26	0.63	0.19	0.20	1.91	3.68	2.13	1.9
2013	1.29	1.91	4.02	4.36	2.56	0.89	0.19	0.22	1.25	1.21	1.16	0.60	1.6
2014	2.14	1.49	3.26	2.97	1.08	0.28	0.35	0.17	0.29	3.71	3.22	2.69	1.8
2015	2.68	2.82	1.93	1.41	0.32	0.14	0.02	0.19	0.82	1.28	2.29	3.17	1.4
2016	4.16	3.78	4.06	0.81	0.10	0.11	0.24	0.13	0.54	4.81	5.41	0.94	2.1
2017	1.99	3.08											
Avg	2.88	2.72	2.47	2.35	1.46	0.65	0.28	0.18	0.54	1.75	3.06	2.41	1.73
Min	1.29	1.49	1.27	0.81	0.10	0.11	0.02	0.06	0.20	0.27	0.73	0.60	1.2
Max	5.17	5.84	4.39	4.36	3.54	1.49	0.63	0.45	1.25	4.81	5.67	5.62	2.3
Avg UR (l/s/km^2)	52	49	45	43	26	12	5	3	10	32	55	44	31

Notes:

1) Unit Runoff is based on an intake drainage area of: 55.1 km2

2) Simulated Data from 1988-1995 is from scaled Lang Creek and from 2004-2017 is from MMR results against Theodosia and Robert's Creek.

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7 FIGURES

Notes:
1) This satellite image is from Google Earth.
2) This image is tilted and therefore does not have a constant scale.

TLA'AMIN CAPITAL ASSETS INC.	
KWAHTUM TEESHOHSUM HYDROELECTRIC	
KWAHTUM TEESHOHSUM SATELLITE IMAGE	
AQUARIUS Research & Development Inc.	Figure 2
VER 0.6 / May 27, 2017	

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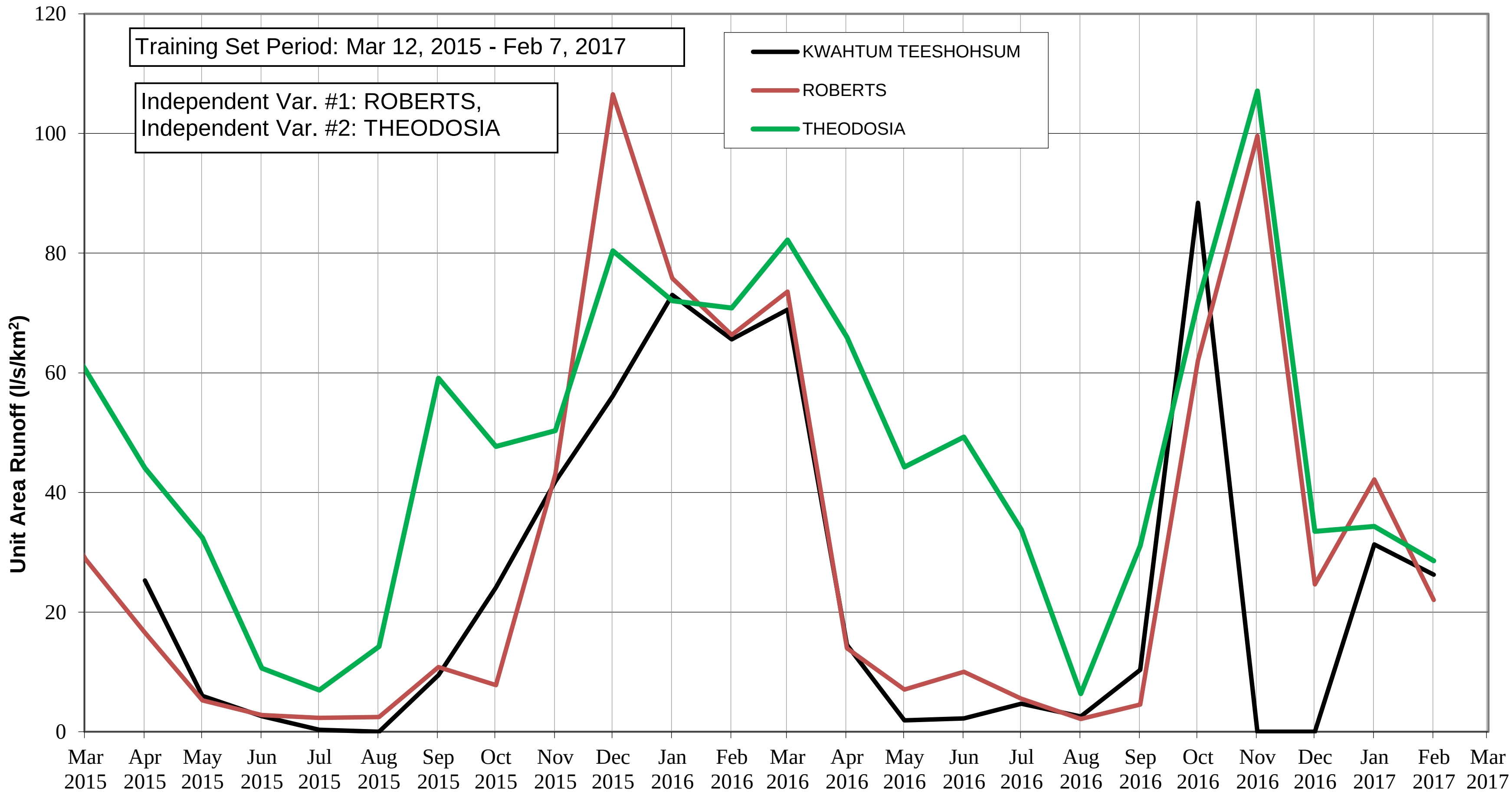
Figure 2: Kwahtum Teeshohsum Satellite Image



Notes:

1) This figure shows higher flows in April 2015 at Tla'amin than at Robert's Creek. Data is missing from Tla'amin in Jun-Jul 2015 and from Nov 2016-Jan 2017.

TLA'AMIN CAPITAL ASSETS INC.

KWAHTUM TEESHOHSUM HYDROELECTRIC PROJECT

COMPARISON OF REGIONAL MONTHLY UNIT RUNOFF (2015-2017)

AQUARIUS Research & Development Inc.

Ver 0.1.6 | May 27, 2017

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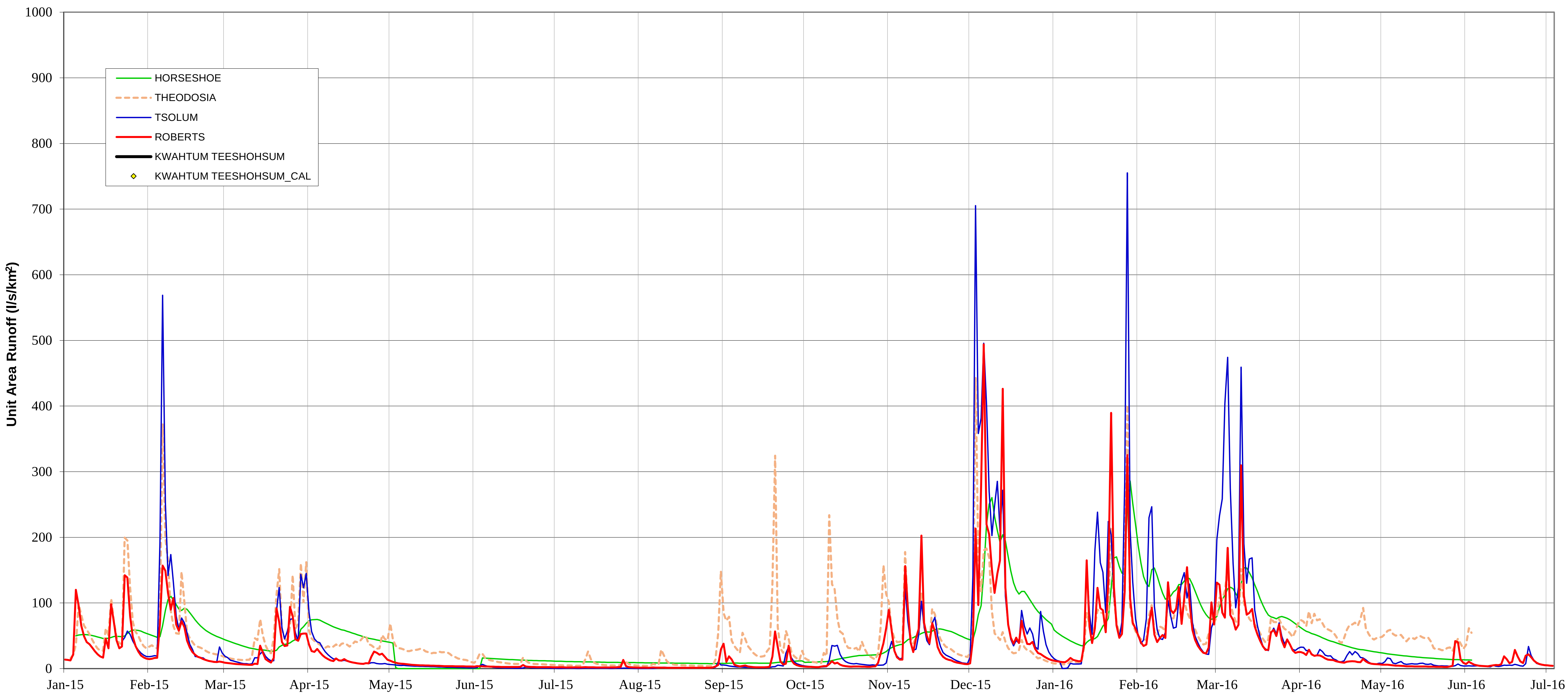
Figure 3: Comparison of Regional Monthly Unit-Runoff (2015-2017)

Figure 3



Notes:

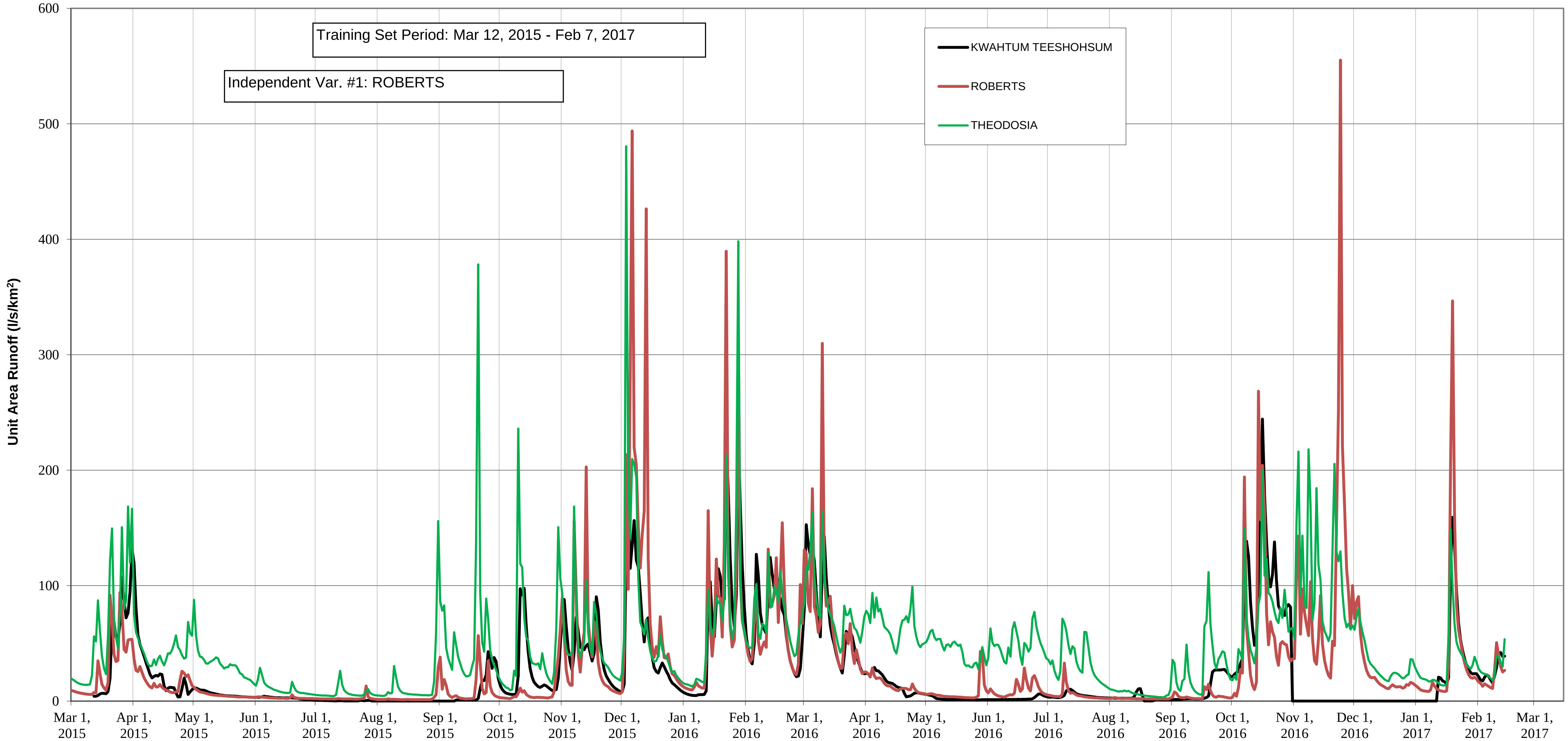
1) This runoff is based on the following drainage areas in km²: Horseshoe River Above Lois Lake: 133.2, Theodosia River Above Scotty Creek: 94.9, Tsolum River Near Courtenay: 264, Roberts Creek at Roberts Creek: 32.6, Kwahtum Teeshohsum Gauge at 125m: 43.6..

2) The Roberts Creek gauge best matches Kwahtum Teeshohsum from April to September, while Theodosia best matches from October to March.

TLA'AMIN CAPITAL ASSETS INC.	
KWAHTUM TEESHOHSUM HYDROELECTRIC PROJECT	
COMPARISON OF REGIONAL DAILY UNIT RUNOFF (2015-0-2016)	
AQUARIUS Research & Development Inc. Ver 0.1.1 May 27, 2017	Figure 4

C:\Users\FATHOM\Desktop\DK\Sliammon\data\[Sliammon_Regional_Compare_V0.1.2.xlsx]Notes

Figure 4: Comparison of Regional Daily Unit-Runoff (2015-2016)



Notes:
1) Kwahtum Teeshohsum is highly correlated with Roberts Creek, except in summer and early fall when the Tla'amin lake regulates outflow. Theodosia has much larger snowpacks than Kwahtum Teeshohsum, but display similar storm hydrographs in March and November..

TLA'AMIN CAPITAL ASSETS INC.

KWAHTUM TEESHOHSUM HYDROELECTRIC PROJECT

COMPARISON OF REGIONAL DAILY UNIT RUNOFF (2015-2017)

AQUARIUS Research & Development Inc. | Ver 0.1.6 | May 27, 2017 | Figure 5

C:\Users\FATHOM\Desktop\DK\Sliammon\data\[Tla-amin_Theodosia_Roberts_ARM_v0.1.7.xlsx]Notes

Figure 5: Comparison of Regional Daily Runoff (2015-2017)

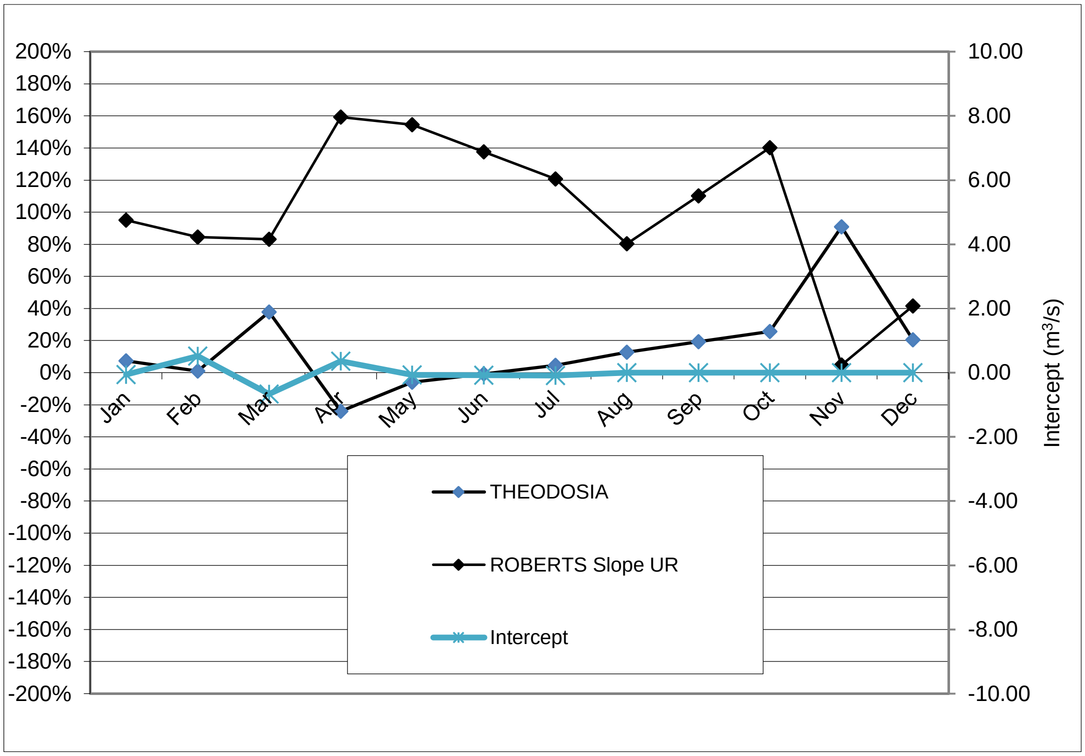
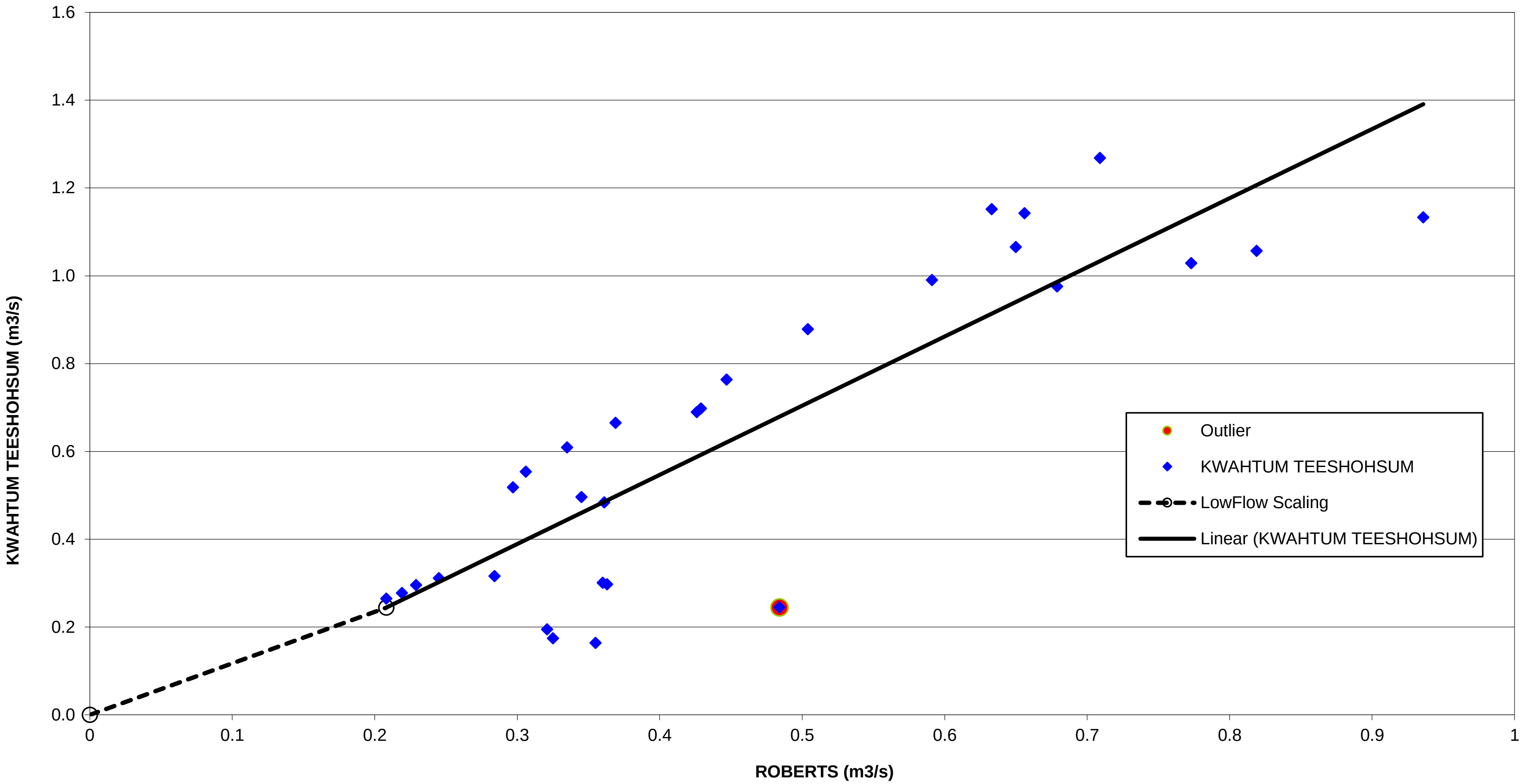


Figure 6: Plot of Regression Coefficients as % Unit Runoff and Intercept at Kwahtum Teeshohsum

Based on this analysis, Kwahtum Teeshohsum is most highly correlated with Robert's Creek, which is much further south than Theodosia, but is more similar in catchment characteristics. Storms in November and March better match those from Theodosia due to proximity and the transitional nature of the Theodosia hydrograph at these times.

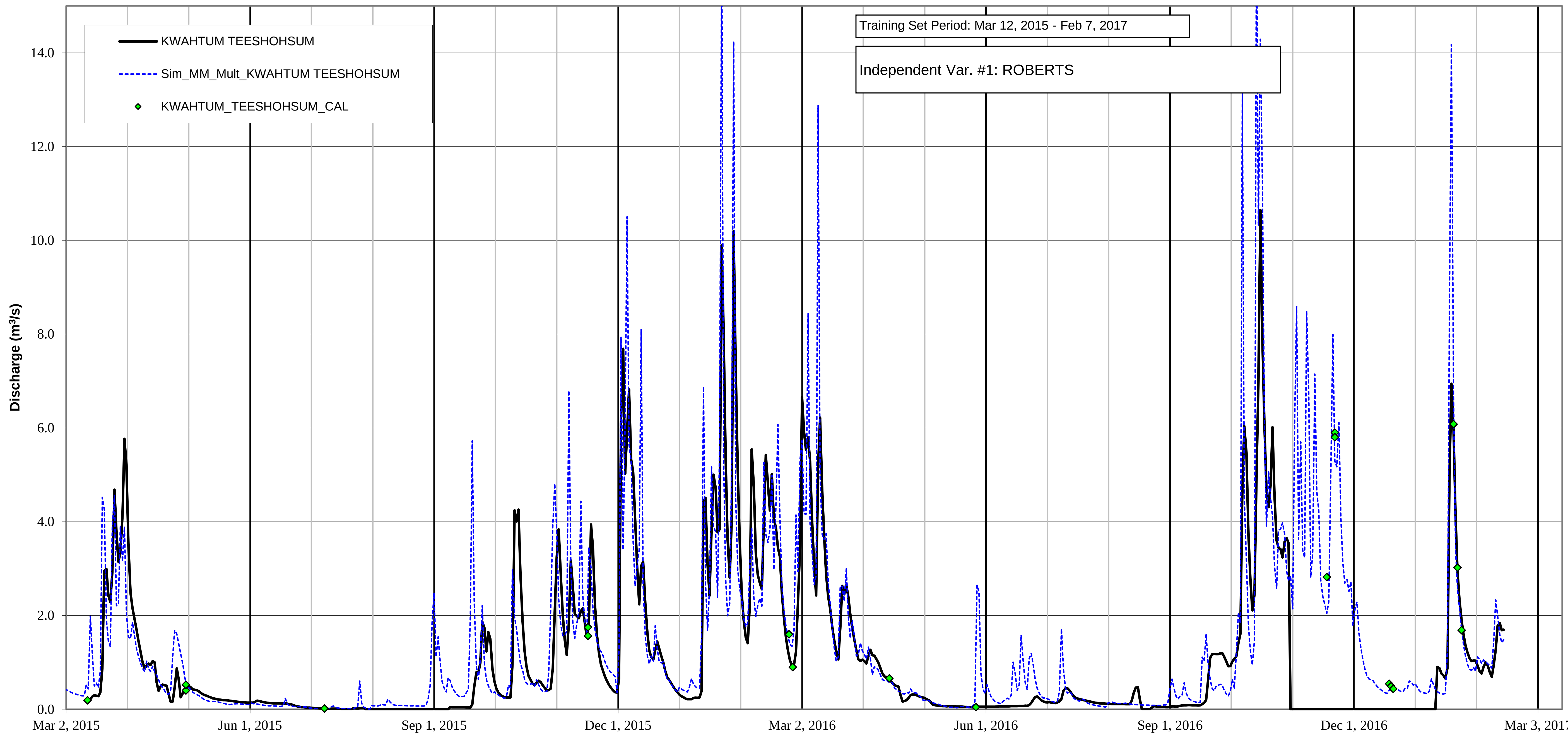


Notes:
1) Regression equation and line are for a single regression between Kwahtum Teeshohsum and Robert's Creek. The Low Flow scaling line is a means to avoid negative flows.

