Duncan Dam Project

Water Use Plan

Revised for Acceptance by the Comptroller of Water Rights

December 20, 2007
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BC hydro Generation

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Preface

The water use planning process for BC Hydro’s Duncan Dam facility was initiated in August 2001 and was completed in September 2005.

The proposed conditions in this Water Use Plan, for the operation of BC Hydro’s Duncan Dam facility, reflect the recommendations of the Duncan Dam Water Use Plan Consultative Committee.

BC Hydro thanks all those who participated in the process that led to the production of this Water Use Plan, for their effort and dedication. The proposed conditions for the operation of BC Hydro’s Duncan Dam facility will not come into effect until implemented under the Water Act.
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1.0 INTRODUCTION

The conditions, proposed in this Water Use Plan, for the operation of BC Hydro’s Duncan Dam facility reflect the recommendations of the Duncan Dam Water Use Plan Consultative Committee.

The proposed terms and conditions to be authorized under the Water Act for the beneficial use of water at the Duncan Dam facility are set out in this document. Future reference to the Duncan Dam facility includes the Duncan Reservoir and the Duncan Dam. Duncan Dam, along with the Mica and Arrow dams, were constructed under the Columbia River Treaty and are operated in accordance with Treaty operating plans. Within accordance to the Treaty operating plans, the proposed conditions will change current operations at Duncan Dam and are expected to positively affect cultural resources, fish habitat, flood protection, recreation, and wildlife habitat and reduce mosquito habitat. The proposed conditions are expected to incidentally decrease power generation revenues associated with Mica and Revelstoke projects.

A monitoring program is proposed in order to study key uncertainties to enable improved operating decisions in the future. Refer to the Duncan Dam Water Use Plan: Consultative Committee Report (September 2005) for details on the consultative process, interests, objectives, performance measures, values associated with operating alternatives, and details of the proposed monitoring program.

2.0 DESCRIPTION OF WORKS

2.1 The Duncan Dam System

The Mica, Hugh Keenleyside, and Duncan projects were constructed under the Columbia River Treaty. The dams are operated to maximize mutual benefits with respect to flood control and power generation for Canada and the United States. The Duncan Dam was completed in 1967. Mica and Keenleyside projects were completed in 1973 and 1968, respectively. A fourth dam, Libby, on the U.S. Kootenai River, upstream of Kootenay Lake, was permitted under the Treaty and was completed in 1974.

The Duncan Dam Project is located within the Regional District of Central Kootenay, and lies within the Duncan River drainage basin that covers 2,400 km². The Duncan Dam is located immediately upstream of the confluence of the Duncan and Lardeau rivers, approximately 8 km upstream of Kootenay Lake and 42 km north of the Village of Kaslo. Figure 2-1 illustrates the location of the Duncan Dam facility within the Columbia River basin.

The Duncan Reservoir, impounded by the dam, is 45 km long when the reservoir is at full pool (~1892 ft). Besides providing storage for downstream hydroelectric
generation and flood control, the reservoir also provides fish flow regulation for the Duncan River between the dam and the mouth of the river at Kootenay Lake, a distance of approximately 8 km.

There are no power generation facilities at Duncan Dam. The structure consists of an earth-filled dam, two discharge tunnels on the west side of the dam and a concrete spillway located on the east bank of the dam. Water release facilities at the dam consist of two discharge tunnels, controlled at the downstream ends by radial gates and a gated spillway (See Figure 2-2).

Figure 2-1: Columbia River Basin
2.2 Columbia River Treaty

The Columbia River Treaty was signed with the United States in 1961 and ratified in 1964. BC Hydro was appointed as the Canadian Entity under the Treaty. Under the terms of the Treaty, BC Hydro built and now operates 15.5 million acre-feet (MAF) of storage at the Mica (7.0 MAF), Hugh Keenleyside (7.1 MAF), and Duncan (1.4 MAF) projects in co-ordination with the United States to maximize power generation and flood control benefits in both countries. In return, Canada received an up-front payment for the flood control benefits, as well as one-half of the annual additional power generation benefits produced at the downstream U.S. projects on an on-going basis. The Treaty expires no earlier than September 2024.

2.2.1 Flood Control Operating Plan

The Columbia River Treaty requires that a Flood Control Operating Plan (FCOP) be prepared and agreed to by the Canadian and U.S. Entities. The first FCOP was prepared in 1968, and major revisions were completed in 1972, 1999, and 2003. The FCOP specifies Flood Control Curves for each of the three Treaty projects in Canada and the Libby Reservoir in the United States portion of the Columbia River basin. It also defines the flood protection objectives and outlines the system flood control operation of the Columbia River basin.

2.2.2 Assured Operating Plan

The Columbia River Treaty requires that an Assured Operating Plan (AOP) be prepared and agreed to each year by the Entities for the operation of Treaty storage during the sixth succeeding year. The AOP provides information to the Entities for planning the power systems in the two countries, which are dependent on or co-ordinated with the operation of Treaty storage.

Key results from the AOP studies include a set of four “critical rule curves” (CRC) for each reservoir. The CRC guide the operation to meet firm load in the United States and parameters for deriving operating rule curves (ORC) used to direct the operation to meet the secondary market. Each of the CRCs corresponds to one of the four years of the critical runoff sequence for the combined system (generally from mid August 1928 through February 1932). The curves represent the month-end reservoir level trajectories that would have resulted over this time period had the reservoir been full at the start, empty at the end, and operated optimally to meet firm energy of the U.S. Pacific Northwest area during the critical runoff sequence. The maximum amount of firm load that the system can meet with certainty during the critical period is the Firm Energy Load Carrying Capability (FELCC).
Under the Columbia River Treaty, all storage reservoirs in the combined United States and Canadian system are to be drafted “proportionately” between rule curves whenever needed to meet the FELCC. For example, if one reservoir is drafted to a point halfway between its second and third CRCs, then every reservoir in the system should also be drafted to that point. Individual project constraints, such as minimum flows, sometimes override this principle. The Determination of the Downstream Power Benefits document is attached to each AOP and defines the Canadian Entitlement for that operating year.

2.2.3 Detailed Operating Plan

Under the provision of the Columbia River Treaty, a Detailed Operating Plan (DOP) is also prepared each year for the operation of Treaty storage in the following year. Operating rules developed in the AOP for the following year may be updated or altered by mutual agreement between the two Entities. If no agreement is reached, then the rules developed in the AOP are repeated in the DOP. The DOP contains detailed information on project specific constraints and special operating rules and, once completed, is the guiding document for Treaty storage operation for the year.

2.2.4 Treaty Storage Regulation Study

Under provisions of the Columbia River Treaty, the Entities undertake a Treaty Storage Regulation (TSR) study at least twice per month according to the rules governing Canadian Treaty storage operation, as outlined in the DOP. The study determines monthly storage rights and obligations for the Canadian Treaty projects and is used by the Entities to determine the weekly Treaty storage operation request. The TSR study simulates storage operations for all projects in the Columbia River basin (Canada and United States). System reservoirs are filled or drafted, based on the principle of proportional draft, as needed to meet the specified FELCC first and then, if possible, the secondary load subject to system refill criteria.

If the FELCC cannot be met even after drafting all system reservoirs to empty, the TSR study determines the deficit in FELCC. If the FELCC can be met while maintaining system reservoirs on or above the ORCs, then the TSR study may show generation surplus to the FELCC. In the study, reservoirs are not allowed to fill above their ORCs until a specified non-firm energy market is served. Once this market is served, reservoirs are filled proportionately between ORCs and Flood Control Curves.
2.2.5 **Storage Transfers between Treaty Projects**

The Columbia River Treaty specifies that Canada may alter releases at Mica Dam, Hugh Keenleyside Dam and/or Duncan Dam, as long as the sum of Arrow and Duncan releases are unchanged from the official Treaty request and the flood control requirement is individually met at each Treaty project. This provision allows the Mica Dam to release more or less than that specified by the DOP (over run or under run, respectively), as long as Hugh Keenleyside Dam discharges are unchanged. In addition, this provision allows storage (and release) transfers from Duncan Reservoir to Arrow Lakes Reservoir or Kinbasket Reservoir, and vice versa, to suit BC Hydro’s needs. These transfers are often referred to as “flex” operations, since they are derived from the internal flexibility BC Hydro has to move water among the basin reservoirs.

2.2.6 **Variances from Treaty Storage Regulation – Specified Storage Levels**

At various times, it may be advantageous to both the Canadian and U.S. Entities to draft the total Columbia River Treaty storage below TSR levels or to store above TSR levels. This may be done only with prior agreement from both Entities. Special agreements or variances have been signed and implemented each year since 1993 to allow such an operation, benefiting non-power generation interests on both sides of the border.

2.2.7 **Columbia River Treaty Operations: Weekly Planning**

Through a Thursday conference call, BC Hydro’s Generation Operations (acting on behalf of the Canadian Entity under the Columbia River Treaty) and the U.S. Entity (BPA and the Corps. of Engineers) agree on a preliminary Treaty release schedule for the following week (beginning on Saturday and ending on the following Friday). The weekly Treaty release schedule is normally finalized prior to Friday at 1200 hours.

2.3 **Duncan Project: Existing Works**

2.3.1 **Duncan Reservoir**

Duncan Dam impounds Duncan Reservoir. At full pool, the reservoir covers an area of approximately 7150 ha, and has a usable storage volume of 1727 million m³. The normal operating range of the reservoir is between 546.87 m (1794.2 ft) and 576.68 m (1892.0 ft).

2.3.2 **Duncan Dam**

The dam is earth-filled and is 80 m long and 40 m high. The dam crest elevation is 581.5 m. There are no power generation facilities at this dam. Water release facilities consist of two 6.1 m diameter pressure tunnels approximately 333 m long controlled at the downstream ends by radial gates with dimensions of 5.87 m wide by 4.8 m high (LLOGs). There is also a gated spillway consisting of two 8.7 m wide by 12.2 m high vertical lift gates (SPOGs).
A fish weir was constructed at the toe of the outlet of Low Level Outlet Gate #2 (LLOG #2) in June 1994. This makes LLOG #2 the preferred gate for fish transfers in low tailwater years.

![Duncan Dam Project Schematic]

Figure 2-2: Duncan Dam: Project Schematic

### 3.0 HYDROLOGY OF THE COLUMBIA RIVER BASIN

#### 3.1 Drainage Basin

The Duncan basin is located in the Purcell Trench, a prominent valley between the Purcell and Selkirk Ranges. The Duncan River’s headwaters begin at Mount Dawson, near Glacier National Park where it flows south easterly for 55 km to Duncan Lake Reservoir, which is approximately 45 km long. The Duncan River is joined by the Lardeau River just downstream of the dam and continues to flow southward for about 10 km in a braided channel to the North Arm of Kootenay Lake. The mean basin elevation is approximately 1800 m and the total basin area is 2443 km².

See Appendix 1, the Duncan Dam Water Use Plan Hydrology Memo, for additional information on the physiography, climate and hydrology of the Duncan River basin.