TLA'AMIN CAPITAL ASSETS INC.	
KWAHTUM TEESHOHSUM HYDROELECTRIC PROJECT	
KWAHTUM TEESHOHSUM: ROBERTS CREEK DISCHARGE REGRESSION RELATIONSHIP FOR APRIL	
AQUARIUS Research & Development Inc. Ver 0.1.6 May 27, 2017	Figure 7

C:\Users\FATHOM\Desktop\DK\Wady\[Wady_Zeballos_ARM_v0.7.xlsx]Notes

Figure 7: Kwahtum Teeshohsum Discharge Regression Analysis for April



Notes:

1) The match is very good in 2015-2017. The Kwahtum Teeshohsum gauge failed on Oct 30, 2016 to Jan 20, 2017, but manual measurements during that period agree with the derived synthetic flows.

2) There is a discrepancy between measured and synthetic flows in the summer and early fall when the Kwahtum Teeshohsum lake acts as a reservoir.

TLA'AMIN CAPITAL ASSETS INC.

KWAHTUM TEESHOHSUM HYDROELECTRIC

KWAHTUM TEESHOHSUM COMPARED TO SYNTHETIC FLOW (2015-2017)

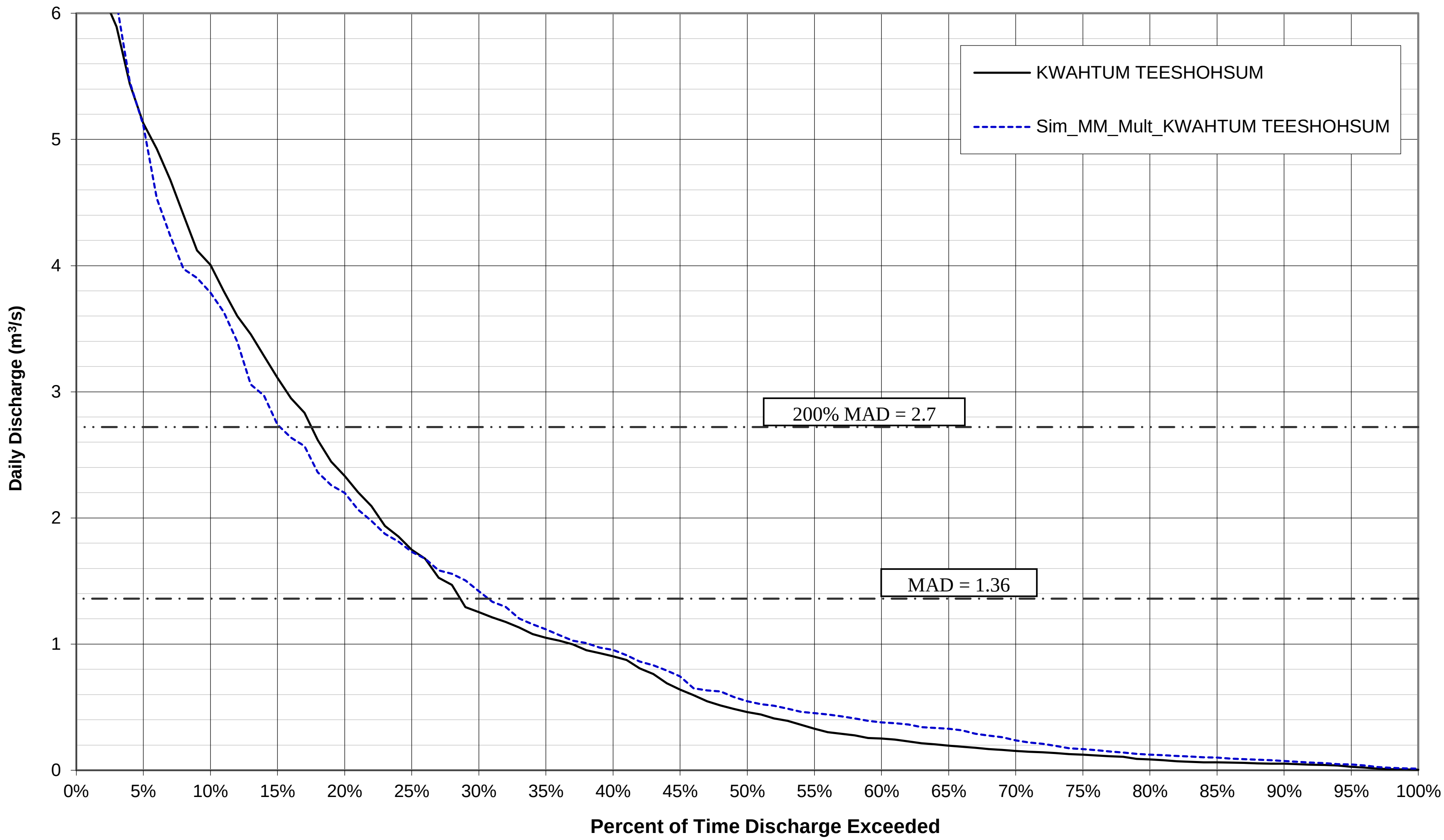
AQUARIUS Research & Development Inc.

Figure 8

Ver 0.1.6 | May 27, 2017

C:\Users\FATHOM\Desktop\DK\Sliammon\data\[Tla-amin_Theodosia_Roberts_ARM_v0.1.7.xlsx]Notes

Figure 8:: Kwahtum Teeshohsum Gauge Synthetic Daily Flow Series compared with Measured: 2015-2017



Notes:
1) This period of comparison is for Mar 12, 2015 to Feb 14, 2017, which includes both the training set and validation set of data.
2) The match is very good over this range.

TLA'AMIN CAPITAL ASSETS INC.

KWAHTUM TEESHOHSUM HYDROELECTRIC PROJECT

COMPARISON OF FLOW DURATION CURVES FOR MEASURED AND SIMULATED (2015-2017)

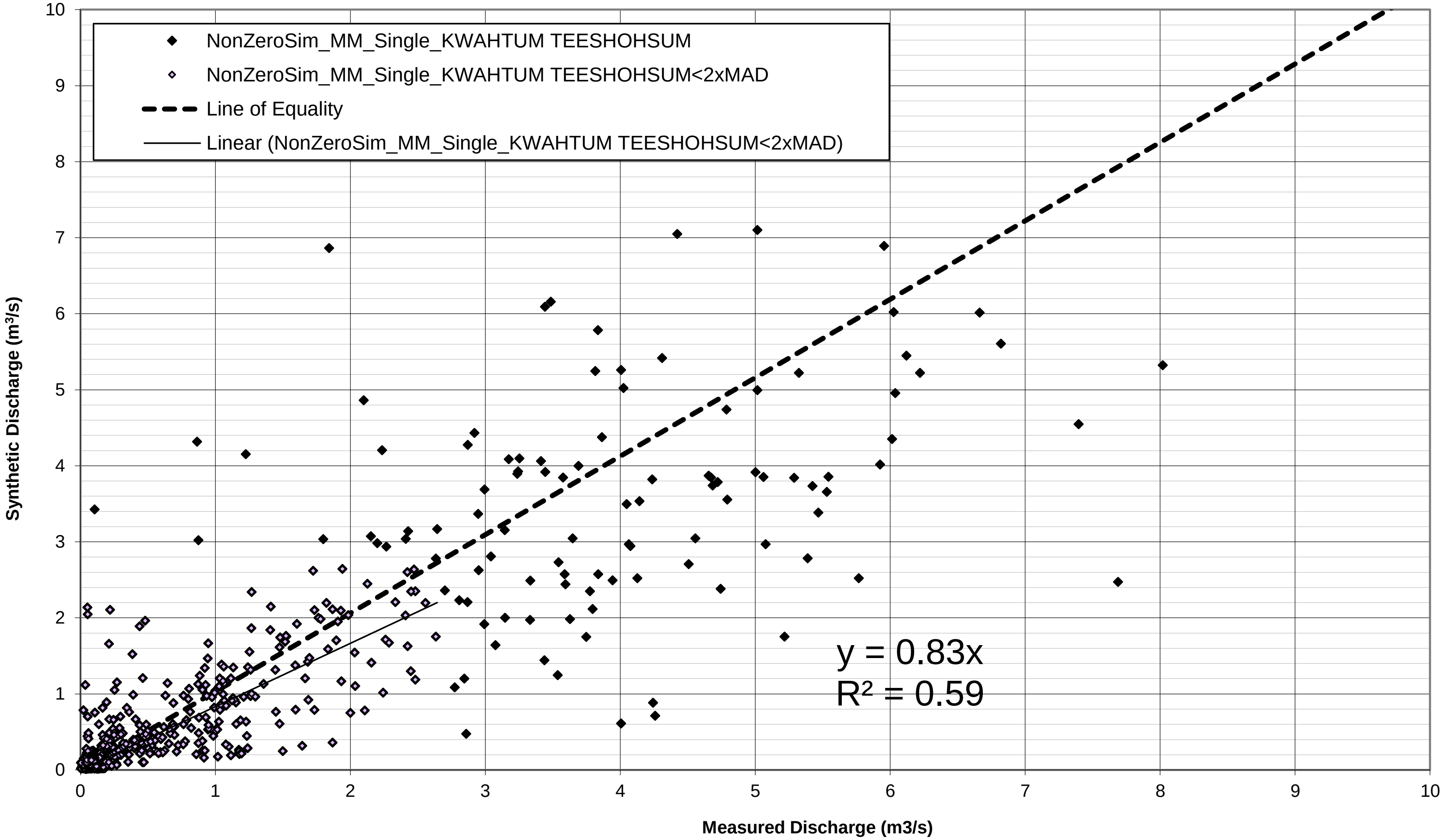
AQUARIUS Research & Development Inc.

Figure 9

Ver 0.1.6 | May 27, 2017

C:\Users\FATHOM\Desktop\DK\Sliammon\data\[Tla-amin_Theodosia_Roberts_ARM_v0.1.7.xlsx]Notes

Figure 9: Kwahtum Teeshohsum Gauge Synthetic FDC Compared with Measured FDC



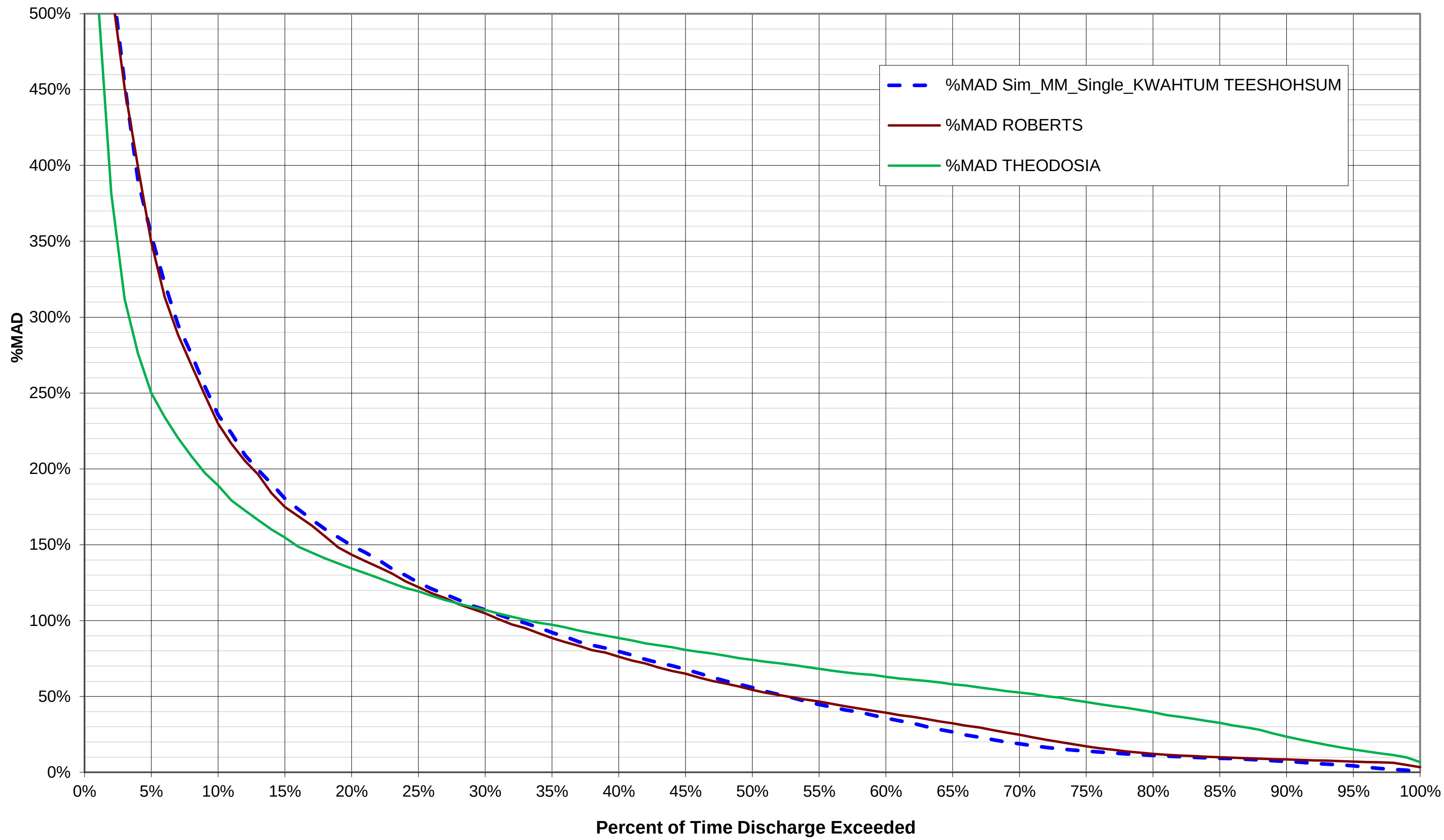
Notes:

1) This scatter plot comparison shows a weak match over the entire period of record with an R2 of 0.59 and slope of 0.83.. This is partially due to the regulation of the Kwahtum Teeshohsum Lake upstream of the gauge.

TLA'AMIN CAPITAL ASSETS INC.	
KWAHTUM TEESHOHSUM HYDROELECTRIC PROJECT	
SCATTERPLOT COMPARISON OF MEASURED AND SYNTHETIC FLOWS AT KWAHTUM TEESHOHSUM	
AQUARIUS Research & Development Inc. — Ver 0.1.6 — May 27, 2017	Figure 10

C:\Users\FATHOM\Desktop\DK\Sliammon\data\[Tla-amin_Theodosia_Roberts_ARM_v0.1.7.xlsx]Notes

Figure 10: Measured Kwahtum Teeshohsum Gauge Daily Discharge Compared with Simulated Discharge

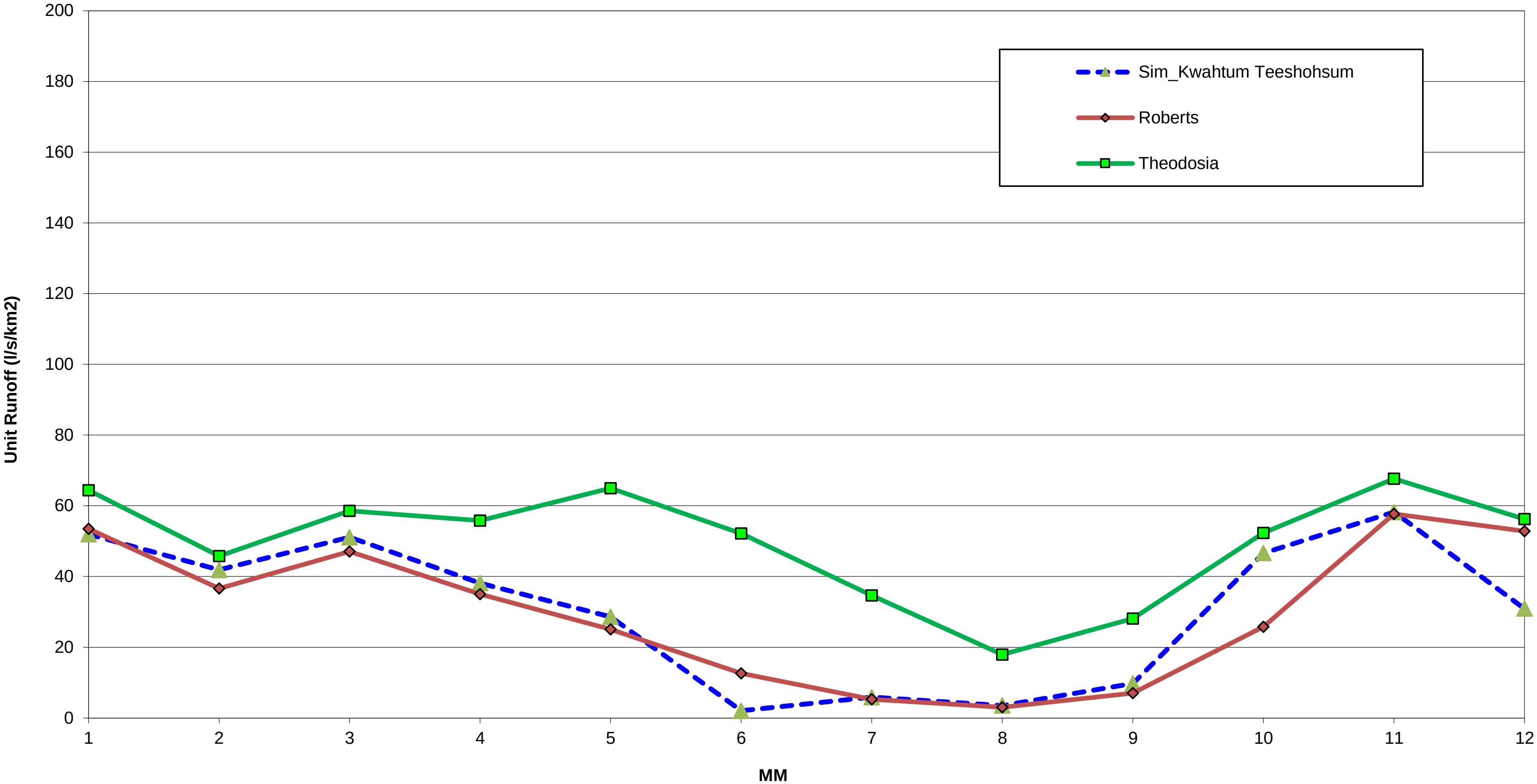


Notes:
1) This figure shows that Roberts Creek and Kwahtum Teeshohsum have very similar FDCs while Theodosia's larger snowpack results in a more regulated FDC.

TLA'AMIN CAPITAL ASSETS INC.	
KWAHTUM TEESHOHSUM HYDROELECTRIC	
COMPARISON OF FLOW DURATION CURVES EXPRESSED AS %MAD	
AQUARIUS Research & Development Inc. — Ver 0.1.6 — May 27, 2017	Figure 11

C:\Users\FATHOM\Desktop\DK\Sliammon\data\[Tla-amin_Theodosia_Roberts_ARM_v0.1.7.xlsx]Notes

Figure 11: Daily % MAD FDC Comparison.



Notes:
1) Sim_Kwahtum Teeshohsum has a similar hydrograph to Roberts but a slighly larger freshet, and larger fall storms

TLA'AMIN CAPITAL ASSETS INC.	
KWAHTUM TEESHOHSUM HYDROELECTRIC PROJECT	
KWAHTUM TEESHOHSUM REGIONAL MONTHLY UNIT-RUNOFF HYDRGRAPHS	
AQUARIUS Research & Development Inc. — Ver 0.1.6 — May 27, 2017	Figure 12

C:\Users\FATHOM\Desktop\DK\Sliammon\data\[Tla-amin_Theodosia_Roberts_ARM_v0.1.7.xlsx]Notes

Figure 12: Monthly Kwahtum Teeshohsum Unit-Runoff Compared to Regional (Jan 1986-October 2016)

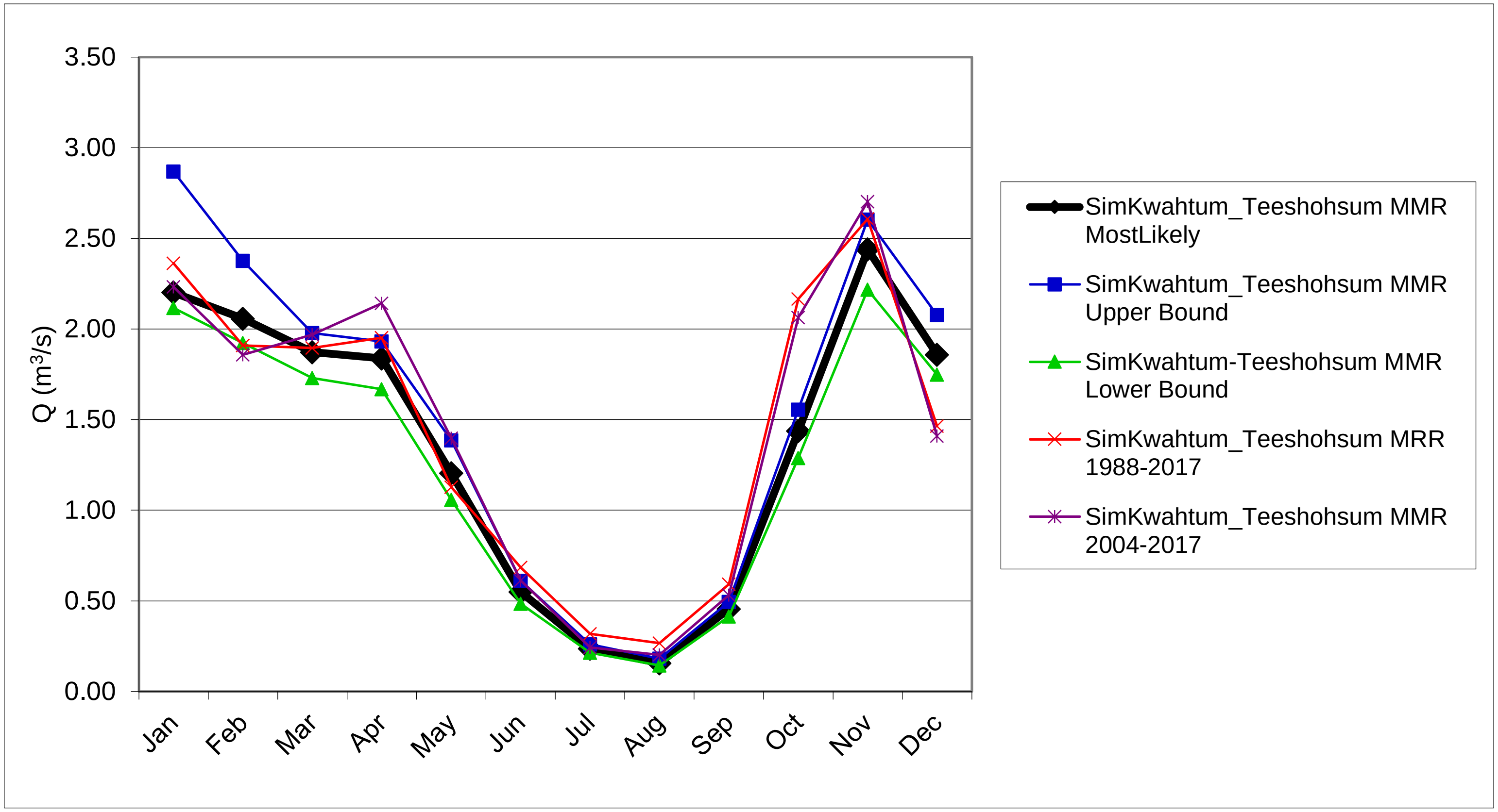


Figure 13: Monthly Average Discharge Uncertainty

The thick black line represents the most likely MMR results. These alternate hydrographs should be considered anecdotal, and not given much consideration except in defining the uncertainty.