#### 3.2 Run-Off Distribution

The Duncan basin is located in the south eastern interior climatic region and is affected by modified maritime and continental conditions. Moisture-laden air is carried over the Monashee and Selkirk Ranges and deposited in the Duncan River basin as systems rise over the higher Purcell Range. Heavy precipitation may occur during both winter and summer months, however, winter precipitation consists mainly of snow. The presence of glaciers throughout the higher elevations in the basin confirms that heavy snow packs build throughout the winter. Mean annual inflow is ~ 126 m³/s.
4.0 OPERATING CONDITIONS FOR FACILITY

4.1 Role of Facility in BC Hydro’s System

The Duncan Dam Project regulates approximately 10 per cent of the runoff in the Kootenay River basin and provides an equivalent amount of usable storage in the Kootenay River system. Hydroelectric plants on the Kootenay River within British Columbia contribute approximately 10 per cent of the hydroelectric generation in British Columbia. The storage provided by Duncan Reservoir improves the amount and timing of downstream hydroelectric generation and contributes to flood control downstream in the Kootenay and Columbia river basins in both Canada and the United States.

4.2 Use of Water for Generation and Flood Control at the Duncan Dam Facility

BC Hydro is responsible for scheduling and implementing Duncan Dam releases under the Columbia River Treaty. Treaty storage releases for Duncan Dam, as well as for Mica and Hugh Keenleyside dams (the other two Treaty projects in Canada), are determined from operating plans designed to maximize power generation and flood control in Canada and the United States. BC Hydro normally has discretion to determine individual releases at each of the three Treaty projects, however, overall Treaty releases must satisfy Treaty operating plans, including requirements for power generation, flood control, and dam safety. From time to time, BC Hydro (the Canadian Entity under the Treaty) and

Figure 3-1   Historical daily inflow to Duncan Lake Reservoir (1967-1999)

See Appendix 1, for a complete description on daily inflow and seasonal volume inflow forecasting procedures. A description of the supporting network of hydrometeorological stations in the area and a summary of the inflow hydrographs for the Duncan Reservoir is also provided in the memo.
the United States Entity may modify Treaty requirements by mutual agreement to improve power generation, fisheries, or other non-power operations.

The Columbia River Treaty requires that an Assured Operating Plan (AOP) be prepared each year by the Canadian and United States Entities for the operation of Columbia Treaty storage for the sixth succeeding year. The Columbia River Treaty also allows for a DOP to be prepared and agreed to each year by the Entities for the operation of Treaty storage in the following year. Operating rules established in the appropriate AOP (i.e., for application in the following year) may be updated and/or altered by mutual agreement of the two Entities. If no agreement is reached, then the rules agreed to in the AOP are the default rules. The DOP is prepared jointly by the Entities (See Section 2.2.).

Regulation of the Duncan Reservoir for flood control purposes in Canada and the United States is governed by the Columbia River Treaty Flood Control Operating Plan (FCOP). The FCOP is developed by the U.S. Army Corps of Engineers (the Corps), in consultation with BC Hydro, based on principles laid out in the Treaty. Duncan Reservoir levels must not exceed Flood Control Rule Curve levels specified in the FCOP except as directed by the Corps to reduce downstream flooding.

The Treaty provides for both system and local flood control objectives. BC Hydro works closely with the Corps to define these flood control needs. In many cases, system flood control needs are more restrictive to Duncan Reservoir operations than are local flood control needs and the Treaty Flood Control Rule Curves reflect this. If necessary to accommodate a desired project operation, BC Hydro may request that the Corps issue a variance from the Flood Control Rule Curve for one of the Treaty projects. The Corps will consider this request in light of the current and forecast system and local flooding potential.

Under most conditions, BC Hydro will have adequate flexibility at the three Columbia River Treaty reservoirs to allow Duncan Project operations to meet the conditions specified in this Water Use Plan. However, there are potential circumstances where this flexibility, including any allowable variances to flood control rules, will be inadequate. In such cases, operations to meet Treaty operating plan obligations shall have precedence over the operational conditions outlined in this Water Use Plan.

4.3 Emergencies and Dam Safety

Emergencies and dam safety requirements shall take precedence over the operational conditions outlined in this Water Use Plan. Emergencies include, but are not limited to, actual and potential loss of power to customers, mechanical failures and environmental incidents. Dam safety requirements for operations are outlined in the Duncan Dam: Operation, Maintenance and Surveillance Requirements issued by BC Hydro’s Director of Dam Safety.
Operational instructions for surcharging the reservoirs and undertaking a special drawdown for dam safety purposes are also described in the OMS Manual for Dam Safety. Community notification procedures are documented in the Generation Emergency Plans.

4.4 Proposed Conditions for the Diversion and Use of Water

BC Hydro proposes to operate the Duncan Dam facilities in accordance with the conditions outlined below, subject to requirements under the Columbia River Treaty. BC Hydro may not be able to operate within these conditions in the event of an emergency, dam safety requirement, or an extreme hydrological event.

Due to the approximate nature of flow and reservoir level measurements, BC Hydro will be considered to have operated in compliance, unless otherwise specified, whenever:

- Duncan Dam discharges are within +/- 5% of the maximum or minimum conditions stated below; and
- Duncan Reservoir levels are within +/- 0.1 m of the conditions stated below.

BC Hydro will make reasonable efforts to adjust Duncan Dam discharges as necessary during normal working hours to maintain discharges and reservoir levels within the conditions stated below. BC Hydro will be considered to have operated in compliance as long as BC Hydro makes a discharge adjustment (or confirms the discharge) at least once during normal working hours each day. Duncan Dam operations will be made with the objective of complying with the conditions specified in the Duncan Dam Water Use Plan.

This operational protocol may be revised based on information collected over the Duncan Dam Water Use Plan review period, upon consultation with federal and provincial fisheries agencies and upon direction from the Comptroller of Water Rights.

4.4.1 Duncan Reservoir Elevation

To improve recreation and provide sufficient storage to maintain summer and fall fish flows, BC Hydro will operate the reservoir to target full pool in August. Reservoir filling will commence in the spring with a target of reaching full pool (between 576.38 and 576.68 m) during the period between August 1st and August 10th. After reaching full pool, or on August 11th if full pool is not obtained, BC Hydro will make reasonable efforts to draft the reservoir to 575.5 m and maintain the reservoir within ±0.3 m of this level until the end of Labour Day (September).

Due to inflow variability, it is expected that the reservoir will not reach the full pool in approximately 10 per cent of years. Maintaining the target minimum flows in the Duncan River below the facility shall take priority over the August Duncan Reservoir level targets noted in this section (refer to Section 4.4.6).
Similarly, due to inflow variability, the lower target reservoir level between August 11\textsuperscript{th} and Labour Day (September) may not always be achieved. Meeting the flow requirements for the Duncan River below the facility (refer to Section 4.4.6) will take precedence over achieving the aforementioned Duncan Reservoir levels. BC Hydro must inform the Comptroller of Water Rights if such a conflict is expected to occur, in advance of deviating from the proscribed operation.

At all times, meeting reservoir levels specified in the Columbia River Treaty Flood Control Operating Plan take priority over the aforementioned constraints.

4.4.2 Argenta Slough Erosion Protection

Argenta Slough, a productive wetland habitat for birds, wildlife, and fish, is located downstream of the confluence with the Lardeau River. In lieu of maintaining a level in Duncan Reservoir less than that proposed in Section 4.4.1 to reduce the frequency of high flow events, erosion protection measures are suggested as a means to maximize the quality and quantity of available habitat area. It is recommended that the Comptroller of Water Rights direct BC Hydro to provide erosion protection at the Argenta Slough. The details regarding this recommendation are provided in the Dunkan Dam Water Use Plan: Consultative Committee Report.

4.4.3 Heritage and Cultural Sites Erosion Protection

Cyclic reservoir operations through the drawdown zone are hypothesised to increase the erosion rates of foreshore heritage sites. Heritage and cultural sites protection is recommended, in lieu of maintaining a more stable level in Duncan Reservoir than that proposed in Section 4.4.1 as a means to protect identified cultural sites and resources. The details regarding this recommendation are provided in the Dunkan Dam Water Use Plan: Consultative Committee Report.

BC Hydro will work with the First Nations to develop a plan to meet the obligations required under the BC Heritage Conservation Act.

4.4.4 Glacier Creek Boat Ramp Extension

Extending the Glacier Creek boat ramp is recommended, in lieu of maintaining Duncan Reservoir higher than that proposed in Section 4.4.1, as a means to increase recreation access. It is recommended that the Comptroller of Water Rights direct BC Hydro to provide an extension to the Glacier Creek boat ramp, conditional upon the Regional District of Central Kootenay assuming maintenance responsibilities. The details regarding this recommendation are provided in the Dunkan Dam Water Use Plan: Consultative Committee Report.
4.4.5 Kootenay Lake Nutrient Loading

A stable Duncan Reservoir is hypothesised to maximize the downstream flux of nutrients into Kootenay Lake. In lieu of maintaining a more stable level in Duncan Reservoir than that proposed in Section 4.4.1, adding nutrients to Kootenay Lake is proposed as a means to maximize fish abundance and diversity. It is recommended that the Comptroller of Water Rights direct BC Hydro to provide a nutrient program for Kootenay Lake. The details regarding this recommendation are provided in the Duncan Dam Water Use Plan: Consultative Committee Report.

4.4.6 Duncan Dam Discharges

4.4.6.1 Minimum and Maximum Discharges

Under the Columbia River Treaty, the minimum monthly discharge from Duncan Dam is 3.0 m$^3$/s. To maintain continuity of fish habitat between the dam the confluence with the Lardeau River, a minimum daily average release from the Duncan Dam of 3 m$^3$/s has been adopted. BC Hydro may deviate from this provision to facilitate bull trout passage between May 1 and June 30. BC Hydro may also deviate from this provision to address annual maintenance requirements associated with the radial gates (LLOGs) providing that impacts to fish habitat in the tailrace are managed.

The normal maximum release from the Duncan Dam (LLOGs and/or SPOGs) under the Columbia River Treaty is 283.17 m$^3$/s (10 kcfs) year round. Discharges in excess of 283.17 m$^3$/s may occur during periods of high inflow routing to meet other Treaty obligations.

When discharge over the spillway (SPOGs) exceeds 115 m$^3$/s, total gas pressure levels may impact downstream fish. Consequently, it is recommended that when total Duncan Dam discharges are nearing 283 m$^3$/s, the LLOGs are preferentially used, if available, to restrict spill volumes from the SPOGs to less than 115 m$^3$/s to minimize downstream TGP levels.

Operation to the aforementioned flows is acceptable within ±5% during normal operations.

4.4.6.2 Duncan Dam Ramp Rates

To minimize the potential to strand fish, the maximum ramp down ramp rate for flow releases from Duncan Dam into the Duncan River is 28 m$^3$/s ±5% per hour, year-round and not to exceed a total ramp rate of change of 113 m$^3$/s ±5% per day.