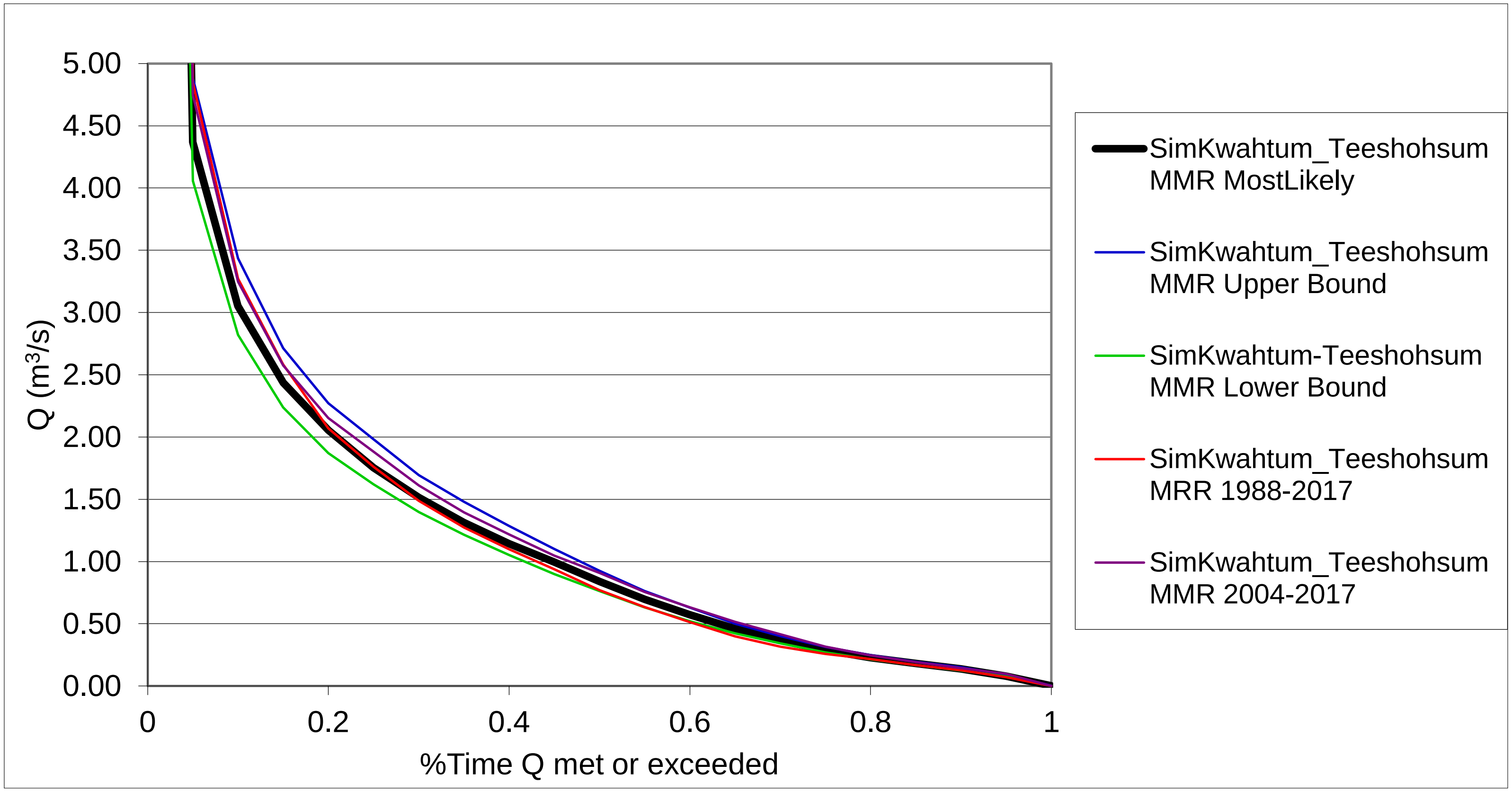


Figure 14: Daily FDC as a function of Regression Training Set

The thick black line represents the most likely MMR results between Theodosia and Roberts Creek. The shapes of the other possible FDCs are similar to the most likely. The largest source of uncertainty is from the rating curve.

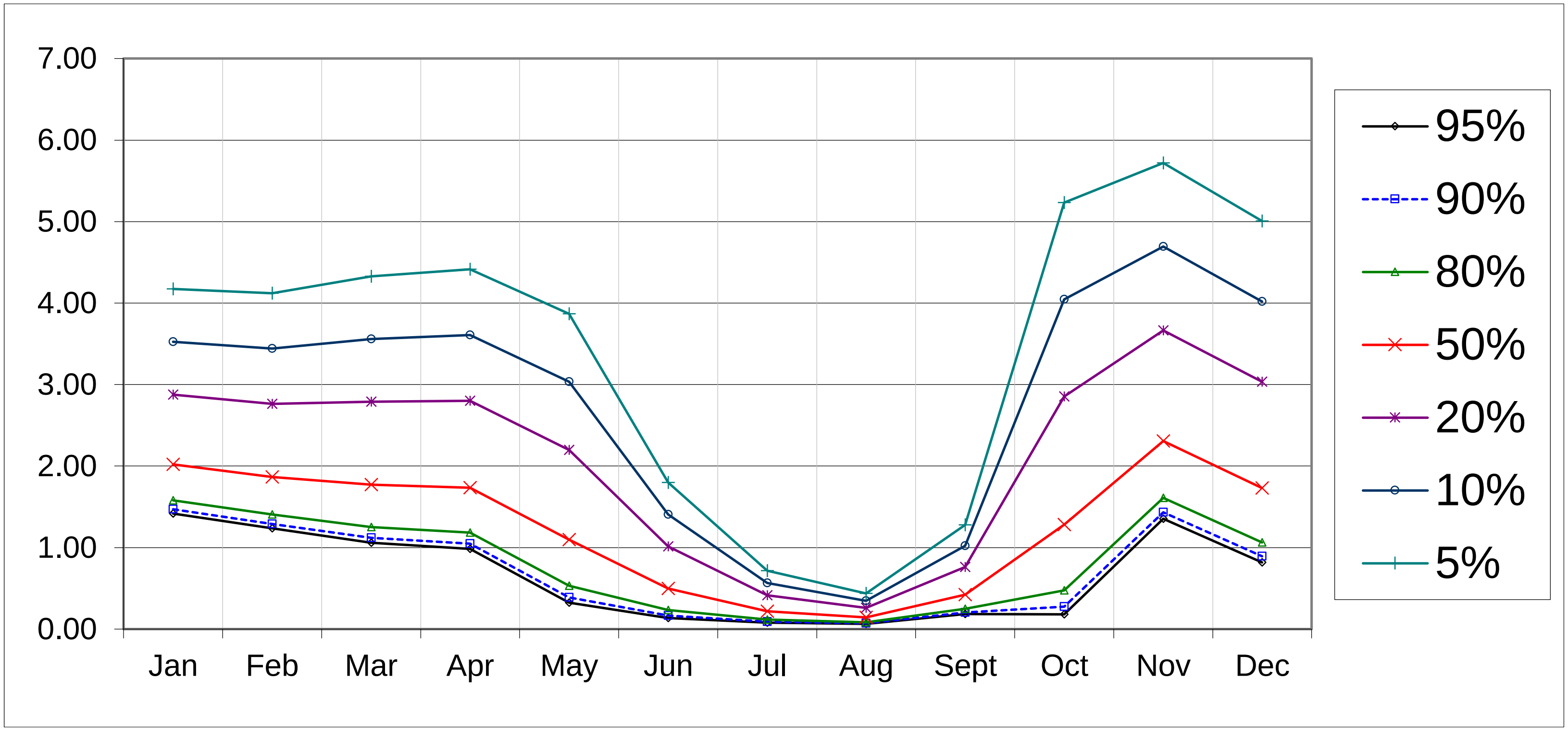


Figure 15: Summary Plot of Mean Monthly Flows for the 5-, 10-, and 20- year Dry and Wet Return Periods at the Kwahtum Teeshohsum Intake

This figure shows the Hydrograph for the probability that the mean monthly flow will be wetter one year. For example, in any given year, there is only a 5% chance that the mean monthly flow at the gauge site will be larger than 0.75 m^3/s in June. This translates to a 20-year return period. The corresponding Wet return periods are 5%:20year, 10%:10year, 20%:5year. The 50% hydrograph is the median of average monthly discharges, not the average of average monthly discharges. The 80% series corresponds to an 80% probability that the particular month will be wetter one year, or a 20% probability that it will be drier, which in turn corresponds to a 5 year dry return period. The dry return periods are 80%:5year, 90%:10 year, 95%:20year. These probabilities are based on a log normal fit to 20 complete water years of synthetic data.

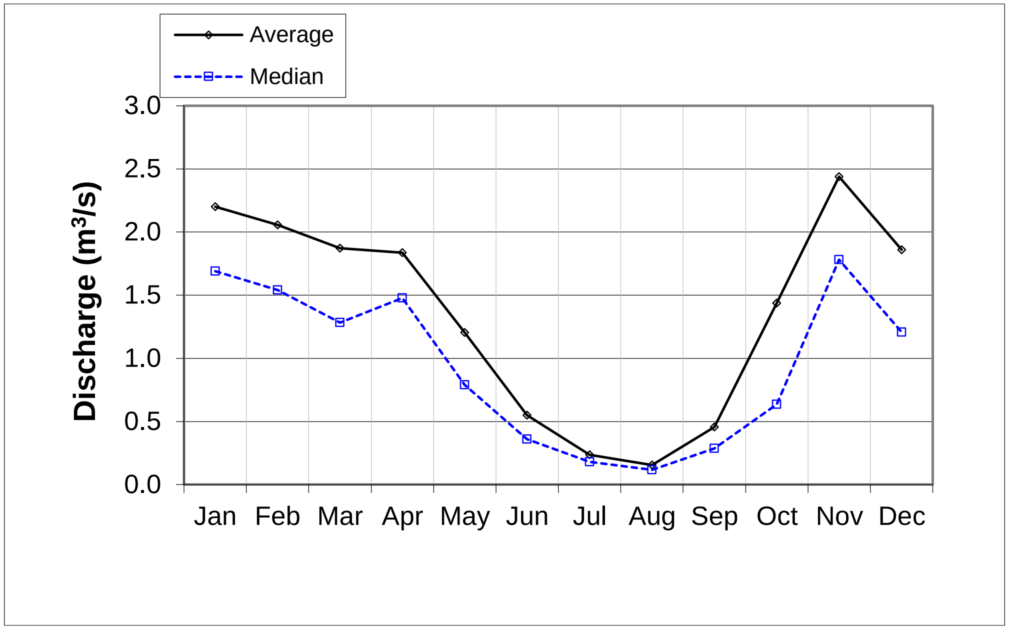
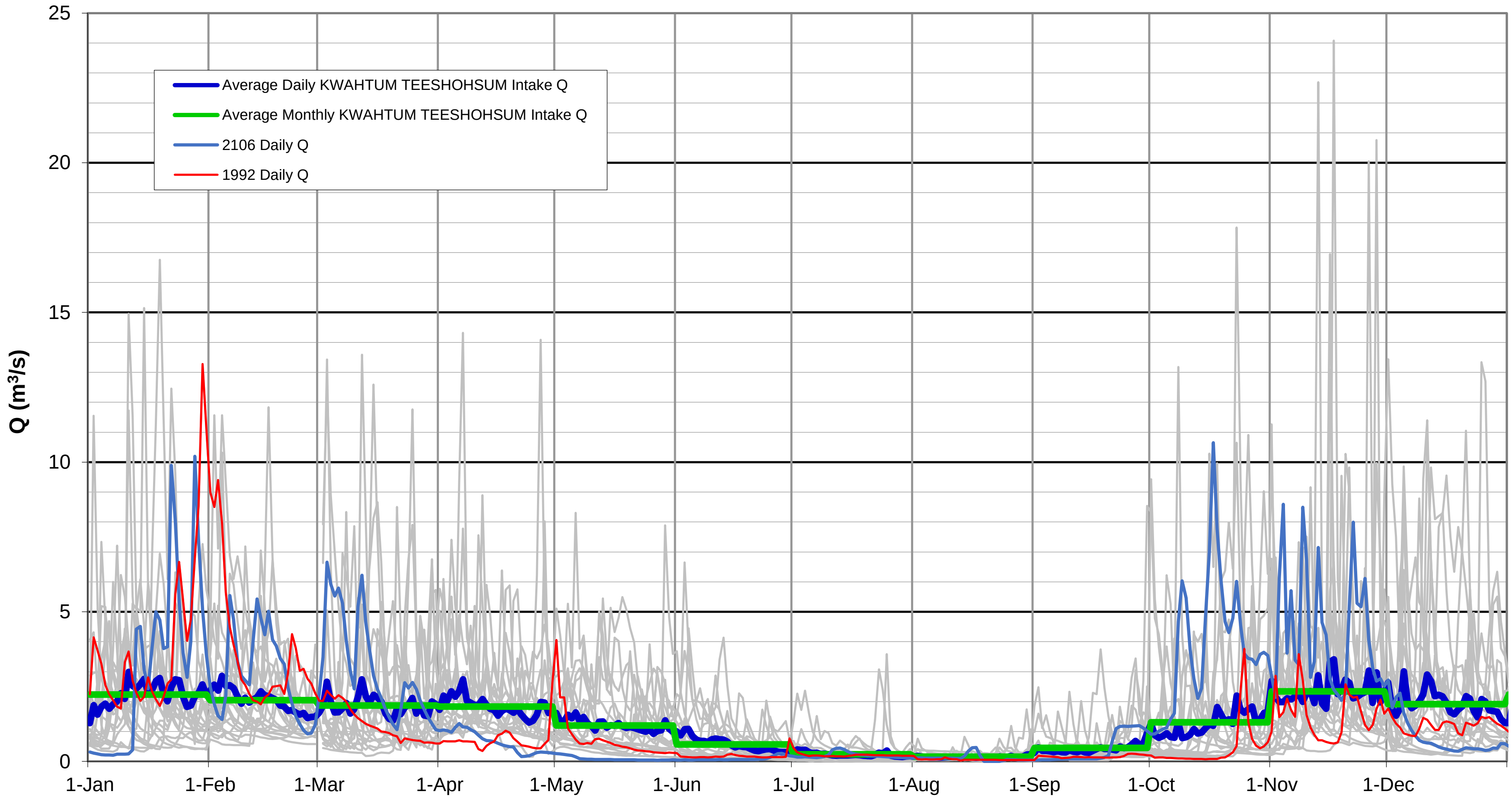


Figure 16: Comparison of Average and Median Daily Discharges at the proposed intake (DA: 43.6 km²)

Because of the skew in the dataset towards lower flows, the median daily flows for all months are lower than the average monthly flows, as expected. This figure includes tributary contributions.



Notes:
1) The average Q over this 20 year period is 1.36 m^3/s for a DA of 43.6km^2.
2) 1992 is shown as an example year.

TLA'AMIN CAPITAL ASSETS INC.	
KWAHTUM TEESHOHSUM HYDROELECTRIC	
SPAGHETTI PLOT OF AVERAGE DAILY DISCHARGE AT KWAHTUM TEESHOHSUM	
AQUARIUS Research & Development Inc. — Ver 0.7 — May 27, 2017	Figure 17

C:\Users\FATHOM\Desktop\DK\Sliammon\data\[SimSliammonQ_v0.7.xlsx]Notes

Figure 17: Spaghetti Plot of Average Daily Discharge at Kwahtum Teeshohsum

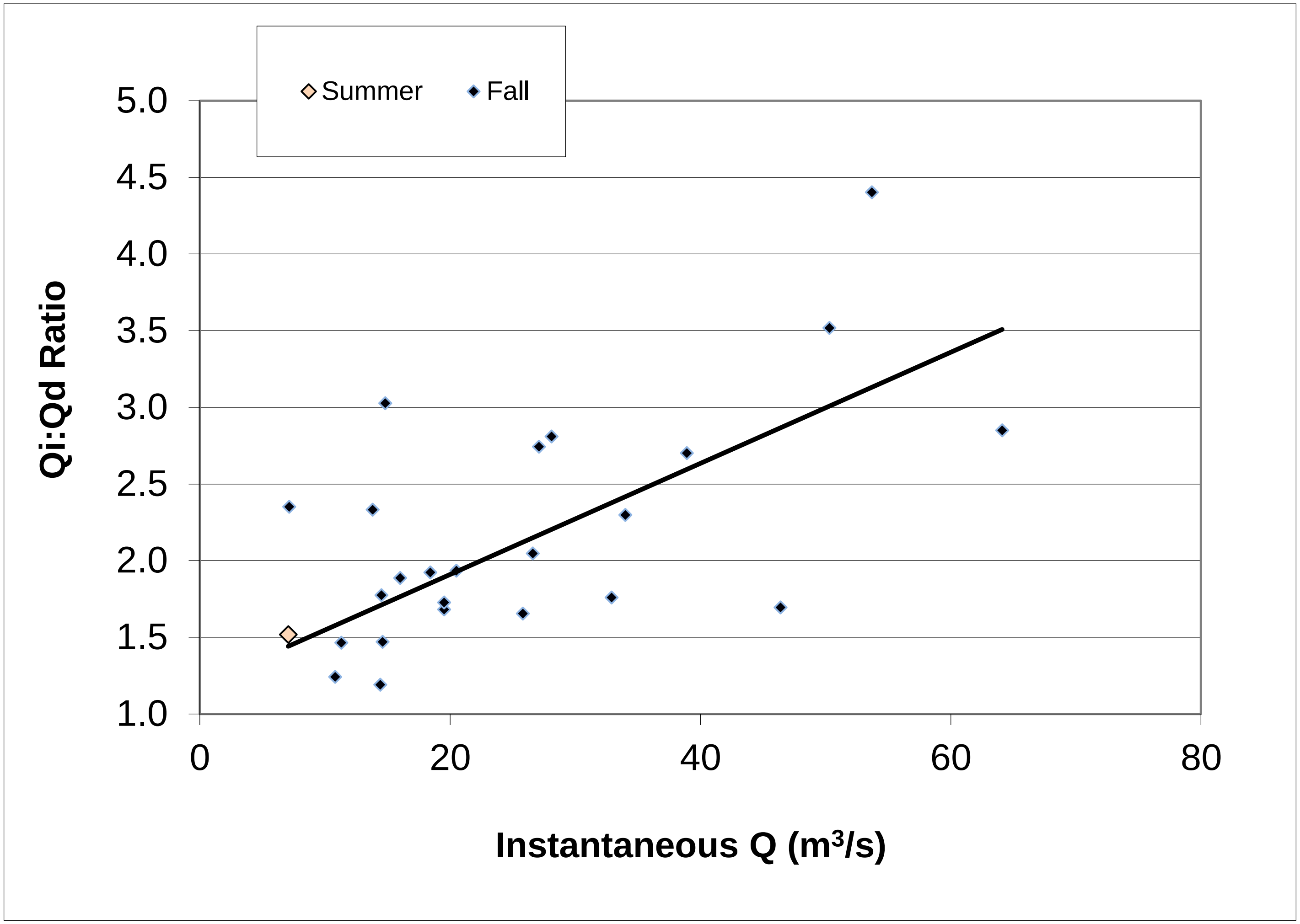
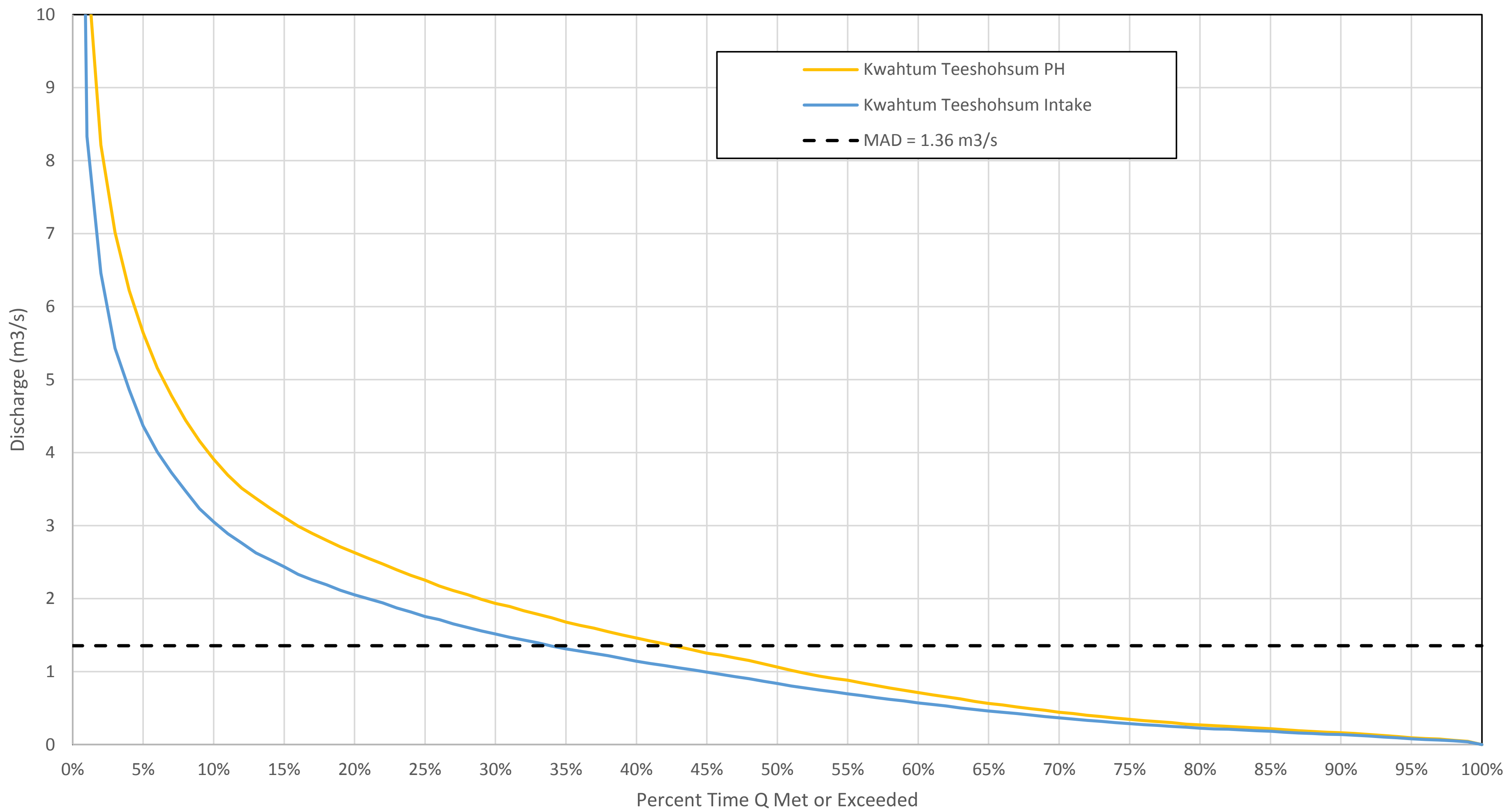


Figure 18: Ratio of Qi:Qd at Roberts Creek

Only concurrent (±1 day) instantaneous and daily average flows are considered. There is a positive relationship between the ratio and the instantaneous discharge. The largest measured Qi has a ratio of 2.8 in 1998. The largest ratio of 3.6 is for a the second smallest event.