To minimize the likelihood of downstream erosion, the maximum up ramp rate for flow releases from Duncan Dam into the Duncan River is 113 m$^3$/s ±5% per day, year-round.
Three years after BC Hydro receives direction from the Comptroller of Water Rights to implement the Duncan Water Use Plan, a review of the ramp rates will be undertaken. Ramp rate criteria can be revised, if deemed necessary, upon consultation with federal and provincial fisheries agencies and upon direction from the Comptroller of Water Rights in advance of the formal WUP review.

Ramp rate obligations take precedence over meeting the scheduled flow changes between maximum flow limits required under Table 4-1.

4.4.7 Duncan River Downstream the Confluence of Lardeau River

Operation to the following flows (sections 4.4.7.1 & 4.4.7.2) is acceptable within ±5% during normal operations provided that the 3 day rolling average is within the minimum and maximum limits under Table 4-1.

Operation to the following minimum and maximum flows takes precedence over meeting the reservoir levels targeted in section 4.4.1. At all times, meeting reservoir levels specified in the Columbia River Treaty Flood Control Operating Plan takes priority over meeting either the reservoir and Duncan River flow constraints. BC Hydro must inform the Comptroller of Water Rights if such a conflict is expected to occur, in advance of deviating from the proscribed operation.

4.4.7.1 Minimum Flows

To maintain and enhance fisheries habitat in the Duncan River, BC Hydro will make reasonable efforts to provide a minimum flow of 73 m$^3$/s year round in the Duncan River as measured in the vicinity of the Water Survey of Canada gauge 08NH118, below the Duncan and Lardeau rivers confluence.

In the event that the minimum flows between March 1 and May 30 cannot be met as a result of reservoir level constraints under the Columbia River Treaty, BC Hydro will request a flood control variance from the US Army Corps of Engineers (Section 4.2). If a variance is not granted, BC Hydro must consult with federal and provincial fisheries agencies and seek direction from the Comptroller of Water Rights to implement a revised minimum flow regime for a specified time period.

4.4.7.2 Maximum Flows

To maintain and enhance fisheries habitat in the Duncan River downstream of the confluence of the Lardeau, BC Hydro will make reasonable efforts to limit the maximum flows, as measured in the vicinity of Water Survey of Canada gauge 08NH118, to the following:
Table 4-1 Maximum Flows: Duncan River d/s Lardeau River Confluence

<table>
<thead>
<tr>
<th>Date</th>
<th>Maximum Flow (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 1 to August 24</td>
<td>400</td>
</tr>
<tr>
<td>August 25 to September 24</td>
<td>250</td>
</tr>
<tr>
<td>September 25 to September 27</td>
<td>190</td>
</tr>
<tr>
<td>September 28 to September 30</td>
<td>130</td>
</tr>
<tr>
<td>October 1 to October 21</td>
<td>76</td>
</tr>
<tr>
<td>October 22 to December 21</td>
<td>110</td>
</tr>
<tr>
<td>December 22 to April 9</td>
<td>250</td>
</tr>
<tr>
<td>April 10 to May 15</td>
<td>120</td>
</tr>
<tr>
<td>May 16 to July 31</td>
<td>400</td>
</tr>
</tbody>
</table>

Between August 1 and August 24, BC Hydro will target a flow of 250 m³/s. It is expected, however, that flows will routinely exceed this level during above average inflow years.

Between October 1 and October 21, the maximum and minimum flow limits are limited to between 73 and 76 m³/s. BC Hydro will make reasonable efforts to adjust dam discharges at least once a day during normal working hours to maintain discharges within this range.

In the event that the maximum flows between December 22 and April 9 cannot be met as a result of reservoir level constraints under the Columbia River Treaty, BC Hydro will request a flood control variance from the US Army Corps of Engineers (Section 4.2). If the variance is not granted, BC Hydro may increase the maximum flow to 300 m³/s for the period between December 22 and April 9 providing that the Comptroller of Water Rights is notified in a timely manner.

If further increases to the maximum flow between December 22 and April 9 are required, BC Hydro must consult with federal and provincial fisheries agencies and seek direction from the Comptroller of Water Rights to implement a revised maximum flow regime for a specified time period.

4.4.8 Action Plan to Minimise Kokanee Stranding in Duncan R Sidechannels

BC Hydro will develop, in consultation with federal and provincial fisheries agencies, an action plan to minimize the risk of stranding kokanee spawning in the Duncan River sidechannels downstream of the dam. The action plan is in lieu of operational constraints that would maintain a minimum flow in the Duncan River below the facility from 15 September to 30 September less than that proposed in Section 4.4.7.1.
The action plan will include monitoring sidechannel use, assessment of exclusion methods, and implementation of physical works where appropriate. It is recommended that the Comptroller of Water Rights direct BC Hydro to implement this action plan. The details regarding this recommendation are provided in the *Duncan Dam Water Use Plan: Consultative Committee Report*.

### 4.4.9 Bull Trout Migration Operations

During the summer, the low-level outlet is operated similarly to a navigation lock to assist the upstream migration of bull trout. Around late May or early June of each year, bull trout migrate from Kootenay Lake up the Duncan River to the base of the Duncan Dam. At this time, the project outflows are normally between 3.0 and 30.0 m³/s (106 and 1060 cfs). Duncan Dam operations are then modified to allow fish to pass up one of the discharge tunnels in much the same way as a boat is allowed to pass through a navigation lock.