S



Notes:
1)The estimated MAD at the intake of 1.36 m^3/s is met or exceeded 35% of the time. The Median daily flow is 0.83 m^3/s

TLA'AMIN CAPITAL ASSETS INC.	
KWAHTUM TEESHOHSUM HYDROELECTRIC PROJECT	
KWAHTUM TEESHOHSUM LONG TERM DAILY FDC	
AQUARIUS Research & Development Inc. — Ver 0.7 — May 27, 2017	Figure 19

C:\Users\FATHOM\Desktop\DK\Sliammon\data\[SimSliammonQ_v0.7.xlsx]Notes

Figure 19: Kwahtum Teeshohsum Long Term Daily FDC

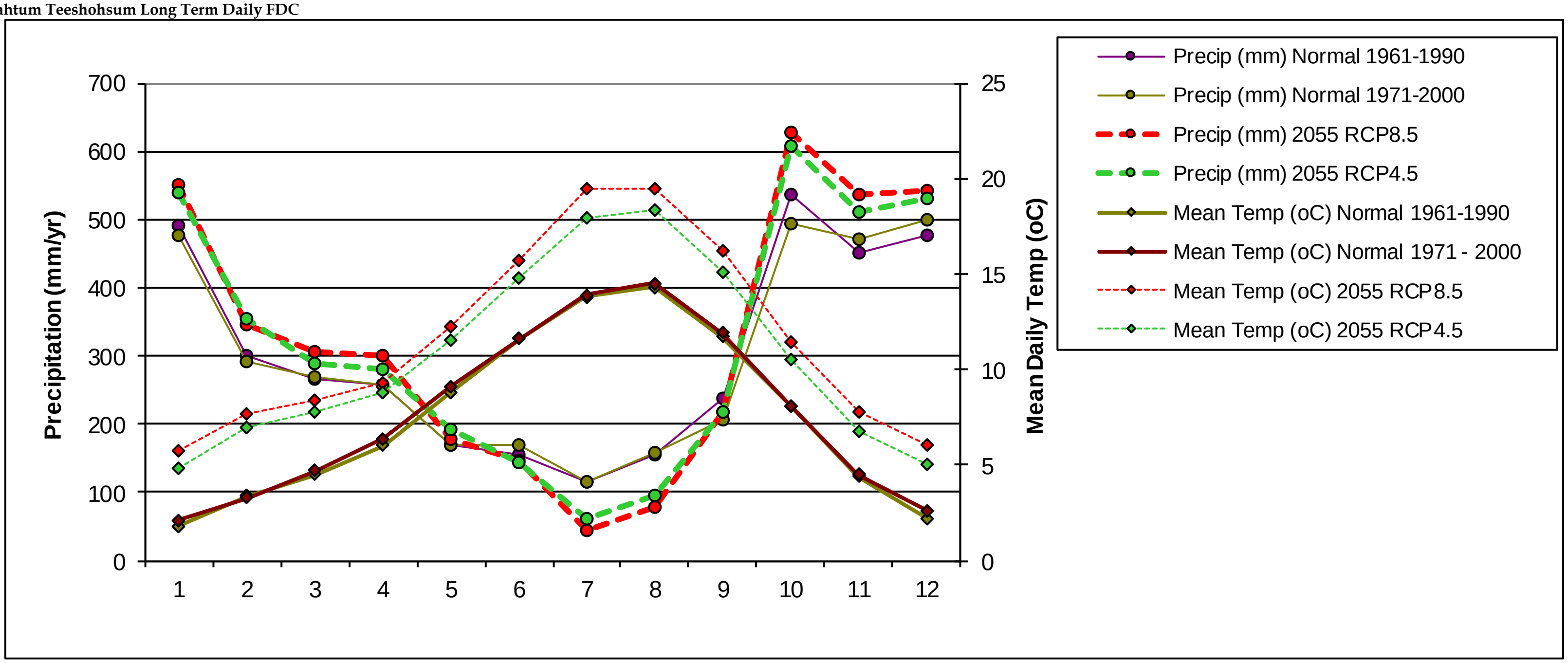


Figure 20: Comparison of Predicted Temperature and Precipitation Change

This data is based on data from CanESM2 / CGCM4 and PRISM model data using ClimateBCV5.10 comparing climate normals (1961-1990 and 1971-2000) and predicted climate change in 2055 for the worst case (RCP8.5) and best case (RCP4.5) climate scenarios. This figure shows temperatures increasing by 3.1°C (RCP4.5) to 4.0°C (RCP8.5) degrees on average, and precipitation increasing by 6%(RCP4.5) to 7% (RCP8.5) on average, with more fall-winter precipitation and less precipitation in May-Jun.

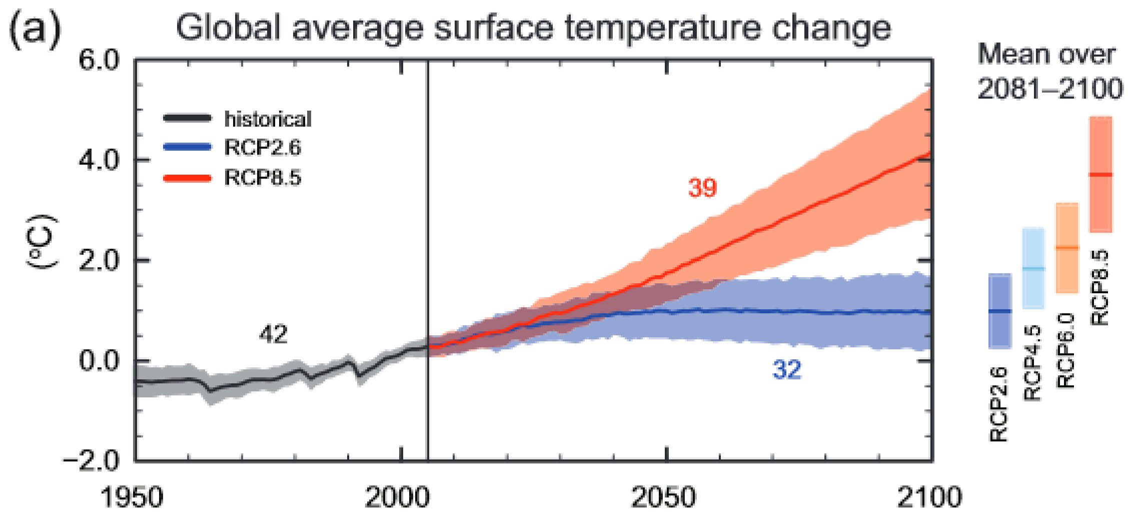
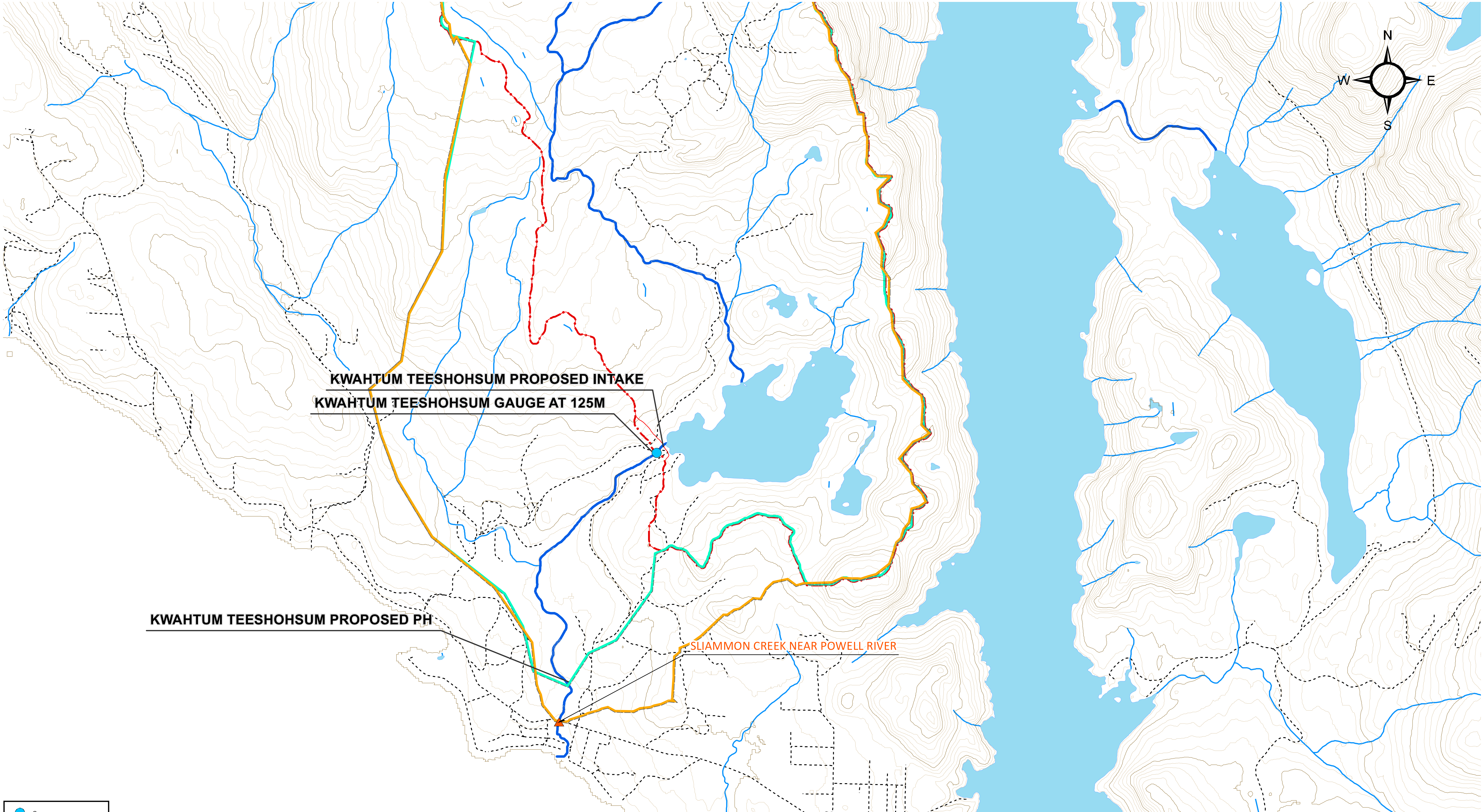


Figure 21: Global Average Surface Temperature Change

The Representative Concentration Pathways (RCPs) describe plausible alternative trends in the evolution of society and ecosystems over a century time scale. The number represents the increase in radiation. For example, RCP8.5 describes the radiative forcing pathway leading to 8.5 W/m^2(~1370 ppm CO2eq) by 2100. RCP 4.5 and RCP 2.6 assume climate policy intervention to transform associated reference scenarios. RCP 6.0 assumes climate policy intervention late in the century. RCP 8.5 does not include climate policy interventions.

APPENDIX A: MAPS



Legend

- Gauge
- WSC Station
- Project Catchment

contours_area_1_20m

Index100m

- Index contour (100m)
- Intermediate contour (20m)
- WSC Sliammon Catch
- Sliammon PH Catch

NOTES:

1. WATER FEATURES PROVIDED BY BC FRESHWATER ATLAS
2. ROAD FEATURES PROVIDED BY BC DIGITAL ROAD ATLAS.
3. ALL BEARINGS ARE CLOCKWISE FROM GRID NORTH
4. CADASTRE INFORMATION FROM BC ONLINE CADASTRE

SCALE 1:40,000

0 0.5 1 2 Kilometers

TLA'AMIN CAPITAL ASSETS INC.

KWAHTUM TEESHOHSUM GAUGE SITES

PREPARED BY: AQUARIUS R&D INC

DRAWN BY: AV

CHECKED BY: GS

DATE: JUN 10, 2017

DRAWING NUMBER: 100

REVISION NUMBER: 0.6

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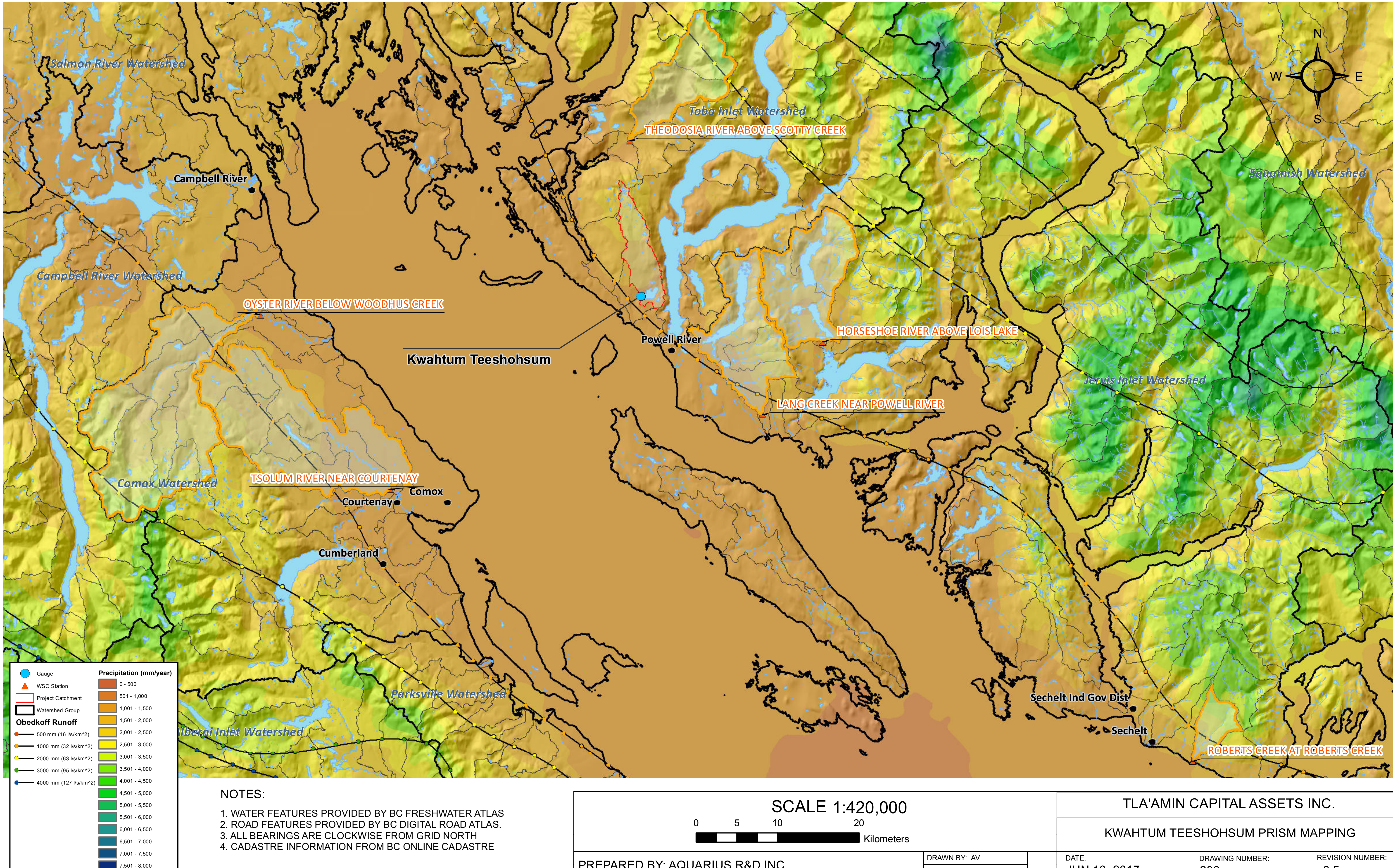


NOTES:

1. WATER FEATURES PROVIDED BY BC FRESHWATER ATLAS
2. ROAD FEATURES PROVIDED BY BC DIGITAL ROAD ATLAS.
3. ALL BEARINGS ARE CLOCKWISE FROM GRID NORTH
4. CADASTRE INFORMATION FROM BC ONLINE CADASTRE

SCALE 1:420,000

0 5 10 20 Kilometers

TLA'AMIN CAPITAL ASSETS INC.

KWAHTUM TEESHOHSUM PRISM MAPPING

PREPARED BY: AQUARIUS R&D INC	DRAWN BY: AV	DATE: JUN 10, 2017	DRAWING NUMBER: 202	REVISION NUMBER: 0.5
	CHECKED BY: GS			

Appendix B: Microhabitat Photos

Contrasting flows at SCIF-4 on September 9, 2015 (above) and February 25, 2016 (below).

Contrasting flows at SCIF-5 on August 13, 2015 (above) and February 25, 2016 (below).

Contrasting flows at SCIF-6 on August 12, 2015 (above) and February 25, 2016 (below).

Tla'amin Nation
SLIAMMON FIRST NATION

Appendix C: Fathom Scientific Output

Appendix C

Table C-1: Water Allocation Table provided by Fathom Scientific Ltd. (2018).

Water Licence No.	Licensee	Date	Type	Waterbody	Annual Quantity	Units	m^3/year	Yearly Max Q (m^3/s)	Limit per day	m^3/day	Daily Max Q (m^3/s)
116139	Tla'amin (formerly DFO)	8-May-03	Storage for conservation purposes	Sliammon Lake	1,320	acre feet per annum throughout the year	**1,628,196**				
112612	Tla'amin Nation	15-Jul-98	Divert, store, and use for waterworks	Sliammon Lake	40,296,000	gallons per yer (max. 184,000 gpd)	183,189	0.00581	184,000	836	0.009681
113456	Tla'amin Nation	15-Jul-98	Divert, store, and use for waterworks	Sliammon Lake	-	Max of 100,000 gpd throughout the whole year.	165,932	0.00526	100,000	455	0.005262
Water Reservation	Tla'amin Nation	11-Apr-14	Water Reservation under Treaty	Sliammon Cr./Appleton Cr.	11,225	11,225 cubic DAM of water per year, but cannot >29% of the monthly flow in Sliammon Cr. 1834099 per month in November	112,250				
						Total Licensed	1,977,318	0.01107	284,000	1,291	**0.01494**
						Total Licensed+Reseved	2,089,568				

NOTES

A] Maximum Licenced Withdrawal of 0.01494 is based on the maximum Daily withdrawal limits.

B]Total licensed withdrawal is 21.4% of licensed storage volume.

Ver 0.6

Table C-2: Lake Area-Storage-Elevation Curve provided by Fathom Scientific Ltd. (2018).

WSE (mASL)	Area (m^2)	Storage (m^3)	Storage[A] (Mm^3)	Gross Head[B] (m)	Capacity[C] (Mm^3)
123	1898205	0	0.000	83.0	1.630
122	1779313	1838759	1.839	82.0	-0.21
121	1670000	1724657	1.725	81.0	-1.93
120	1550000	1610000	1.610	80.0	-3.54
119	1410000	1480000	1.480	79.0	-5.02
Meters down from top for Zero Capacity				0.90	

Notes

A) Storage between contours (in million of m^3)

B) Capacity is remaining storage in reservoir using the proposed active storage at a given WSE.

Ver 0.4

Table C-3: Storage Model Scenario Outcomes provided by Fathom Scientific Ltd. (2018).

Scenario			S1		S2		S3		S4		S5		S6		S7
Nominal IFR (10%MAD) (m^3/s)			0.136		0.136		0.136		0.136		0.250		0.500		0.500
Licensed Withdrawal (m^3/s)			0.01494		0.01494		0.01494		0.01494		0.01494		0.01494		0.01494
Storage (Mm^3)			-		0.500		1.100		1.630		1.630		1.630		5.100
Maximum Lake WSE (mASL)			122.00		123.00		123.00		123.000		123.00		123.000		125.000
Minimum Lake WSE (mASL)			122.00		122.75		122.39		122.10		122.10		122.10		122.49
Days of Storage for L.W. + IFR			-		38		84		125		71		37		114
Month	**# of Years in Model**	**#of Years**	**%Time IFR+ LW Met**	**# of Years**	**%Time IFR+ LW Met**	**# of Years**	**%Time IFR+ LW Met**	**# of Years**	**%Time IFR+ LW Met**	**# of Years**	**%Time IFR+ LW Met**	**# of Years**	**%Time IFR+ LW Met**	**# of Years**	**%Time IFR+ LW Met**
Jan	22	22	100%	22	100%	22	100%	22	100%	22	100%	22	100%	22	100%
Feb	22	22	100%	22	100%	22	100%	22	100%	22	100%	22	100%	22	100%
Mar	22	22	100%	22	100%	22	100%	22	100%	22	100%	22	100%	22	100%
Apr	21	21	100%	21	100%	21	100%	21	100%	21	100%	21	100%	21	100%
May	21	19	90%	20	95%	21	100%	21	100%	21	100%	21	100%	21	100%
Jun	21	14	67%	19	90%	21	100%	21	100%	21	100%	19	90%	21	100%
Jul	21	6	29%	18	86%	21	100%	21	100%	21	100%	14	67%	21	100%
Aug	21	2	10%	9	43%	21	100%	21	100%	21	100%	6	29%	21	100%
Sep	21	11	52%	17	81%	21	100%	21	100%	20	95%	3	14%	21	100%
Oct	21	18	86%	20	95%	21	100%	21	100%	21	100%	9	43%	21	100%
Nov	21	21	100%	21	100%	21	100%	21	100%	21	100%	19	90%	21	100%
Dec	21	21	100%	21	100%	21	100%	21	100%	21	100%	21	100%	21	100%

Notes

A] This is simply a study in volume of active storage, not inundation, and assumes a stage (WSE) dependent Q through the fishway.

B] The "# of Years" is the number of years for a particular month that the Licensed Withdrawal + IFR is met 100% of the time.

C] S1 assumes no active storage.

D] S2 assumes no multi-year storage (equal to 29% of total licensed storage).

E] S3 is smallest volume of storage to achieve 100% IFR and licensed withdrawal (equal to 67% of total licensed storage).