A fish weir was constructed at the toe of the outlet of Low Level Outlet Gate #2 (LLOG #2). This makes LLOG #2 the preferred gate for fish transfers in low tailwater years. The weir has removable stoplogs and helps fish enter the flip bucket by staggering the jump from the tailwater. In a normal year, this fish transfer operation is repeated 10 to 12 times, allowing fish to transfer from the Duncan River downstream of the dam into the Duncan Reservoir. This operation does not affect normal storage/discharge operations at the project since the other tunnel and the spillway are normally available.

It is recommended that the Comptroller of Water Rights direct BC Hydro to continue this practice and assess its efficacy. The details regarding this recommendation are provided in the *Duncan Dam Water Use Plan: Consultative Committee Report*.

### 5.0 PROGRAMS FOR ADDITIONAL INFORMATION

Development of the proposed conditions for the Duncan Dam facility was complicated by uncertainties and information gaps. The April 2004 recommendations of the Consultative Committee were contingent upon the implementation of a monitoring program to reduce these uncertainties over time.

Accordingly, it is recommended that the Comptroller of Water Rights direct BC Hydro to undertake a monitoring program that will:

- Assess expected outcomes of the operational changes being recommended; and
- Provide improved information for future operating conditions.

Details and costs of the proposed monitoring program are provided in the *Duncan Dam Water Use Plan: Consultative Committee Report*. The monitoring programs are designed to address key questions that affected decision-making throughout the consultative process. Table 5-1 provides a summary.
Table 5-1: Monitoring Program Components and Objectives

<table>
<thead>
<tr>
<th>Component</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Duncan River</strong></td>
<td></td>
</tr>
<tr>
<td>Adaptive Stranding Protocol Development Stages 1 and 2: Develop and Implement Interim Protocol</td>
<td>Develop and implement an interim ramping rate to minimize fish stranding based on current information</td>
</tr>
<tr>
<td>Adaptive Stranding Protocol Development Stage 3: Data Collection and Interim Protocol Continued</td>
<td>Develop and implement an interim ramping rate to minimize fish stranding based on best available information</td>
</tr>
<tr>
<td>Adaptive Stranding Protocol Development Stage 4: Finalize Protocol and Monitor</td>
<td>The protocol will be finalized and a ramping rate and operating protocol will be implemented. The remaining years in the review period will be dedicated to monitoring effectiveness of the protocol and calibrating model assumptions.</td>
</tr>
<tr>
<td>Kokanee Spawning Study</td>
<td>To assess the relative importance of Kokanee spawning in the Duncan River below the facility on overall run strength (Lardeau/Meadow/Duncan) and develop appropriate flow options to protect as required.</td>
</tr>
<tr>
<td>Bull Trout Passage Studies</td>
<td>Develop an understanding of bull trout migration importance to Duncan and Kootenay river systems and determine the best management practice.</td>
</tr>
<tr>
<td>Temperature and Total Gas Pressure Monitoring Studies</td>
<td>Collect baseline temperature and total gas pressure monitoring to further refine the total gas pressure performance measure and determine if temperature is an issue.</td>
</tr>
<tr>
<td>Cottonwood Studies</td>
<td>To monitor the influence of the Duncan Dam Water Use Plan alternative on Cottonwood Recruitment and other riparian communities in the Duncan River floodplain.</td>
</tr>
<tr>
<td>Mosquito Management Study</td>
<td>To determine if the mosquito breeding habitat performance measure and index site are appropriate for other sites in the Duncan River below the facility.</td>
</tr>
<tr>
<td><strong>Duncan Reservoir</strong></td>
<td></td>
</tr>
<tr>
<td>Stock Assessment and Fish Habitat Utilization Studies</td>
<td>Stock assessment program to verify the relative abundance and distribution of indicator species to ensure no negative trend in abundance associated with deep Duncan Reservoir drawdown.</td>
</tr>
<tr>
<td>Burbot Studies</td>
<td>To define spawning locations of Duncan Reservoir burbot population and assess the implications of reservoir operations.</td>
</tr>
<tr>
<td>Reservoir Riparian Studies</td>
<td>Determine the pre-alteration distribution of wetland and riparian vegetation and monitor changes in the aerial coverage and plant species composition of vegetated communities in the Duncan Reservoir drawdown zone.</td>
</tr>
<tr>
<td>Archaeology Study</td>
<td>To survey other potential sites in the Duncan Reservoir that is likely being impacted by operations, including examination of rock bluffs and alluvial fan cutbacks.</td>
</tr>
<tr>
<td>Erosion Studies</td>
<td>Non intrusive monitoring and of the rate of erosion (caused by changing Duncan Reservoir water levels) at the two identified cultural sites. This includes assessing the importance of areas within the located sites that may be impacted by operations.</td>
</tr>
</tbody>
</table>
6.0 IMPLEMENTATION OF RECOMMENDATIONS
The operating conditions, the monitoring program, and the non-operational physical works proposed in this Water Use Plan will be implemented after BC Hydro receives direction from the Comptroller of Water Rights.

7.0 EXPECTED WATER MANAGEMENT IMPLICATIONS
Implications for the provincial interests that were considered during the preparation of this Water Use Plan are expected outcomes and are relative to current operations based on the best available information. After BC Hydro has been directed to implement the proposed conditions, BC Hydro will be responsible for meeting the operational parameters, but not for achieving the expected outcomes.

7.1 Other Licensed Uses of Water
The proposed conditions in this Water Use Plan are not expected to affect other current licensed uses of water associated with the Duncan Reservoir or the Duncan River below the facility.

7.2 Riparian Rights
The proposed conditions in this Water Use Plan are not expected to affect riparian rights associated with the Duncan Reservoir or the Duncan River below the facility.