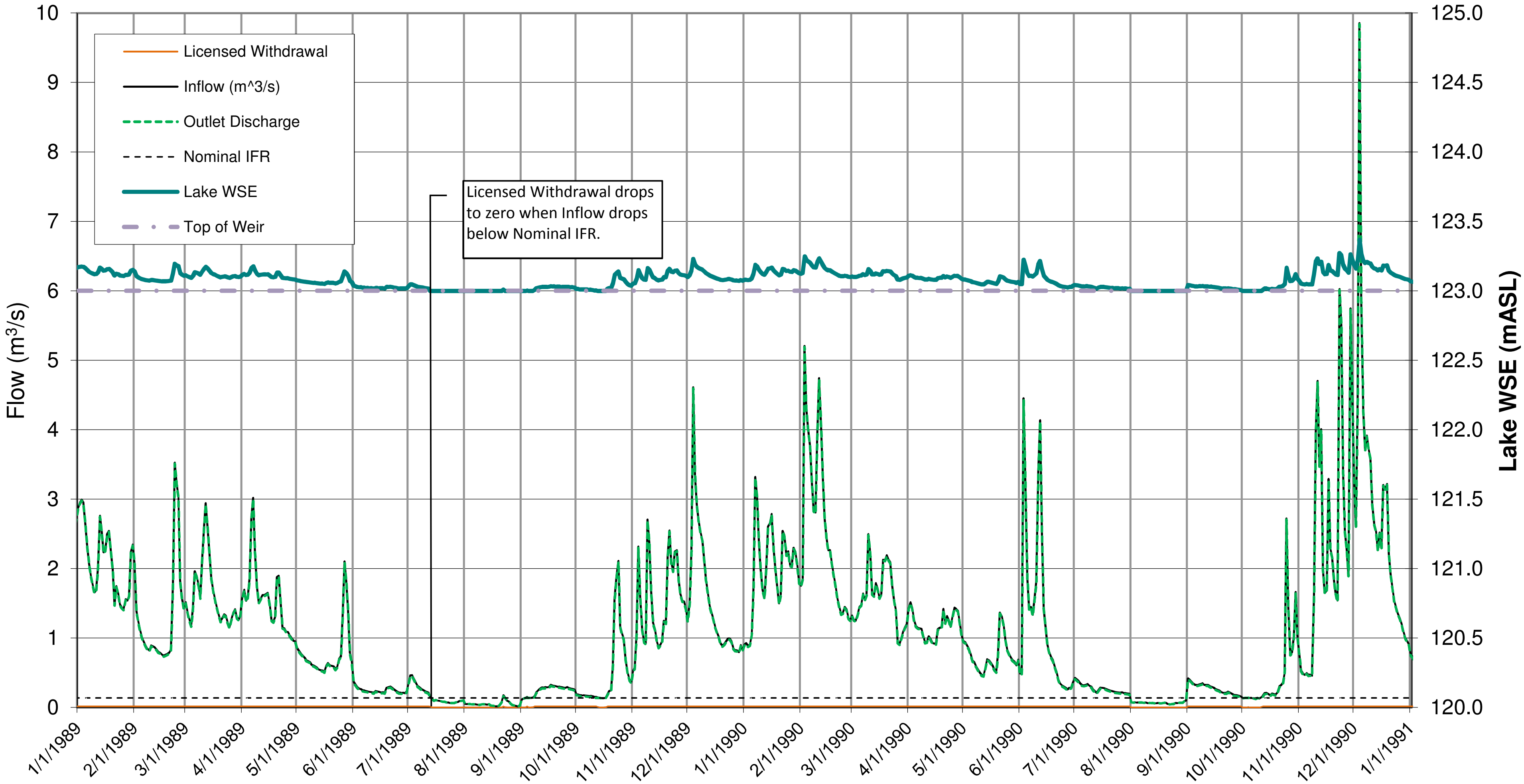
F] S4 uses the total licensed storage (1.63 Mm^3)

G] S5 uses the total licensed storage (1.63 Mm^3) and an IFR of 0.25m^3/s

H] S6 uses the total licensed storage (1.63 Mm^3) but increases the IFR to 0.50 m^3/s. The currently licensed storage cannot meet this IFR 100% of the time.

I] S7 uses a storage volume of 5.1 Mm^3/s which raises the lake about 2.5-3m above the current lake level, in order to meet the hypothetical IFR of 0.50m^3/s

Ver 0.6



Notes:

1) Licensed Withdrawal is the total licensed flow (0.01494 m^3/s). In scenario S1, 0 Mm^3 (i.e. Zero Storage) is used for the lake storage amount. This is ignoring natural lake storage. IFR is assumed to be 10% MAD or 0.136 m^3/s.

2) The Outlet Discharge flow assumes a 1.25 m wide by 1 m tall fishway with stoplogs up to 0.37 m below the crest to limit the fishway flow to a maximum of 0.50m^3/s. The Outlet Discharge is generally Lake Inflow minus the Licensed Water Use of 0.01494 m^3/s unless the Inflow falls below the assumed IFR of 10% MAD in the summer when it is reduced to zero.

3) 1989-1990 are chosen as example years and not for any special reason.

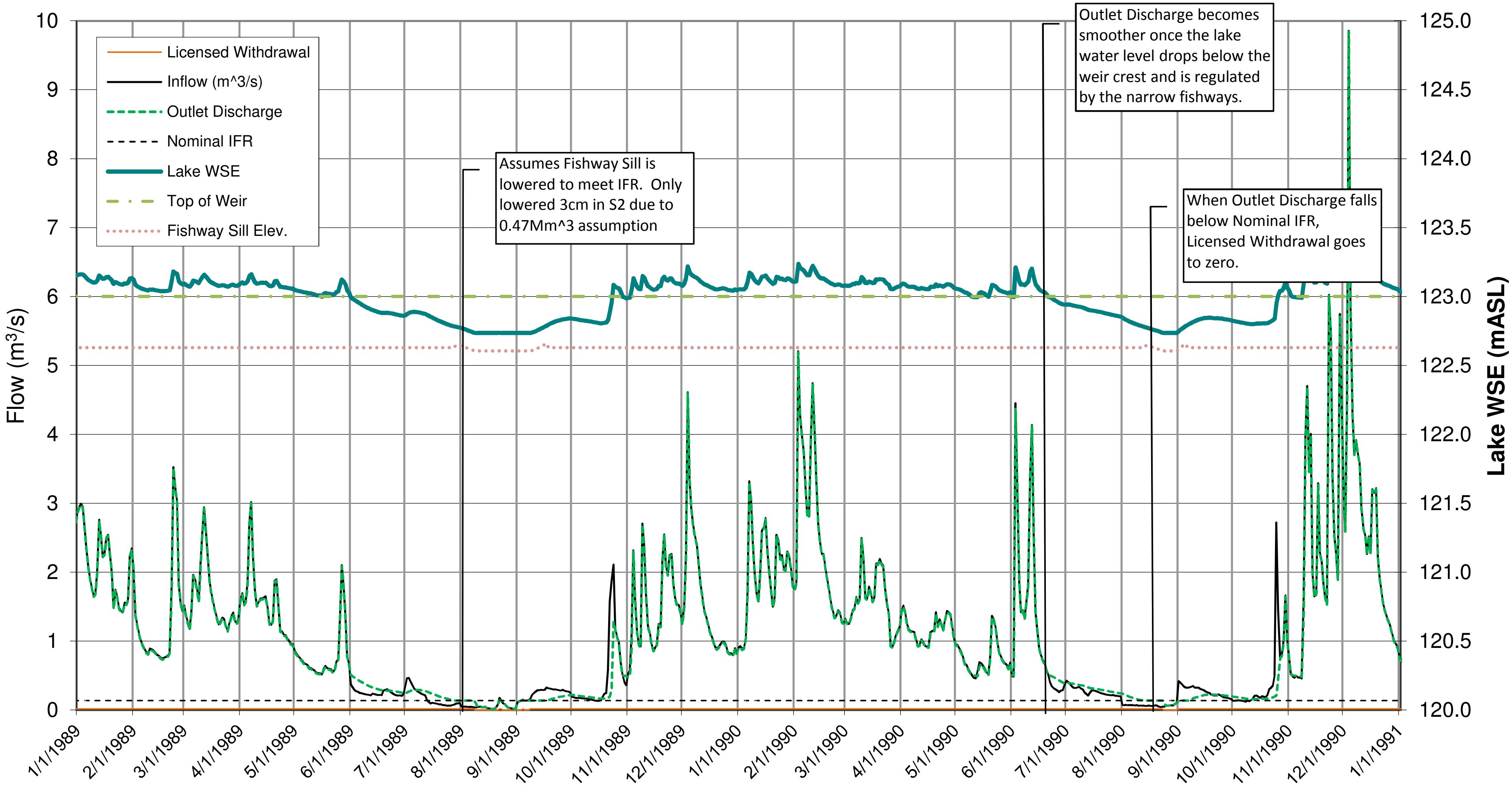
TLA'AMIN NATION

SLIAMMON LAKE REPLACEMENT WEIR DAM

SIMULATED SLIAMMON LAKE STORAGE FOR 1989-1990 USING 0 Mm^3 OF STORAGE (S1)

Fathom Scientific Ltd.

Ver 0.6 | Jan 30, 2015



Notes:
1) Licensed Withdrawal is the total licensed flow (0.01494 m^3/s). The 0.47 Mm^3 storage equates to 38 days of storage at LW (0.01494 m^3/s) + IFR (0.136 m^3/s).
2) The Outlet Discharge flow assumes a 1.25 m wide by 1 m tall fishway with a maximum flow of 0.50 m^3/s by starting the Sill at 0.37m below the weir crest and lowering through the summer to meet IFR of 0.136m^3/s.
3) 1989-1990 are chosen as example years and not for any special reason.

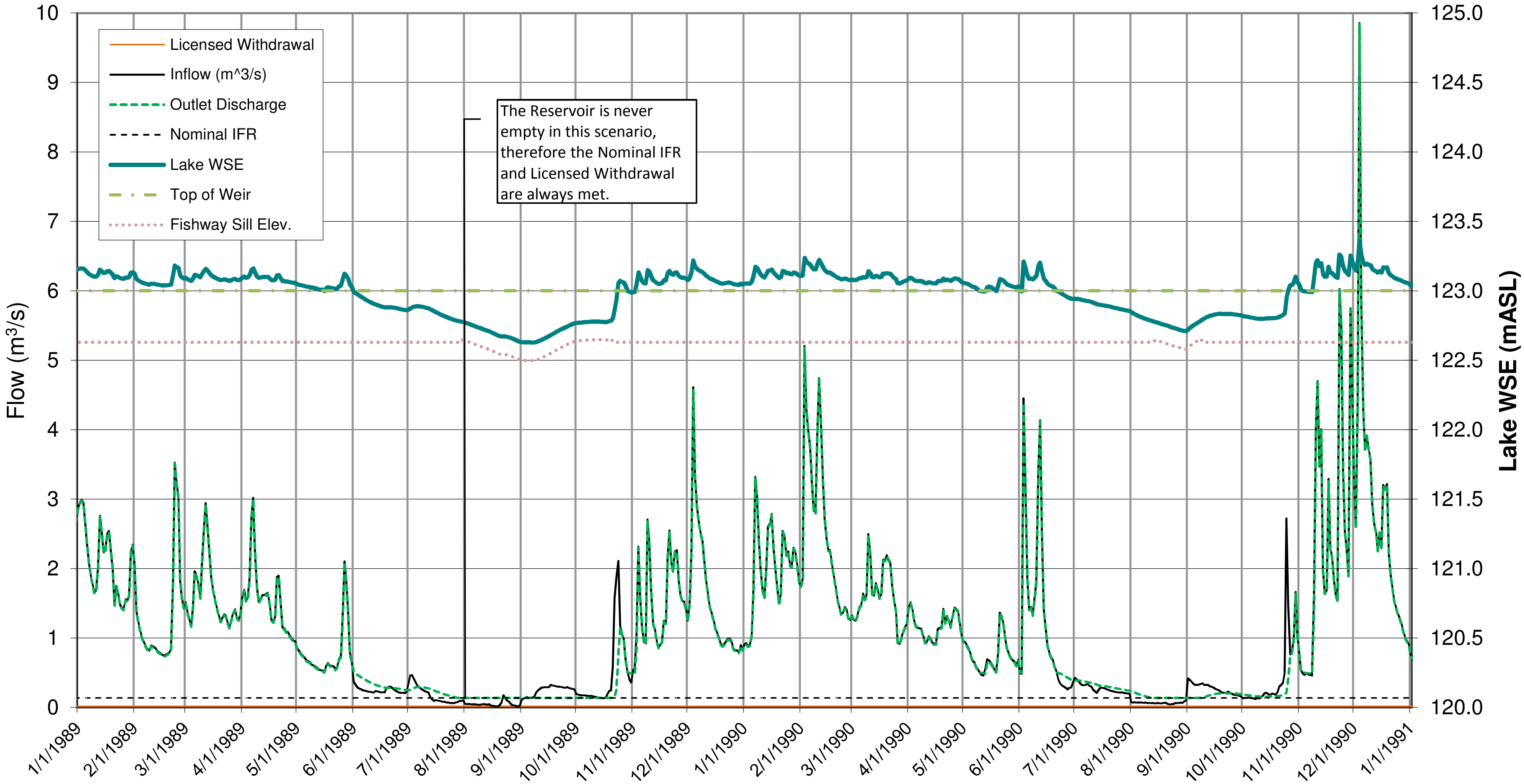
TLA'AMIN NATION

SLIAMMON LAKE REPLACEMENT WEIR DAM

SIMULATED SLIAMMON LAKE STORAGE FOR 1989-1990 USING 0.47 Mm^3 OF STORAGE (S2)

Fathom Scientific Ltd.

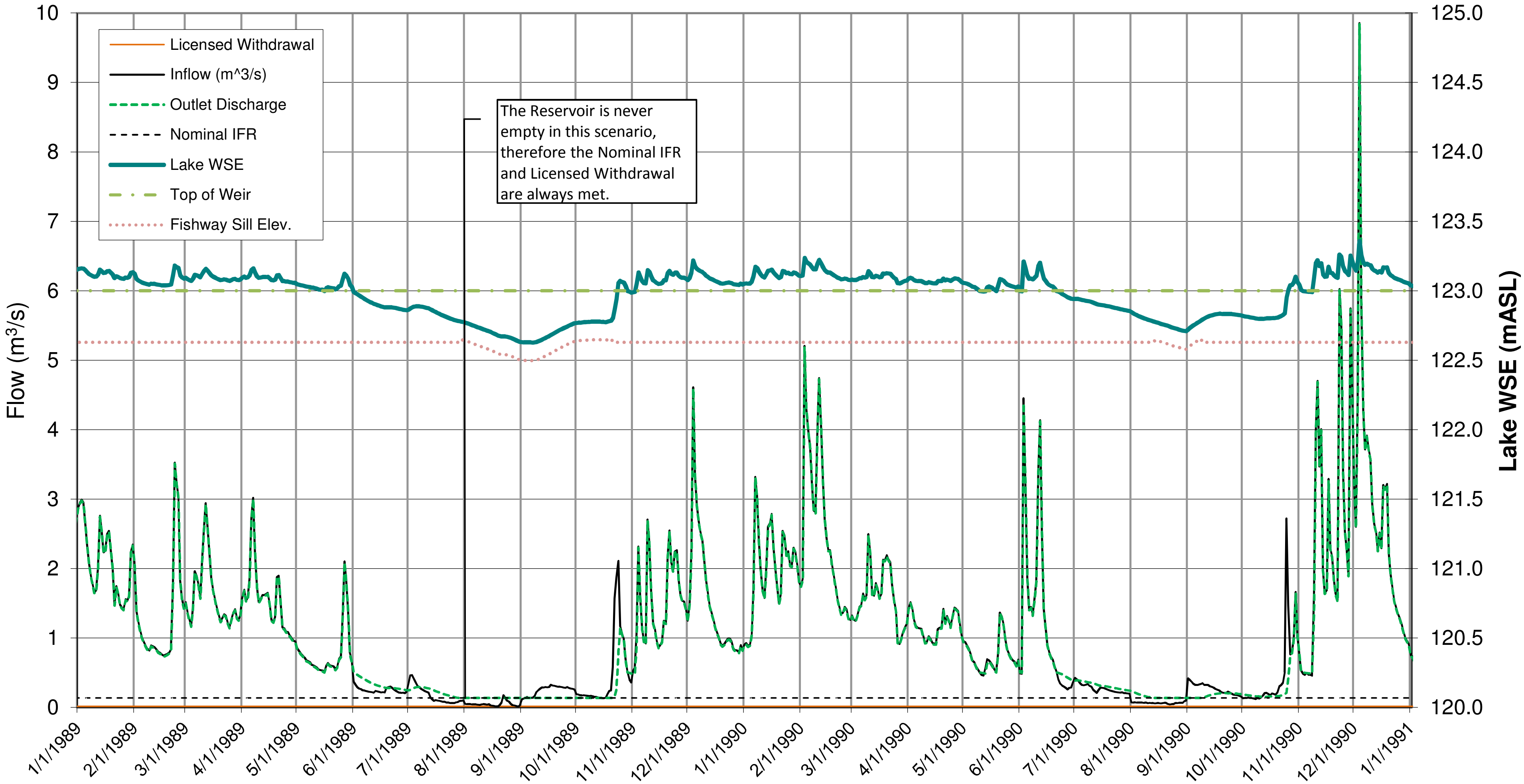
Ver 0.6 | Jan 30, 2015



Notes:

1) Licensed Withdrawal is the total licensed flow (0.01494 m3/s). The 1.10 Mm^3 storage is the minimum amount of storage required to have 100% IFR and Licensed Withdrawal. This storage equates to 84 days of storage at a LW (0.01494 m^3/s) + IFR (0.136 m^3/s).
2) The Discharge Outlet flow assumes a 1.25 m wide by 1 m tall fishway and a maximum flow of 0.50 m^3/s by starting the Sill at 0.37 m below the weir crest and lowering through the summer to meet IFR.
3) 1989-1990 are chosen as example years and not for any special reason.

TLA'AMIN NATION
SLIAMMON LAKE REPLACEMENT WEIR DAM
SIMULATED SLIAMMON LAKE STORAGE FOR 1989-1990 USING 1.10 Mm^3 OF STORAGE (S3)
Fathom Scientific Ltd.
Ver 0.6 / Jan 30, 2015



Notes:
1) Licensed Withdrawal is the total licensed flow (0.01494 m^3/s). This storage equates to 125 days of storage at a LW (0.01494 m^3/s) + IFR (0.136 m^3/s).
2) The Discharge Outlet flow assumes a 1.25 m wide by 1 m tall fishway and a maximum flow of 0.50 m^3/s by starting the Sill at 0.37m below the weir crest and lowering through the summer to meet IFR.
3) 1989-1990 are chosen as example years and not for any special reason.

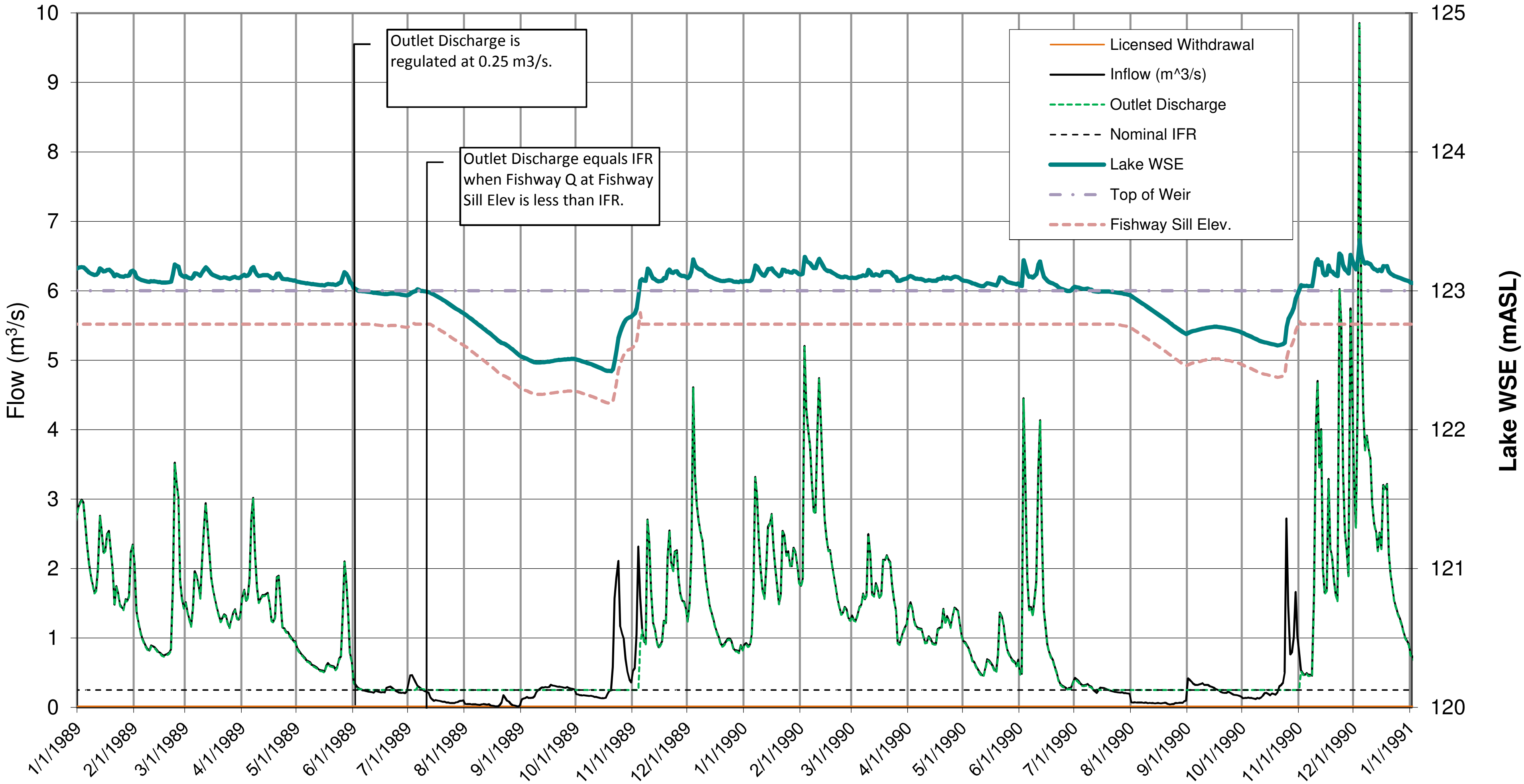
TLA'AMIN NATION

SLIAMMON LAKE REPLACEMENT WEIR DAM

SIMULATED SLIAMMON LAKE STORAGE FOR 1989-1990 USING 1.63 Mm^3 OF STORAGE (S4)

Fathom Scientific Ltd.

Ver 0.6 | Jan 30, 2015



Notes:

1) Licensed Withdrawal is the total licensed flow (0.01494 m^3/s). Using the Maximum Licensed storage of 1.63 Mm^3, an IFR of 0.25 m^3/s is the maximum IFR that able to be be maintained 100% of the time over the 21 year series. This storage equates to 71 days of storage at a LW (0.01494 m^3/s) + IFR (0.25 m^3/s).

2) The Outlet Discharge flow assumes a 1.25 m wide by 1.0 m tall fishway with a maximum flow of 0.25 m^3/s. From the top of the Weir at 123 mASL to 122.1 mASL is 1.63 Mm3. The IFR would be maintained by lowering the Fishway sill.

3) 1989-1990 are chosen as example years and not for any special reason.