7.3 Fish Habitat
The proposed conditions in this Water Use Plan are expected to increase overall fish abundance and diversity in the Duncan River below the facility through the provision of a flow regime, ramp rates, an Adaptive Stranding/Ramping Protocol, a Flood Control Rule Curve Risk Protocol, a Total Gas Pressure Procedure and an action plan to minimize the risk of stranding kokanee spawning in Duncan River sidechannels. Fish habitat in the Duncan Reservoir is not expected to be affected. Partial funding for the existing Columbia Basin Fish and Wildlife Nutrient Loading Program in Kootenay Lake is expected to maintain nutrient retention in Kootenay Lake.

7.4 Wildlife Habitat
The proposed conditions in this Water Use Plan are expected to improve recruitment of cottonwood and overall riparian productivity in the Duncan River below the facility through the provision of target flows. Wildlife habitat in the Duncan Reservoir is expected to decrease through the provision of a reservoir level target. Erosion protection physical works at Argenta Slough and wetlands is expected to improve wildlife habitat in the Duncan River system.
The proposed conditions in this Water Use Plan are expected to decrease potential mosquito breeding habitat in the Duncan River below the facility through the provision of target maximum flows.

The proposed conditions in this Water Use Plan are expected to increase erosion protection in the Duncan River below the facility through the provision of erosion protection physical works for Argenta Slough and wetlands.

7.5 Flood Management
The proposed conditions in this Water Use Plan are expected to decrease the frequency and duration of local flooding events in the Duncan River below the facility from August 1st to August 31 through restrictions on flow releases from the Duncan Dam.

7.6 Recreation
The proposed conditions in this Water Use Plan are expected to increase opportunities for recreation on the Duncan Reservoir through the provision of reservoir level targets and an extension to the Glacier Creek boat ramp.

7.7 Water Quality
The proposed conditions in this Water Use Plan are not expected to affect water quality associated with the Duncan Reservoir or the Duncan River below the facility.

7.8 Industrial Use of Water
The proposed conditions in this Water Use Plan are not expected to affect industrial use of water associated with the Duncan Reservoir or the Duncan River below the facility.

7.9 First Nations Considerations
BC Hydro’s Duncan Dam facility is located within the claimed traditional territory of the Ktunaxa-Kinbasket Tribal Council. First Nations interests included:

- Maintain the cultural, aesthetic and ecological context of important cultural resources and spiritual sites; and

- Maximize abundance and diversity of fish and wildlife populations to support First Nations harvesting and associated activities in the reservoir and along the Duncan River.

With respect to fish and wildlife interests, the proposed conditions in this Water Use Plan are expected to aid these objectives. Refer to Section 7.3 Fish Habitat and Section 7.4 Wildlife Habitat.
7.10 Archaeological Considerations

BC Hydro’s Duncan Dam facility is located within the claimed traditional territory of the Ktunaxa–Kinbasket Tribal Council. First Nations interests included:

- Protect cultural sites and resources from erosion in the reservoir;
- Protect cultural sites and resources from exploitation in the reservoir;
- Provide opportunities for archaeological investigation in the reservoir; and
- Maintain the cultural, aesthetic and ecological context of important cultural resources and spiritual sites.

The proposed conditions in this Water Use Plan are expected to increase knowledge and understanding of the cultural sites, and provide opportunities to protect cultural sites and resources and for non intrusive archaeological investigation through the provision of a monitoring study and erosion protection physical works in the Duncan Reservoir.

7.11 Power Generation

The proposed conditions in this Water Use Plan are expected to decrease the value of power generation at Canadian projects on the Kootenay and Columbia River systems. There will be no impact on power generation at United States plants.

8.0 RECORDS AND REPORTS

8.1 Compliance Reporting

BC Hydro will submit data as required to the Comptroller of Water Rights, to demonstrate compliance with the conditions conveyed in the Water Licences. The submission will include records of:

- Duncan Reservoir level;
- Duncan Dam discharges; and
- Flow in the vicinity of the Water Survey of Canada gauge 08NH118 (Duncan River downstream of Lardeau River).

8.2 Non-compliance Reporting

Non-compliance with operating conditions required by the water licence, or anticipation thereof, will be reported to the Comptroller of Water Rights in a timely manner.
8.3 Monitoring Program Reporting

Reporting procedures will be determined as part of the detailed terms of reference for each study or undertaking.

9.0 PLAN REVIEW

A review is recommended after 10 years. A review of the Duncan Dam Water Use Plan could be triggered sooner if significant risks are identified that could result in a recommendation to change operations.

10.0 NOTIFICATION PROCEDURES

Notification procedures for floods and other emergency events are outlined in the Generation Emergency Plan for Duncan Dam. This document is filed with the Office of the Comptroller of Water Rights.
Appendix 1
Inter-office memo

TO: Eric Weiss  
7 August 2002

FROM: Mike Homenuke  
File: PSE 151.0  
C-DDM-151.0

SUBJECT: Duncan WUP - Hydrology of Duncan River Basin

1 INTRODUCTION

The Duncan Dam project was constructed from 1965-1967 under the Columbia River Treaty to provide storage for the Kootenay system. The project has the following general characteristics:

- Duncan Lake Reservoir is impounded by Duncan Dam.
- Duncan Lake is a storage reservoir; there is no powerhouse at Duncan Dam.
- All releases from Duncan Lake discharge into the Duncan River just upstream of the confluence with the Lardeau River.

This report highlights the hydrology of the Duncan Dam project. Physiography and climatology are reviewed for the Duncan River watershed.