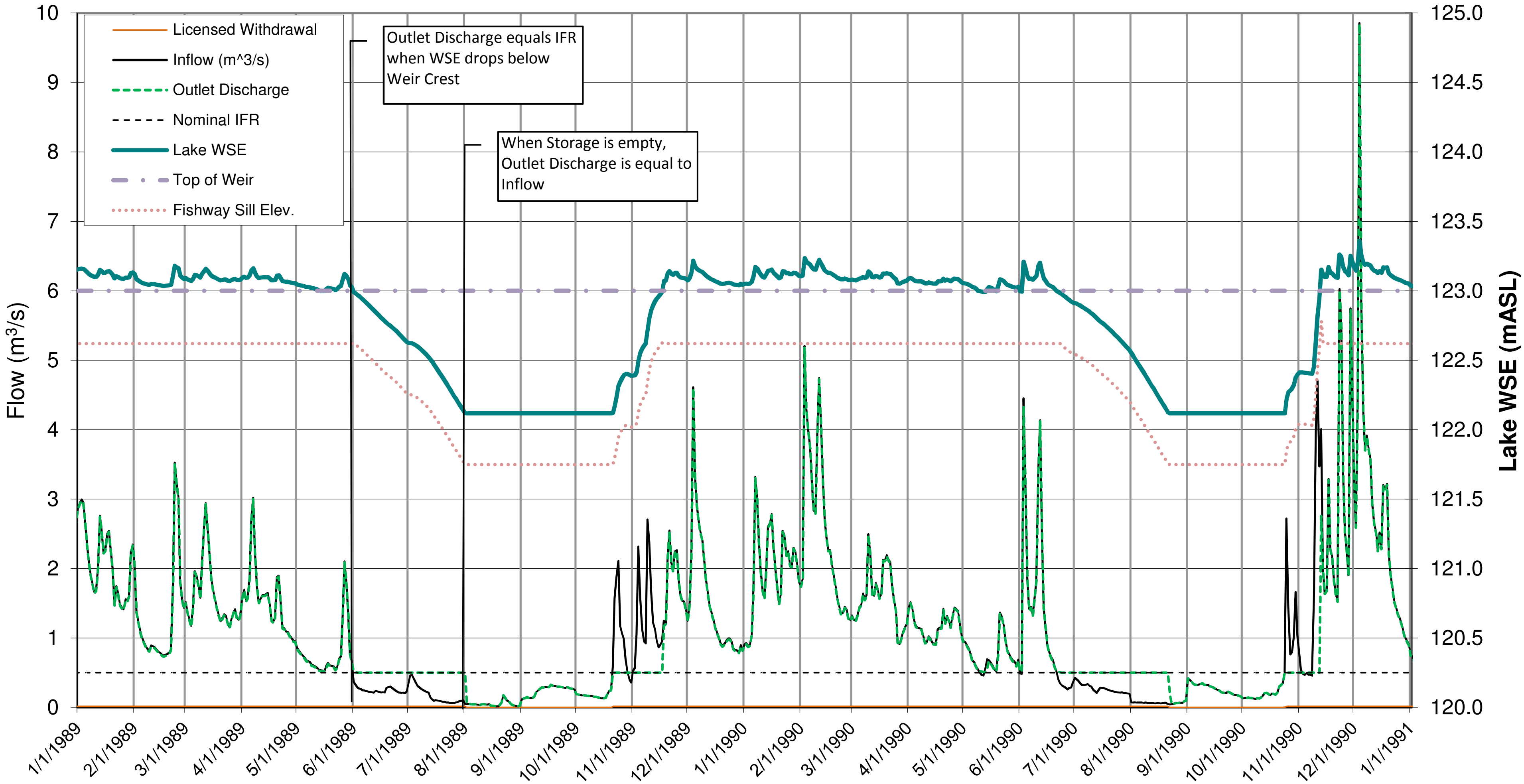
TLA'AMIN NATION

SLIAMMON LAKE REPLACEMENT WEIR DAM

SIMULATED SLIAMMON LAKE STORAGE FOR 1989-1990 USING IFR OF 0.25 m^3/s AND 1.63 Mm^3 OF STORAGE (S5)

Fathom Scientific Ltd.

Ver 0.6	Jan 30, 2015



Notes:

1) Licensed Withdrawal is the total licensed flow (0.01494 m^3/s). Using the Maximum Licensed storage of 1.63 Mm^3, this setup is not able to meet an IFR of 0.50 + 0.01494 m^3/s for all years and frequently drops below 0.5 m^3/s. This storage equates to 37 days of storage at a LW (0.01494 m^3/s) + IFR (0.500 m^3/s).

2) The Outlet Discharge flow assumes a 1.25 m wide by 1.0 m tall fishway with a maximum flow of 0.50 m^3/s. From the top of the Weir at 123 mASL to 122.1 mASL is 1.63 Mm3. The IFR would be maintained by lowering the Fishway sill as the WSE drops below the Starting Fishway Sill Elev.

3) 1989-1990 are chosen as example years and not for any special reason.

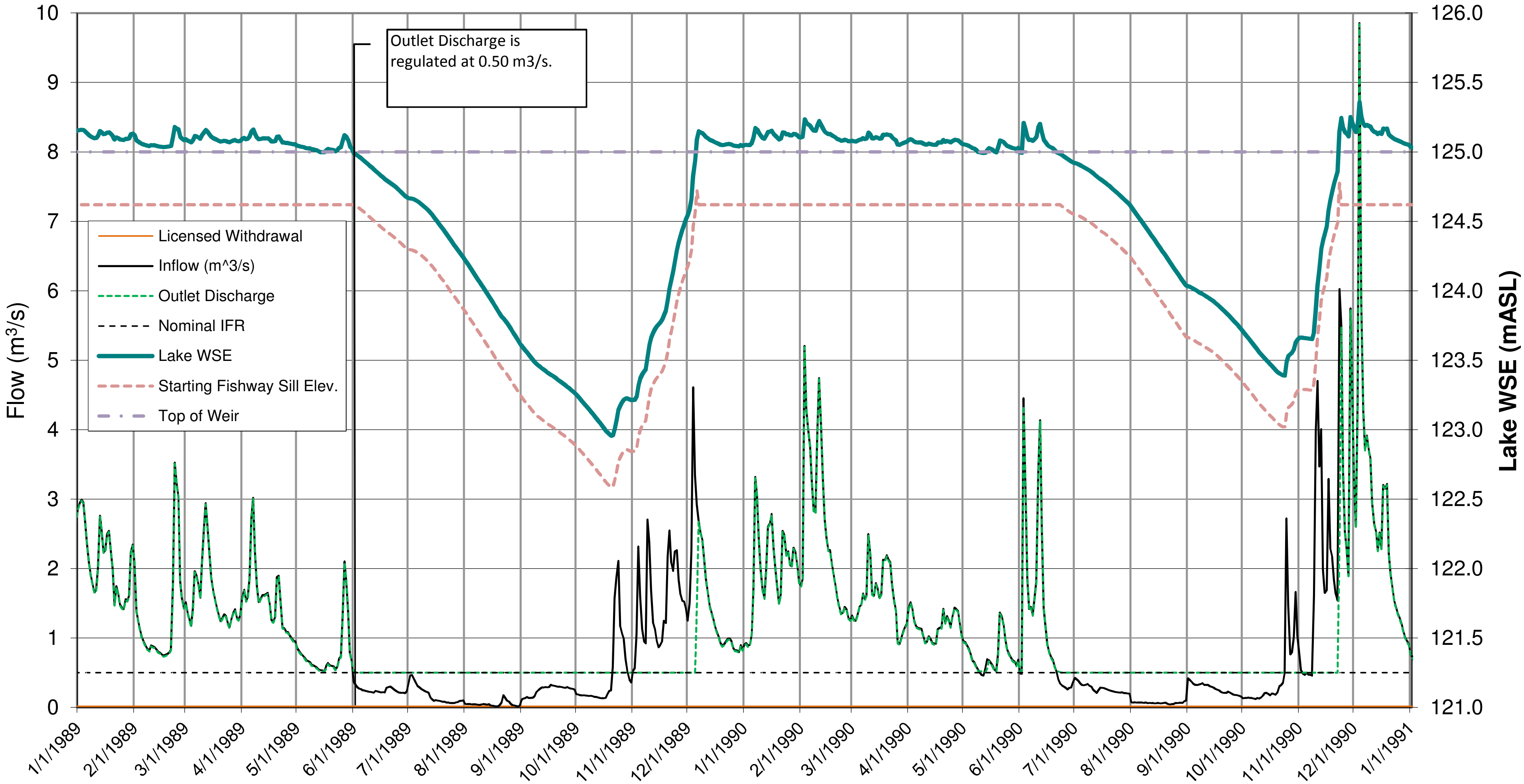
TLA'AMIN NATION

SLIAMMON LAKE REPLACEMENT WEIR DAM

SIMULATED SLIAMMON LAKE STORAGE FOR 1989-1990 USING IFR OF 0.50 m^3/s AND 1.63 Mm^3 OF STORAGE (S6)

Fathom Scientific Ltd.

Ver 0.6 | Jan 30, 2015



Notes:

1) Licensed Withdrawal is the total licensed flow (0.01494 m³/s). This scenario asked the question "What storage would be required to meet an IFR of 0.5 m³/s + Licensed Withdrawal 100% of the time. The answer is about 5.1 Mm³, which would require raising the lake level by 2.5-3.0m from the current lake level of 122 mASL.

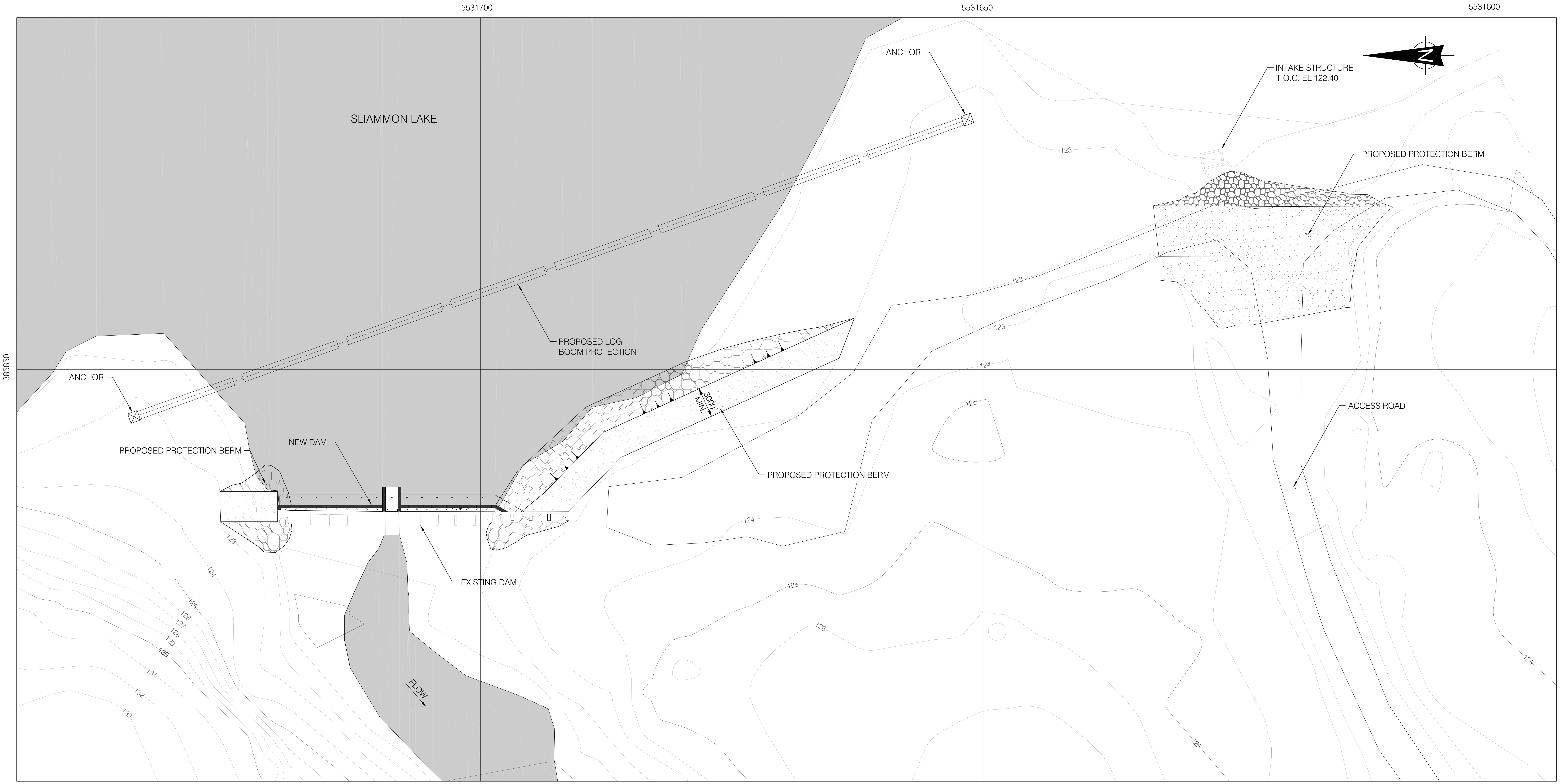
2) 1989-1990 are chosen as example years and not for any special reason.

TLA'AMIN NATION
SLIAMMON LAKE REPLACEMENT WEIR DAM
SIMULATED SLIAMMON LAKE STORAGE FOR 1989-1990 USING 5.1 Mm³ OF STORAGE (S7)

Fathom Scientific Ltd.

Ver 0.6 | Jan 30, 2015

Appendix D: Drawings



NOTES:

1. CONTOURS GENERATED FROM EMERY AND RAE LAND SURVEYING Ltd. FILE No: 10436-02.
2. SURVEY GRID SHOWN IS UTM ZONE 10 NAD83.
3. COORDINATE STATIONS AND ELEVATIONS ARE IN METERS UNLESS OTHERWISE NOTED.
4. FINAL HEADPOND CONFIGURATION TO BE DETERMINED BY GEOTECHNICAL ENGINEER.
5. SPILLWAY DESIGN FLOW IDF=370 m³/s AND Q_{1000}=112 m³/s. DIVER FLOW Q2=30m³/s.
6. Q_{IFR}=0.25m³/sec (IFR: INSTREAM FLOW REQUIREMENT).
7. TIE IN TO BE FINALIZED BY GEOTECHNICAL ENGINEER BASED ON GROUND CONDITION.
8. BED ROCK CONDITION SHOULD BE REASSESSED DURING THE CONSTRUCTION.
9. PRESSURE GROUTING REQUIREMENT SHOULD BE REVIEWED BASED ON ACCEPTABLE SEEPAGE CRITERIA IN THE DETAILED DESIGN IF REQUIRED.
10. DAM BREACH ANALYSIS TO BE FINALIZED AT LATER STAGE.
11. DUE TO THE CONFLICT IN AVAILABLE SURVEY DATA THE ELEVATIONS /ROCK ELEVATIONS ARE NOT ACCURATE AT THIS STAGE AND WOULD BE FINALIZED BASE ON ACCURATE SURVEY AT LATER STAGE.
12. PROTECTION BERM ELEVATION TO BE 0.9m ABOVE Q_{1000} FLOOD ELEVATION.

FOR INFORMATION
NOT TO BE USED FOR CONSTRUCTION
DATE: 2018-12-20
BBA

SCALE 1:200 — 4 2 0 4 8 12 16 20 m

DRAWING No.	DESCRIPTION
REFERENCE DRAWINGS	

REV	DESCRIPTION	VERIFIED BY	APPROVED BY	DATE
AA	ISSUED FOR INFORMATION	F. HATAMI	A. ABOUTALEBI	2018-12-20

REVISIONS

SEAL:

BBA

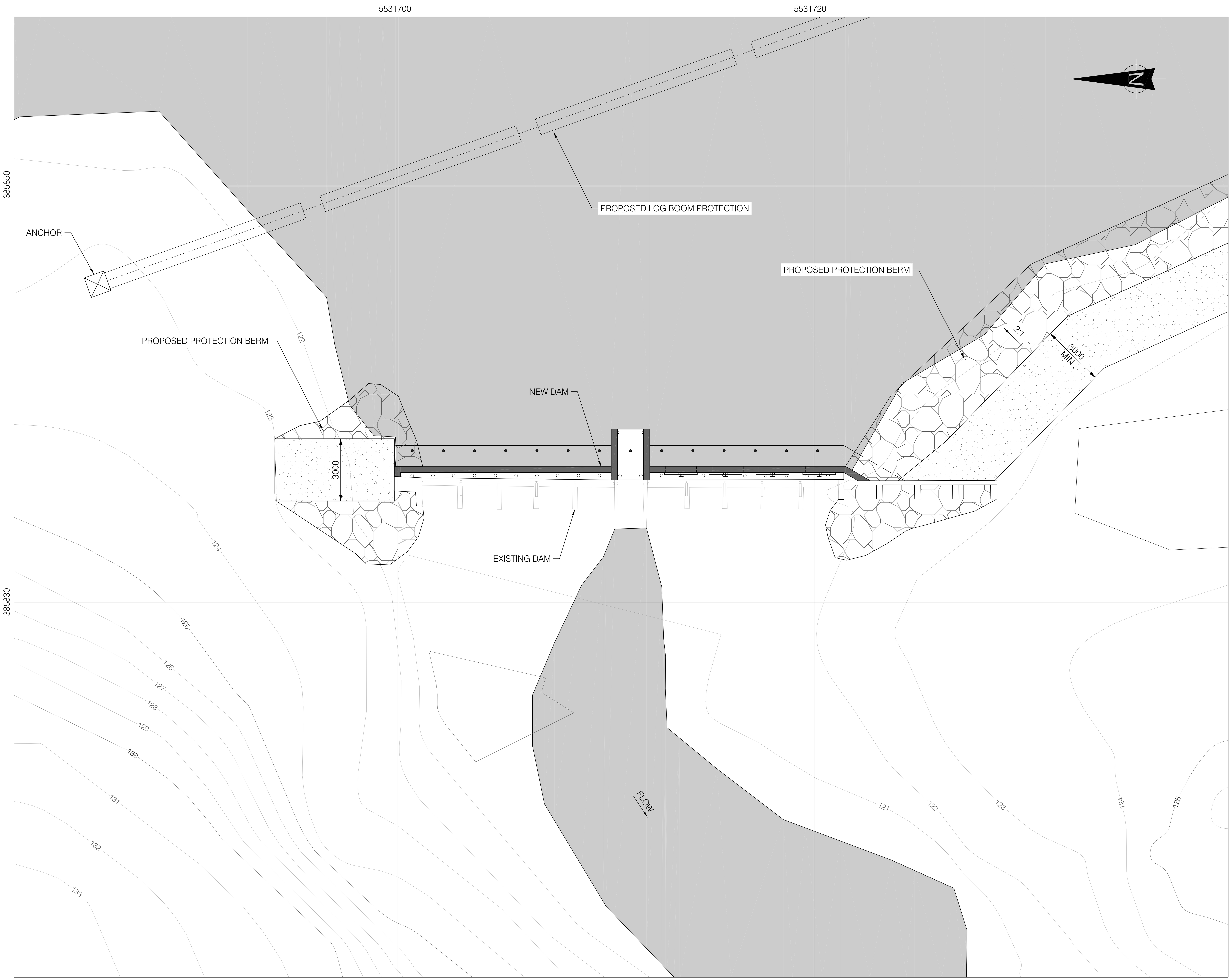
CLIENT: TLA'AMIN NATION
SLIAMMON FIRST NATION

PROJECT: SLIAMMON CREEK HYDROELECTRIC PROJECT

TITLE: CONCRETE DAM & INTAKE
GENERAL ARRANGEMENT
OVERALL PLAN
DAM REPAIR AND REQUIRED MITIGATION

DESIGNED BY: M. SHAHRAKI	DRAFTED BY: S. CHEUNG
VERIFIED BY: F. HATAMI	APPROVED BY: A. ABOUTALEBI
SCALE: AS SHOWN	DATE: 2018-12-20

DRAWING No.	SHEET:	SIZE:	REV.
3774003-000000-41-D20-1000	01	A1	AA



NOTES:

1. CONTOURS GENERATED FROM EMERY AND RAE LAND SURVEYING Ltd. FILE No: 10436-02.
2. SURVEY GRID SHOWN IS UTM ZONE 10 NAD83.
3. COORDINATE STATIONS AND ELEVATIONS ARE IN METERS UNLESS OTHERWISE NOTED.
4. FINAL HEADPOND CONFIGURATION TO BE DETERMINED BY GEOTECHNICAL ENGINEER.
5. SPILLWAY DESIGN FLOW IDF=370 m^3/s AND Q_{1000}=112 m^3/s. DIVER FLOW Q2=30m^3/s.
6. Q_{IFR}=0.25m^3/sec (IFR: INSTREAM FLOW REQUIREMENT).
7. TIE IN TO BE FINALIZED BY GEOTECHNICAL ENGINEER BASED ON GROUND CONDITION.
8. BED ROCK CONDITION SHOULD BE REASSESSED DURING THE CONSTRUCTION.
9. PRESSURE GROUTING REQUIREMENT SHOULD BE REVIEWED BASED ON ACCEPTABLE SEEPAGE CRITERIA IN THE DETAILED DESIGN IF REQUIRED.
10. DAM BREACH ANALYSIS TO BE FINALIZED AT LATER STAGE.
11. DUE TO THE CONFLICT IN AVAILABLE SURVEY DATA THE ELEVATIONS /ROCK ELEVATIONS ARE NOT ACCURATE AT THIS STAGE AND WOULD BE FINALIZED BASE ON ACCURATE SURVEY AT LATER STAGE.
12. PROTECTION BERM ELEVATION TO BE 0.9m ABOVE Q_{1000} FLOOD ELEVATION.

FOR INFORMATION
NOT TO BE USED FOR CONSTRUCTION
DATE: 2018-12-20
BBA

SCALE 1:100 — 2 1 0 2 4 6 8 10 m

REV	DESCRIPTION	VERIFIED BY	APPROVED BY	DATE
AA	ISSUED FOR INFORMATION	F. HATAMI	A. ABOUTALEBI	2018-12-20

REVISIONS

DRAWING No.	DESCRIPTION

REFERENCE DRAWINGS

SEAL:

BBA

CLIENT: TLA'AMIN NATION
SLIAMMON FIRST NATION

PROJECT: SLIAMMON CREEK HYDROELECTRIC PROJECT

TITLE: CONCRETE DAM & INTAKE
GENERAL ARRANGEMENT
PLAN
DAM REPAIR AND REQUIRED MITIGATION

DESIGNED BY: M. SHAHRAKI	DRAFTED BY: S. CHEUNG
VERIFIED BY: F. HATAMI	APPROVED BY: A. ABOUTALEBI
SCALE: AS SHOWN	DATE: 2018-12-20

DRAWING No.	SHEET:	SIZE:	REV.
3774003-000000-41-D20-1001	01	A1	AA

BY:CHEUNG, SIMON
PRINTED:2018-12-20 4:53:40 PM

G:\3774\003\40_ING_ENG\41_CIVIL\DESS_DWGS\PROJET_PROJECT\IN PROGRESS\DRAWINGS\1000 - DIVERSION WEIR AND INTAKE STRUCTURE\3774003-000000-41-D20-1001.DWG

3774003-000000-41-D20-1001

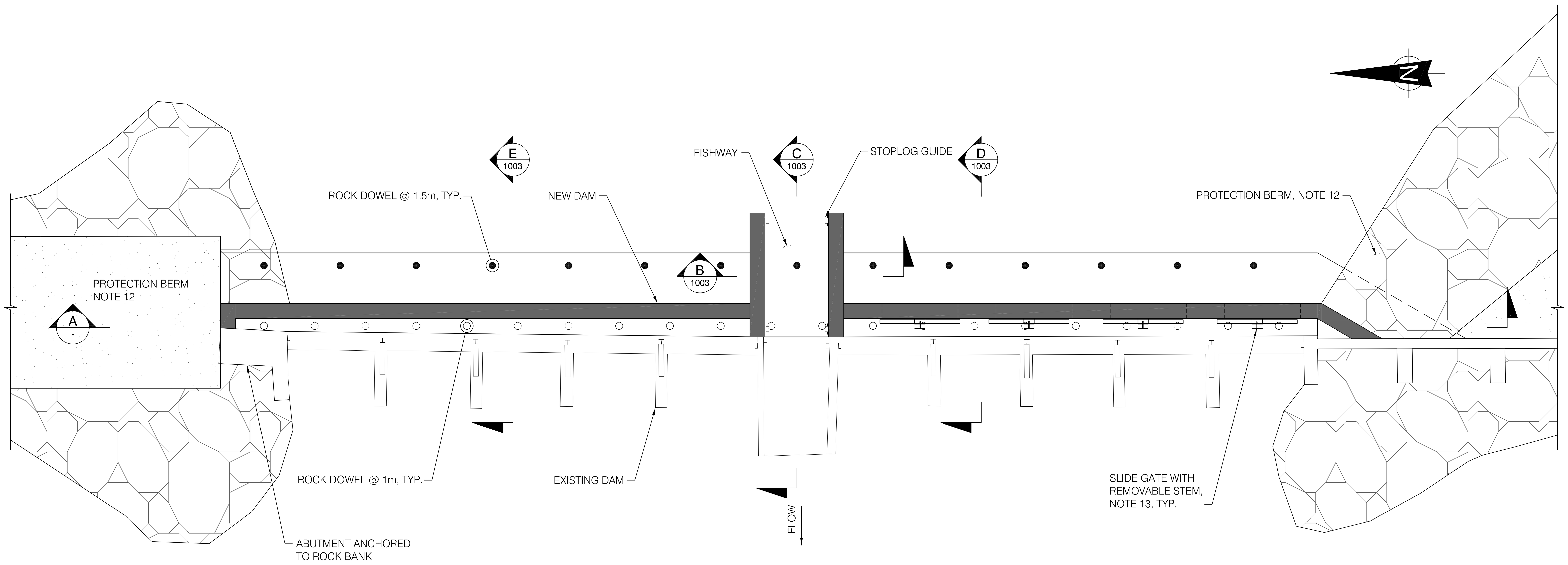
NOTES:

1. CONTOURS GENERATED FROM EMERY AND RAE LAND SURVEYING Ltd. FILE No: 10436-02.
2. SURVEY GRID SHOWN IS UTM ZONE 10 NAD83.
3. COORDINATE STATIONS AND ELEVATIONS ARE IN METERS UNLESS OTHERWISE NOTED.
4. FINAL HEADPOND CONFIGURATION TO BE DETERMINED BY GEOTECHNICAL ENGINEER.
5. SPILLWAY DESIGN FLOW Q_{IDF}=370m³/s (IDF: INFLOW DESIGN FLOOD) AND Q_{1000}=112m³/s. DIVER FLOW Q2=30m³/s.
6. Q_{IFR}=0.25m³/sec (IFR: INSTREAM FLOW REQUIREMENT).
7. TIE IN TO BE FINALIZED BY GEOTECHNICAL ENGINEER BASED ON GROUND CONDITION.
8. BED ROCK CONDITION SHOULD BE REASSESSED DURING THE CONSTRUCTION.
9. PRESSURE GROUTING REQUIREMENT SHOULD BE REVIEWED BASED ON ACCEPTABLE SEEPAGE CRITERIA IN THE DETAILED DESIGN IF REQUIRED.
10. DAM BREACH ANALYSIS TO BE FINALIZED AT LATER STAGE.
11. DUE TO THE CONFLICT IN AVAILABLE SURVEY DATA THE ELEVATIONS /ROCK ELEVATIONS ARE NOT ACCURATE AT THIS STAGE AND WOULD BE FINALIZED BASE ON ACCURATE SURVEY AT LATER STAGE.
12. PROTECTION BERM ELEVATION TO BE 0.9m ABOVE Q_{1000} FLOOD ELEVATION.
13. FULLY GATE OPENED CAPACITY AT NORMAL LAKE LEVEL IS 1.64m³/s (FOR EACH).

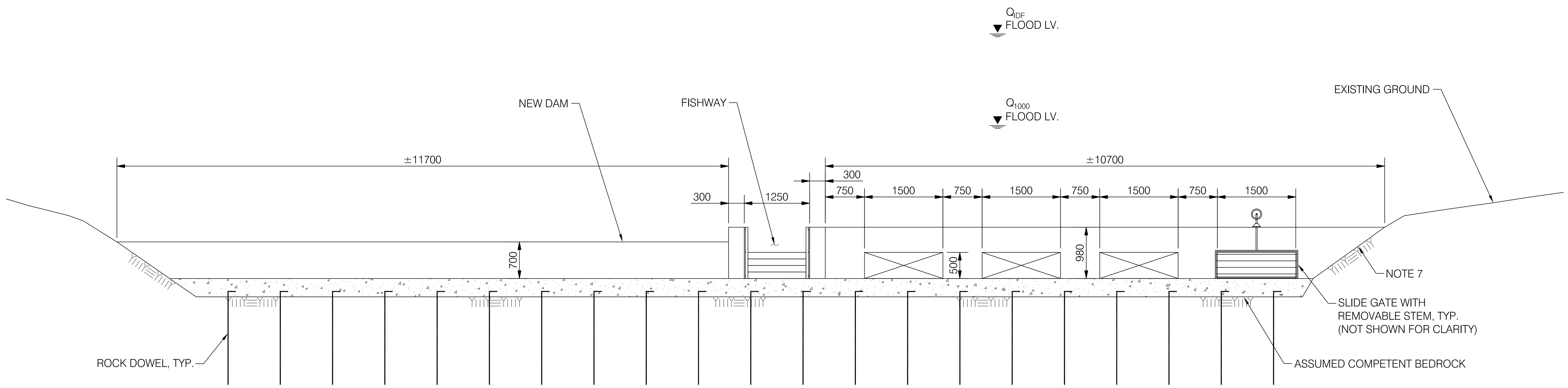
LEGEND:

- ● ROCK DOWEL-TYPE A (3m LENGTH)
- ○ ROCK DOWEL-TYPE B (1m LENGHT)

*SEE 3774003-000000-41-D20-1003 FOR ROCK DOWEL DETAILS



PLAN
SCALE 1:50



A - ELEVATION
SCALE 1:50

FOR INFORMATION
NOT TO BE USED FOR CONSTRUCTION
DATE: 2018-12-20
BBA

SCALE 1:50 — 1 0.5 0 1 2 3 4 5 m

DRAWING No.	DESCRIPTION

REFERENCE DRAWINGS

REV	DESCRIPTION	VERIFIED BY	APPROVED BY	DATE
AA	ISSUED FOR INFORMATION	F. HATAMI	A. ABOUTALEBI	2018-12-20

REVISIONS

SEAL:

BBA

CLIENT: TLA'AMIN NATION
SLIAMMON FIRST NATION

PROJECT: SLIAMMON CREEK HYDROELECTRIC PROJECT

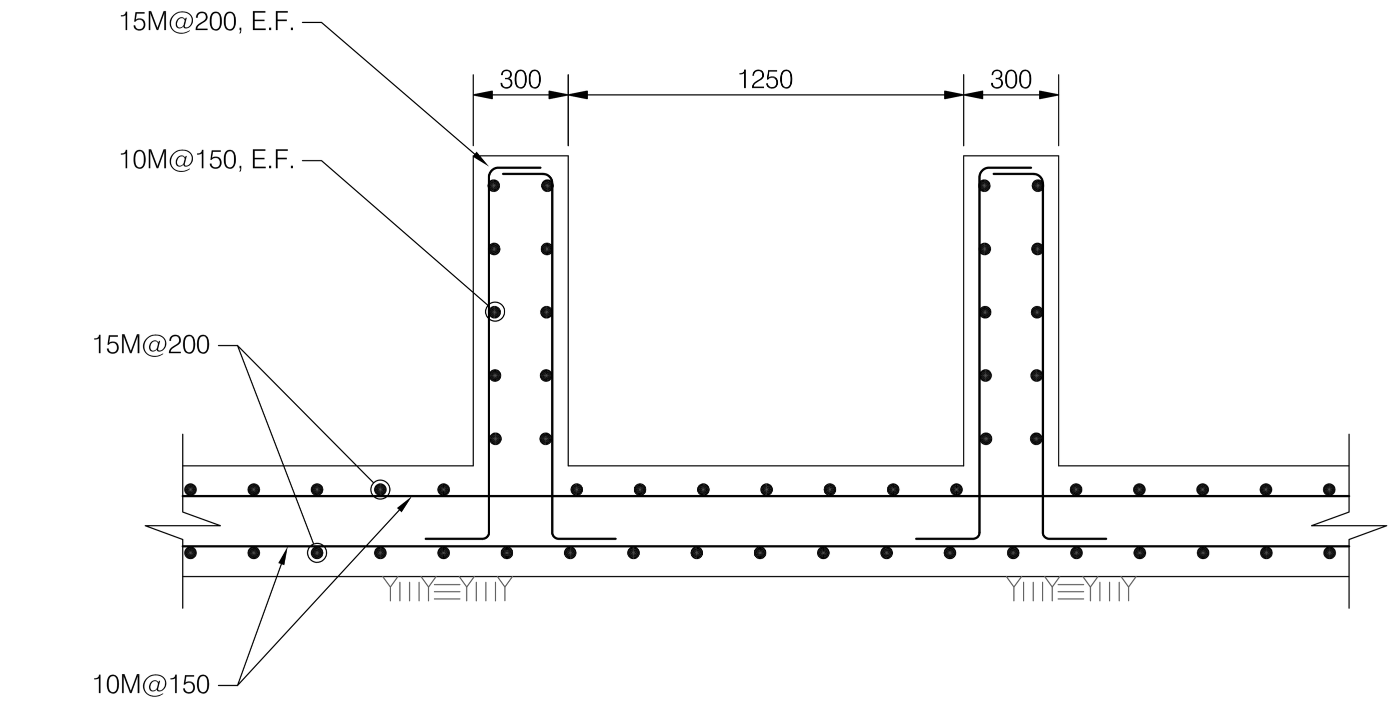
TITLE: CONCRETE DAM
GENERAL ARRANGEMENT
PLAN & ELEVATION

DESIGNED BY: M. SHAHRAKI	DRAFTED BY: S. CHEUNG
VERIFIED BY: F. HATAMI	APPROVED BY: A. ABOUTALEBI
SCALE: AS SHOWN	DATE: 2018-12-20

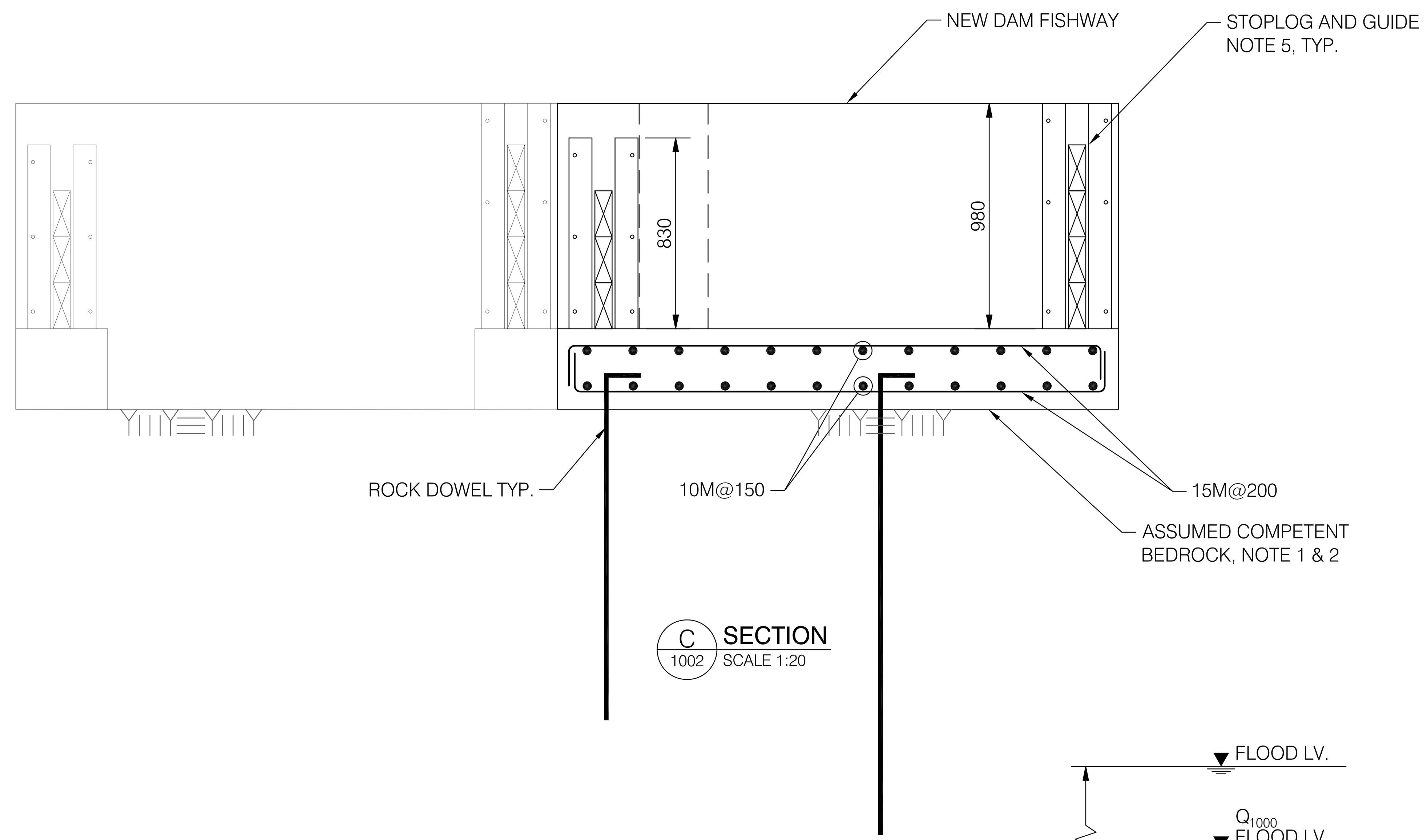
DRAWING No.	SHEET:	SIZE:	REV.
3774003-000000-41-D20-1002	01	A1	AA

NOTES:

1. BEDROCK CONDITION SHOULD BE REASSESSED DURING THE CONSTRUCTION.
2. PRESSURE GROUTING REQUIREMENT SHOULD BE REVIEWED BASED ON ACCEPTABLE SEEPAGE CRITERIA IN THE DETAILED DESIGN IF REQUIRED.
3. STEEL GUIDES TO BE REMOVED AFTER CONSTRUCTION OF NEW DAM.
4. MINIMUM CONCRETE COMPRESSIVE STRENGTH AT 28 DAYS SHOULD BE 35MPa.
5. FISHWAY STOPLOGS AND WIDTH IS BASED ON ORIGINAL DESIGN.

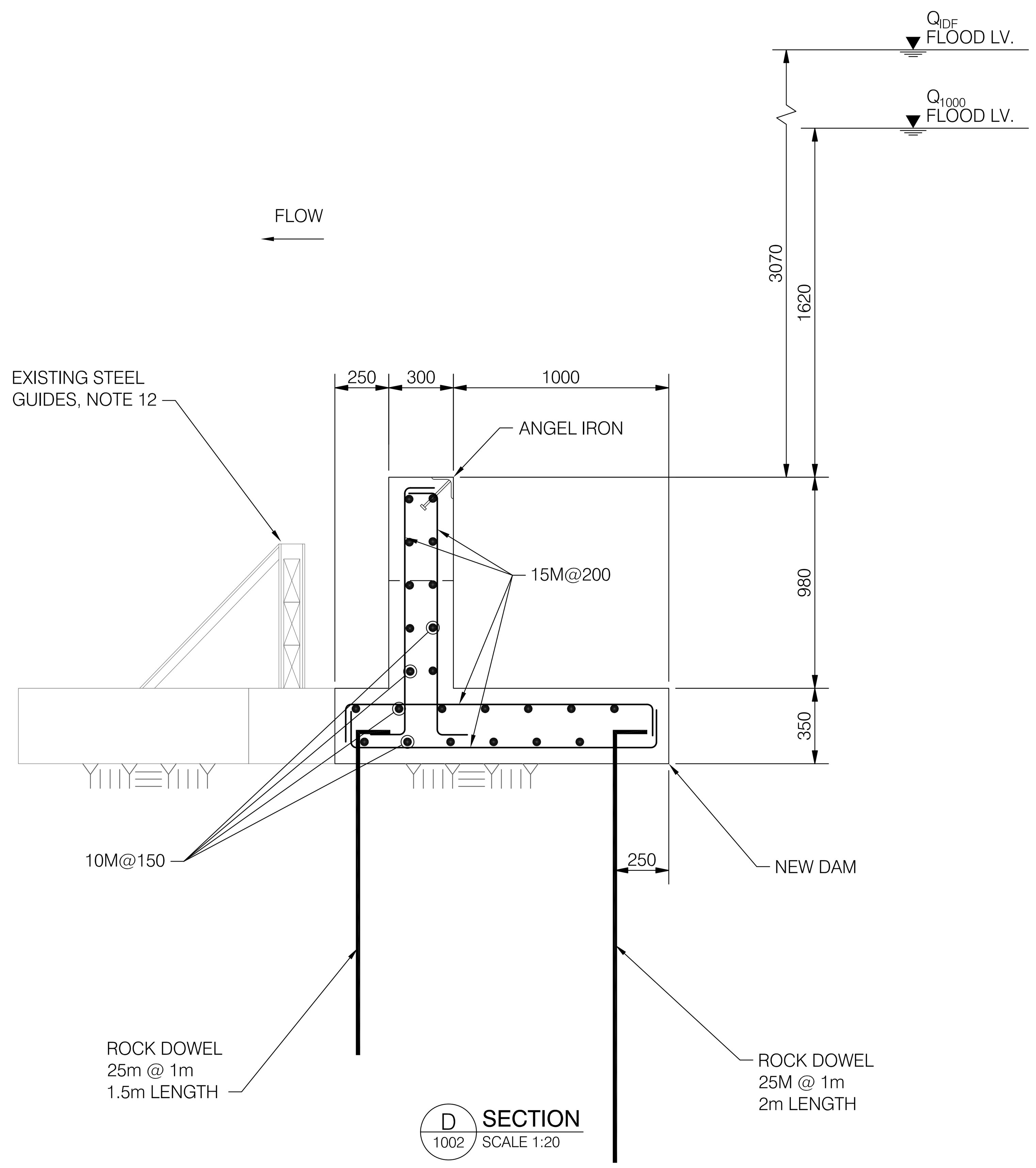


B SECTION 1002 SCALE 1:20

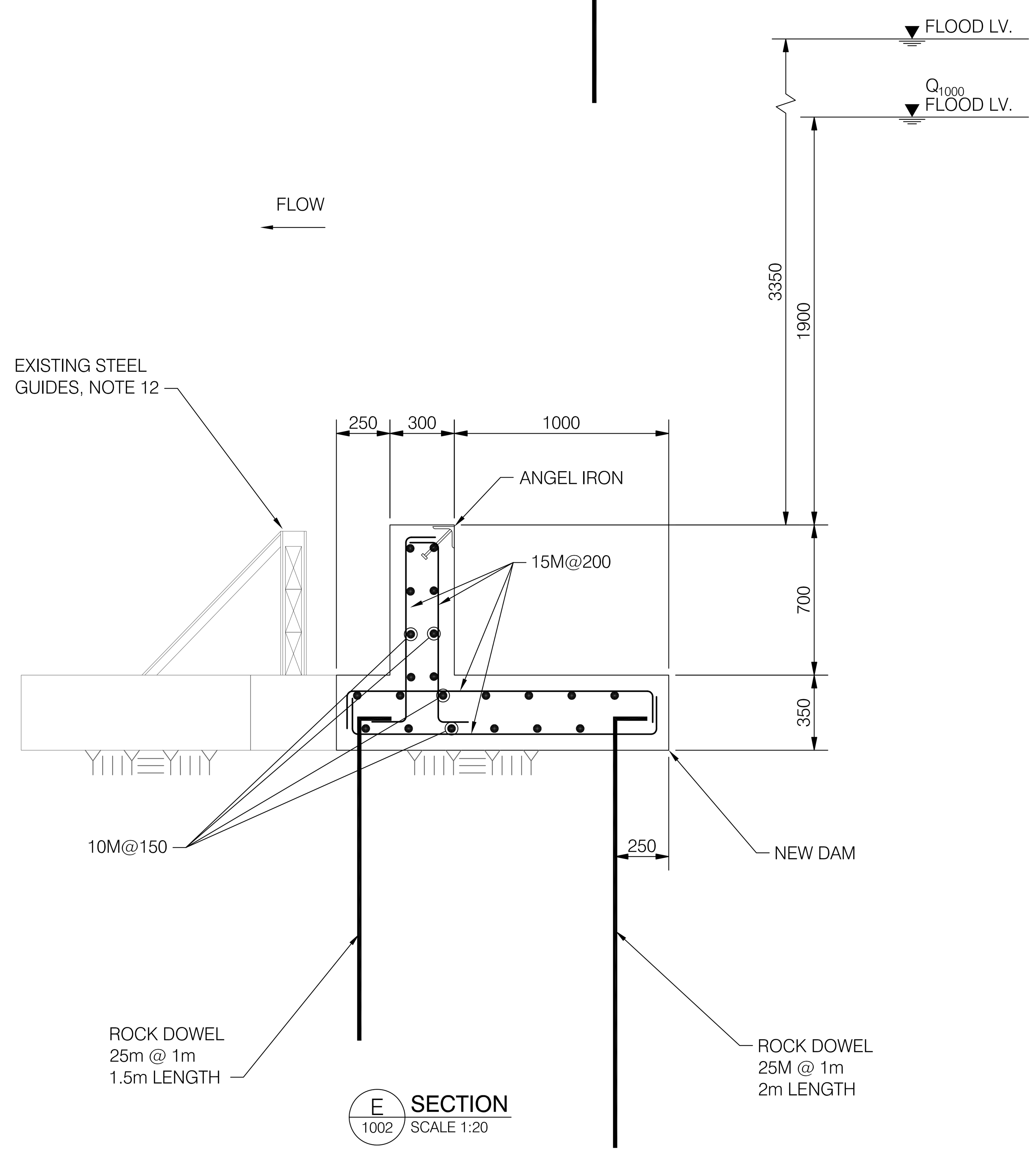


C SECTION 1002 SCALE 1:20

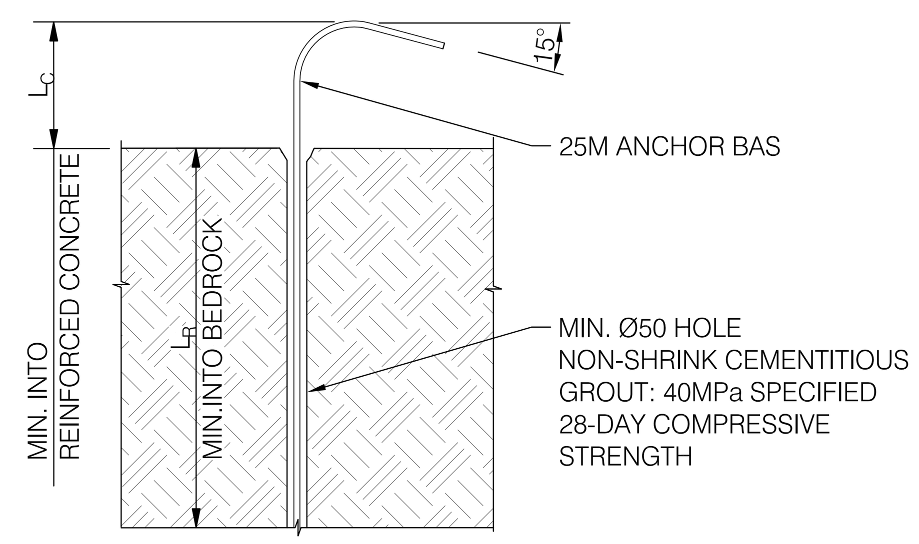
TABLE - DOWEL			
TYPE	SIZE	L_C	L_R
● A	25M	200	2000
○ B	25M	200	1500



D SECTION 1002 SCALE 1:20



E SECTION 1002 SCALE 1:20



ROCK DOWEL DETAIL
N.T.S.

FOR INFORMATION
NOT TO BE USED FOR CONSTRUCTION
DATE: 2018-12-20

SCALE 1:20 — 0.4 0.2 0 0.4 0.8 1.2 1.6 2.0 m

REV	DESCRIPTION	VERIFIED BY	APPROVED BY	DATE
AA	ISSUED FOR INFORMATION	F. HATAMI	A. ABOUTALEBI	2018-12-20

REVISIONS

DRAWING No.	DESCRIPTION

REFERENCE DRAWINGS

SEAL:

CLIENT: TLA'AMIN NATION
SLIAMMON FIRST NATION

PROJECT: SLIAMMON CREEK HYDROELECTRIC PROJECT

TITLE: CONCRETE DAM GENERAL ARRANGEMENT SECTIONS & DETAIL

DESIGNED BY: M. SHAHRAKI	DRAFTED BY: S. CHEUNG
VERIFIED BY: F. HATAMI	APPROVED BY: A. ABOUTALEBI
SCALE: AS SHOWN	DATE: 2018-12-20

DRAWING No.: 3774003-000000-41-D20-1003 | SHEET: 01 | SIZE: A1 | REV.: AA

BY:CHEUNG, SIMON
PRINTED:2018-12-20 11:20:32 AM

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Appendix E: Conditional Water Licences

WATER MANAGEMENT BRANCH	MINISTRY OF ENVIRONMENT, LANDS AND PARKS

THE PROVINCE OF BRITISH COLUMBIA—WATER ACT

CONDITIONAL WATER LICENCE

Sliammon First Nation is hereby authorized to divert, store and use water as follows:

(a) The stream on which the rights are granted is **Sliammon Lake**.

(b) The point of diversion is located as shown on the attached plan.

(c) The date from which this licence shall have precedence is **5th September, 1997**.

(d) The purpose for which this licence is issued is **waterworks.**

(e) The maximum quantity of water which may be diverted is **40,296,000 gallons a year**, and the maximum daily diversion must not exceed **184,000 gallons a day**.

(f) Water may be used throughout **the whole year**.

(g) The land upon which the water is to be used and to which this licence is appurtenant is **Indian Reserve No. 1 Sliammon, Group 1, New Westminster District.**

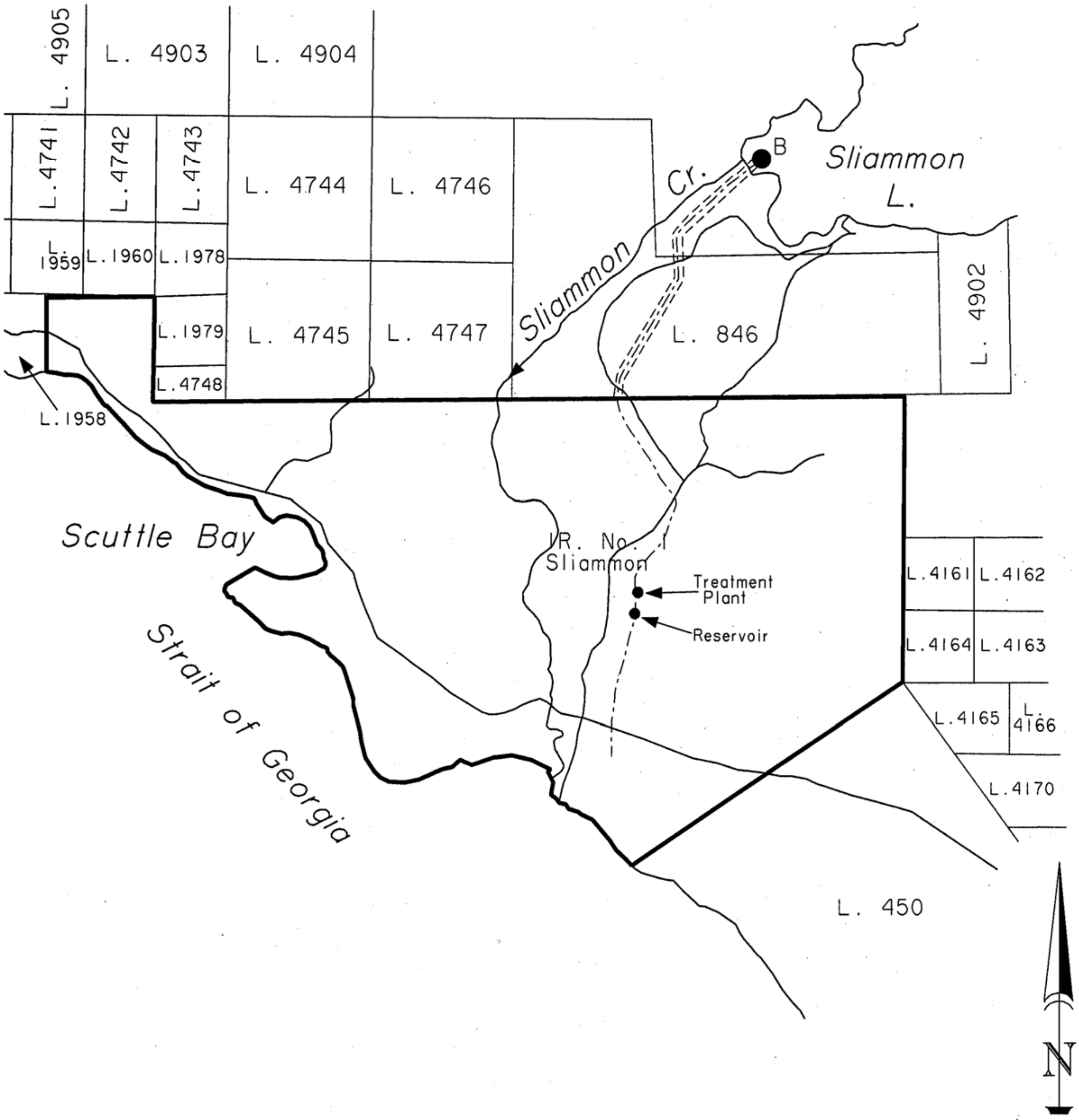
(h) The works authorized to be constructed are **diversion structure, pipe, water treatment plant, reservoir, and distribution system** which shall be located approximately as shown on the attached plan.

(i) The construction of the said works has been completed and the water is being beneficially used. The licensee shall continue to make a regular beneficial use of the water in the manner authorized herein.

D. Barry Paterson
Assistant Regional Water Manager

File No: **2002242** Date issued: **15th July, 1998** Conditional Licence: **112612**

Province of British Columbia



WATER DISTRICT : VANCOUVER
PRECINCT : JERVIS
LAND DISTRICT : GP I NEW WESTMINSTER

Signature: ____
Date: JULY 15/98

LEGEND

Scale : 1:30000
Point of Diversion : ●
Map Number : WR 92F.098
Pipe : — - — - — - — -
Permit over Crown Land : ===========

C.L. 112612
File 2002242
P.C.L. 22800

The boundaries of the land to which this licence is appurtenant are shown thus: ▬▬▬▬▬▬

WATER RESOURCES SERVICE WATER RIGHTS BRANCH	DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES

THE PROVINCE OF BRITISH COLUMBIA—WATER ACT

CONDITIONAL WATER LICENCE

Indian Affairs Branch, Department of Citizenship and Immigration of **Ottawa, Ontario**

is/are hereby authorized to **divert and use** water as follows:—

(*a*) The source(s) of the water-supply is/are **Sliammon Lake.**

(*b*) The point(s) of **diversion** is/are located as shown on the attached plan.

(*c*) The date from which this licence shall have precedence is **8th July, 1965.**

(*d*) The purpose for which the water is to be used is **waterworks.**

(*e*) The maximum quantity of water which may be **diverted is 100,000 gallons a day,** and such additional quantity as the Engineer may from time to time determine should be allowed for losses.

(*f*) The period of the year during which the water may be **used is the whole year.**

(*g*) The land upon which the water is to be used and to which this licence is appurtenant is **Indian Reserve No.1 Sliammon, New Westminster District.**

(*h*) The works authorized to be constructed are **intake box, pipe and distribution system,** and they shall be located approximately as shown on the attached plan.

(*i*) The construction of the said works **shall be commenced on or before the 31st day of October, 1966, and shall be completed and the water beneficially used on or before the 31st day of December, 1969.**

Map 92F/NE(E-3)
R.M BD

H. D. DeBeck,
Comptroller of Water Rights.

File No. 0263377 Date issued: 15 April 1966

Conditional Licence No. 30916

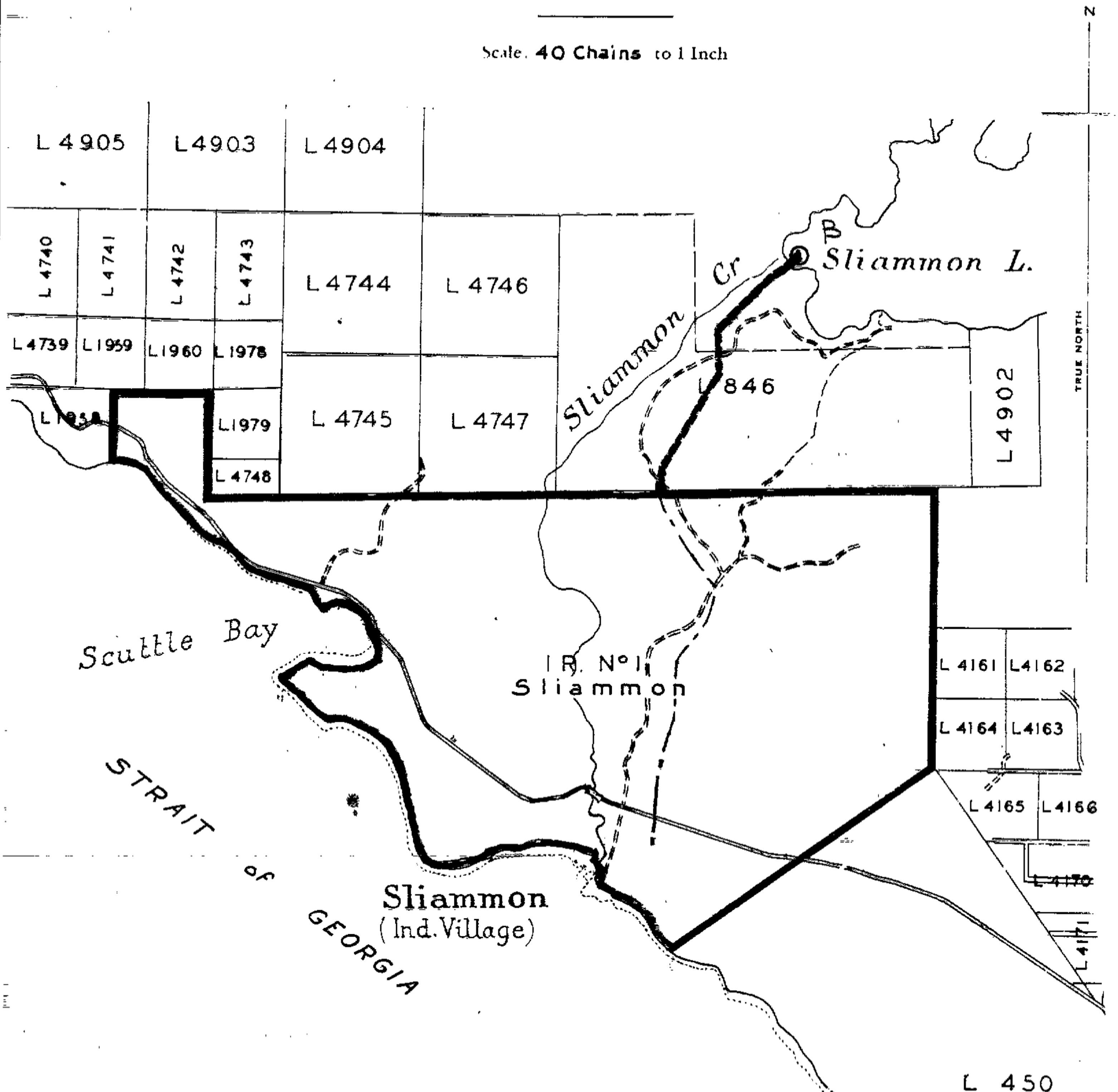
5M-365-3219

British Columbia

VANCOUVER WATER DISTRICT

G.1. NEW WESTMINSTER DISTRICT

Scale. 40 Chains to 1 Inch



LEGEND

Point of Diversion O

Ref. Map ~~92 F/N.E (E-3)~~ 92·F·098

Pipe —·—

Right-of-Way

The boundaries of the land to which this licence is appurtenant are shown thus:

Signature.

Date. April 15, 1966

C.L. 30916

File 0263377

Permit No. 6088

EXHIBIT "A"

8

100-860-6824

Jervis Precinct

WATER LICENCE DISPOSITION RECORD

Cond WATER LICENCE NO. 30916

HAS BEEN

_____ RECORDED AS ABANDONED

_____ ~~CANCELLED~~

✓ SUPERSEDED BY C 113456

NOTATION BY: SKent

DATE: Aug 19/98

WATER MANAGEMENT BRANCH	MINISTRY OF ENVIRONMENT, LANDS AND PARKS

THE PROVINCE OF BRITISH COLUMBIA—WATER ACT

CONDITIONAL WATER LICENCE

Sliammon First Nation is hereby authorized to divert, store and use water as follows:

(a) The stream on which the rights are granted is **Sliammon Lake**.

(b) The point of diversion is located as shown on the attached plan.

(c) The date from which this licence shall have precedence is **8th July, 1965**.

(d) The purpose for which this licence is issued is **waterworks.**

(e) The maximum quantity of water which may be diverted is **100,000 gallons a day**.

(f) Water may be used throughout **the whole year**.

(g) The land upon which the water is to be used and to which this licence is appurtenant is **Indian Reserve No. 1 Sliammon, Group 1, New Westminster District.**

(h) The works authorized to be constructed are **diversion structure, pipe, water treatment plant, reservoir and distribution system** which shall be located approximately as shown on the attached plan.

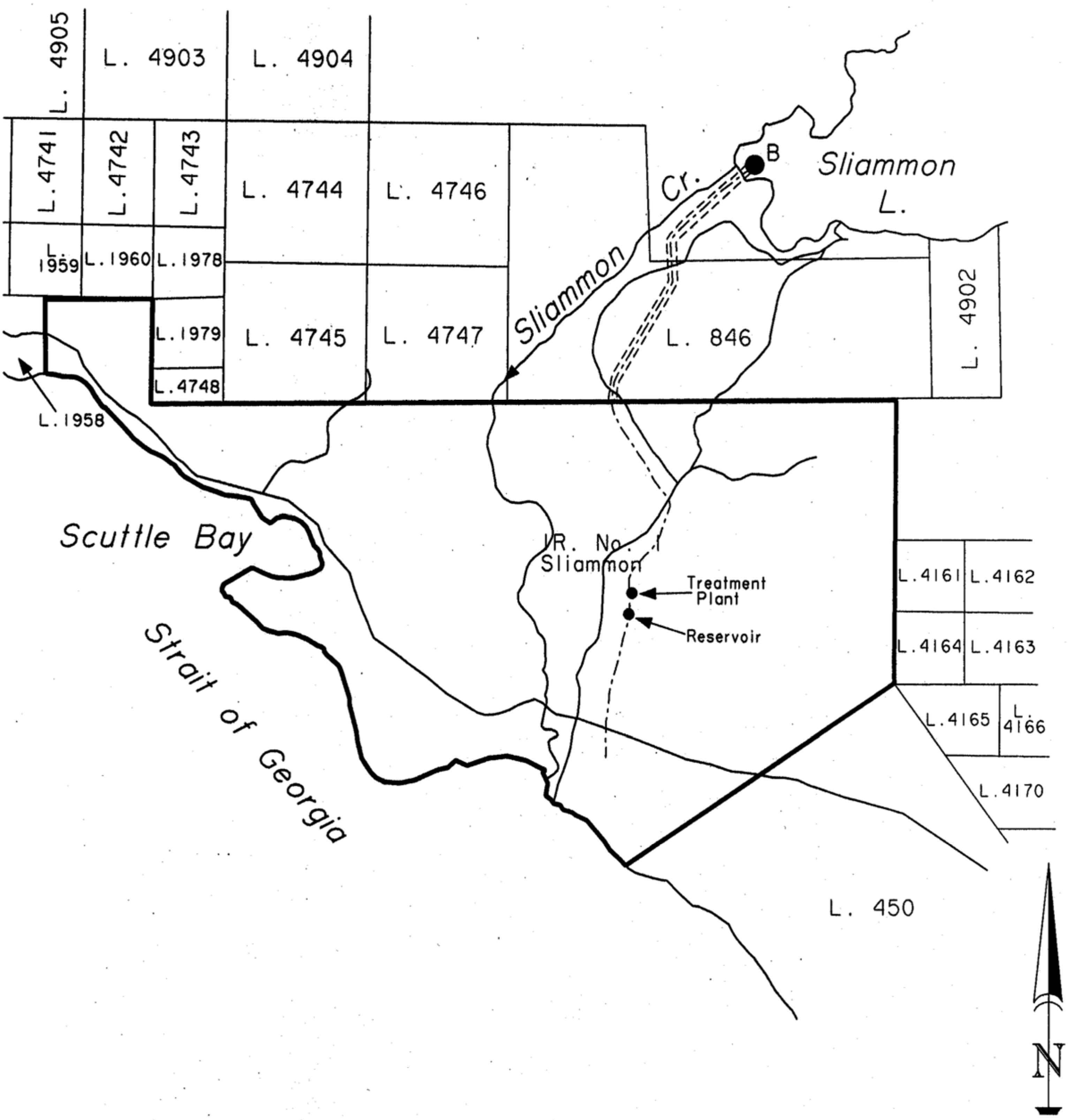
(i) The construction of the said works has been completed and the water is being beneficially used. The licensee shall continue to make a regular beneficial use of the water in the manner authorized herein.

(j) This licence is issued in substitution of Conditional Water Licence 30916.

D. Barry Paterson
Assistant Regional Water Manager

File No: **0263377** Date issued: **15th July, 1998** Conditional Licence: **113456**

Province of British Columbia



WATER DISTRICT : VANCOUVER
PRECINCT : JERVIS
LAND DISTRICT : GP I NEW WESTMINSTER

LEGEND

Scale	:	1:30000
Point of Diversion	:	●
Map Number	:	WR 92F.098
Pipe	:	—·—·—·—·—
Permit over Crown Land	:	===========

Signature: [signature]

Date: JULY 15/98

C.L. 113456 for C.L. 30916
File 0263377
P.C.L. 22800

The boundaries of the land to which this licence is appurtenant are shown thus: ———————

Province of British Columbia
Water Act

CONDITIONAL WATER LICENCE

Fisheries and Oceans Canada are hereby authorized to store and use water as follows:

(a) The stream on which the rights are granted is **Sliammon Lake**.

(b) The point of diversion and storage site is located as shown on the attached plan.

(c) The date from which this licence shall have precedence is **April 17, 2001**.

(d) The purpose for which this licence is issued is **conservation (storage of water)**.

(e) The maximum quantity of water which may be stored is **1,320 acre feet per annum.**

(f) Water may be stored throughout **the whole year.**

(g) This licence is appurtenant to the conservation project of the licensee within **that parcel or tract of Crown land in the vicinity of Sliammon Lake, Group 1, New Westminster District**.

(h) The works authorized to be constructed are **diversion structure and dam** which shall be located approximately as shown on the attached plan.

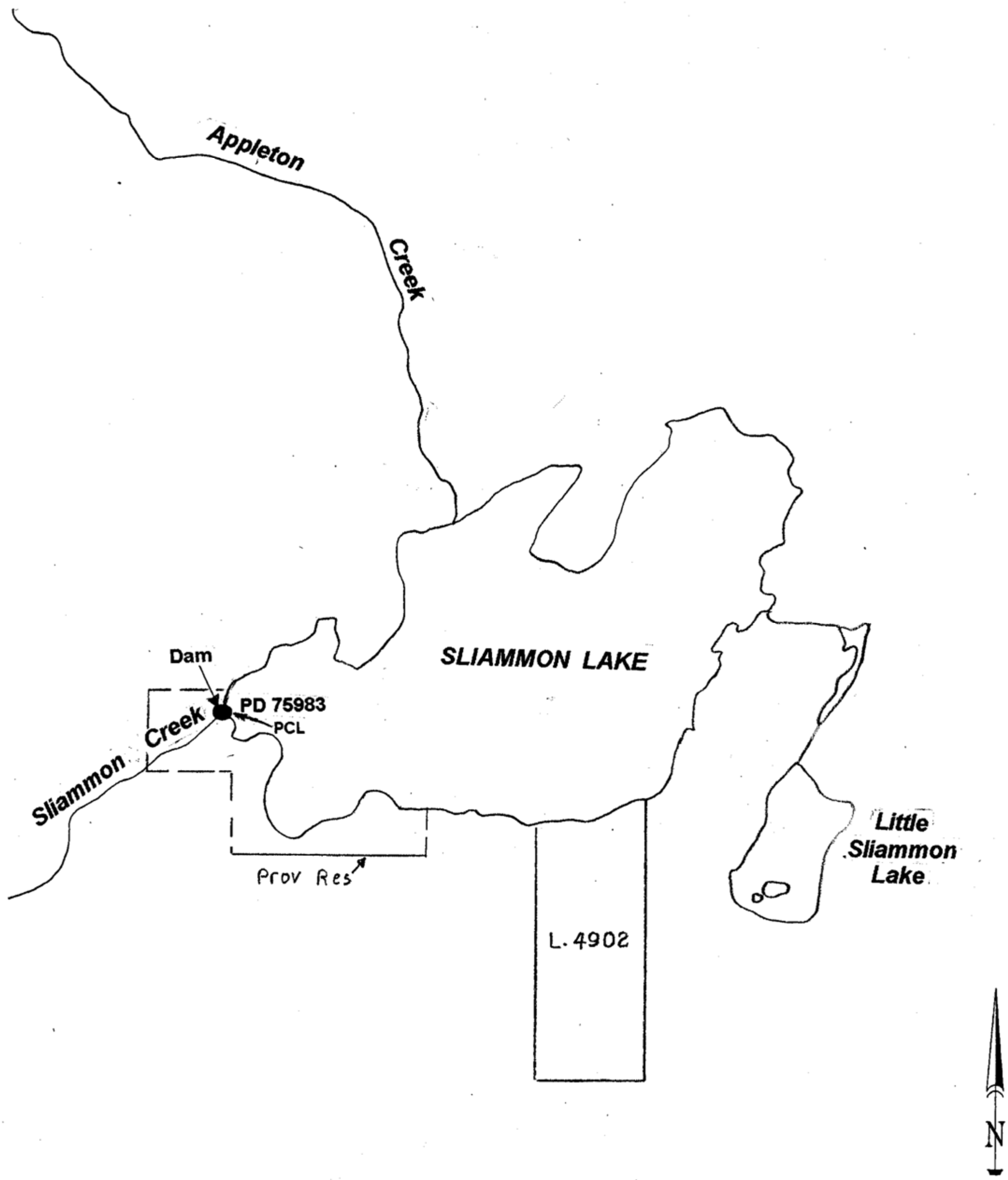
(i) The construction of the said works has been completed and the water is being beneficially used. The licensee shall continue to make a regular beneficial use of water in the manner authorized herein.

(j) The diversion of water authorized under this licence may be restricted or prohibited at any time by an order in writing of the Engineer for the Vancouver Water District in order to maintain a minimum flow in the stream for the preservation of fish life.

Alec Drysdale
A/Regional Water Manager

File No: **2002440** Date issued: **May 8, 2003** Conditional Licence: **116139**

BRITISH COLUMBIA



WATER DISTRICT : VANCOUVER
PRECINCT : JERVIS
LAND DISTRICT : GROUP 1, NEW WESTMINSTER

Scale : 1 : 20,000
Point of Diversion & Storage Site : ● PD 75983
Map Number: : WR 92.F.098
PCL: : Permit Over Crown Land

Signature: ______

Date: May 8, 2003

C.L. 116139
File: 2002440
PCL 24157

BBA