Methods used to calculate reservoir inflows, such as BC Hydro’s FLOCAL program, are discussed. Typical inflow hydrographs and summaries are provided. Flow records for the Duncan Dam project referred to in this report are used in power studies conducted for the Duncan Water Use Plan.

Procedures used to provide daily and seasonal volume inflow forecasts are also described.
2 Physiography

The drainage basin for the Duncan Dam project is shown in Figure 1.

Figure 1: Watershed Map and Hydrometeorological Stations

The Duncan Dam project is located in the southeastern interior about 40 km north of Kaslo. The Duncan basin is located in the Purcell Trench, a prominent valley between the Purcell and Selkirk Ranges. The Duncan River’s headwaters begin at Mount Dawson, near Glacier National Park where it flows southeasterly for 55 km to Duncan Lake Reservoir, which is approximately 45 km long. The Duncan River

---

is joined by the Lardeau River just downstream of the dam and continues to flow southward for about 10 km in a braided channel to the North Arm of Kootenay Lake.

The mean basin elevation is approximately 1800 m and the total basin area is 2443 km$^2$, distributed as shown in the hypsometric curve for the basin (Figure 2).

![Hypsometric Curve for Duncan Lake Basin](image)

**Figure 2: Hypsometric curve for the Duncan Dam project**

Figure 3 shows the elevation-storage relationship for Duncan Lake Reservoir within its normal reservoir operating ranges. Between its normal maximum and minimum operating elevations, Duncan Lake has a storage capacity of approximately 20,000 cms-days (1727 million m$^3$).
3 Climatology\textsuperscript{2}

The Duncan basin is located in the southeastern interior climatic region, and as such is affected by modified maritime and continental conditions. Moisture-laden air is carried over the Monashee and Selkirk Ranges and deposited in the Duncan River basin as systems rise over the higher Purcell Range. Heavy precipitation may occur during both winter and summer months, and winter precipitation consists mainly of snow. The presence of glaciers throughout the higher elevations in the basin confirms that heavy snow packs build throughout the winter.

There are several long-term climate stations in the vicinity of the Duncan basin. The AES station at Rogers Pass in Glacier National Park is considered to be a good representation of temperature and precipitation in the basin. Average annual precipitation is 1573 mm (1965-1999).

Figure 4 shows maximum, average and minimum monthly precipitation at Glacier NP Rogers Pass AES to highlight the year-to-year variations in precipitation conditions.

**Figure 4: Maximum and minimum monthly precipitation at Glacier NP Rogers Pass AES**

Figure 5 shows the maximum, mean, and minimum daily temperatures at Glacier NP Rogers Pass AES.

**Figure 5: Maximum, mean and minimum daily temperature at Glacier NP Rogers Pass AES**
Figure 6 shows the normal monthly snow water equivalent at East Creek snow course (2D08), located in the basin near the northern end of Duncan Lake at El. 2030 m.

Mean, Maximum and Minimum Monthly Snow Water Equivalent at East Creek Snow Course (2D08) (1967-1999)

Figure 6: Maximum, mean and minimum monthly snow water equivalent at East Creek snow course (2D08)

4 Inflow calculations

*Reservoir inflow calculations:* Inflow is the volume of water entering a reservoir within a given period of time. Reservoir inflows are calculated rather measured directly. Daily inflows may be derived from mean daily discharge from the reservoir and change in reservoir storage over a period of 24 hours. The generic formula is:

\[
\text{INFLOW} = \text{OUTFLOW} + \Delta \text{STORAGE} \]

where

- \(\text{INFLOW}\) = average inflow over a one-day period
- \(\text{OUTFLOW}\) = average outflow over a one-day period
- \(\Delta \text{STORAGE} = S_2 - S_1\), where
  - \(S_2\) = reservoir storage at the end of the day
  - \(S_1\) = reservoir storage at the end of the previous day

Reservoir storage for a specific reservoir elevation is derived from a stage–storage curve unique to each reservoir.
The nature of the calculation of inflows can result in “noisier” hydrographs than observed at unregulated, natural river channels. Noisy inflows can arise due to various sources of error, such as wind set up on the reservoir, resolution of elevation measurements, errors in reservoir elevation readings, errors in outflow measurements through turbines, spillways or valves, errors in stage-storage curves and errors in the rating curves for various outlet facilities. The impact of noise tends to reduce as the time interval over which inflow is computed increases.

*Storage relationships:* The Storage relationships used to determine the volume of water in Duncan Lake Reservoir is shown in Figure 3.

*Outflow relationships:* “Rating curves” show the relationship between flow, opening, and elevation for a given release device. A rating curve for spill facilities at Duncan Dam is shown in Figure 7. During May and June each year, the low-level outlet is operated similarly to a navigation lock to assist the upstream migration of bull trout.

![Duncan Dam Elevation-Discharge Rating Curve for All Spill Facilities Fully Open from BC Hydro CRO Database](image)

*Figure 7: Rating curve for Duncan Dam with all spill discharge facilities fully open*

*Data records:* BC Hydro computes inflow using a computer program called FLOCAL. Specifically;
Inflows to Duncan Lake Reservoir are computed based on equation (1).

Various information, including gate openings, reservoir and tailwater elevations, energy, spill, turbine flows, and inflows are stored in FLOCAL. A FLOCAL configuration for the Duncan Dam project and its relation to other projects on the Kootenay system is shown in Figure 8.

Figure 8: Schematic of the FLOCAL configuration for the Duncan Dam project and its relation to other projects on the Kootenay system
5 Reservoir inflow characteristics

Figures 10 shows “spaghetti plots” of historical inflows to the Duncan project. The 10\textsuperscript{th}, 50\textsuperscript{th} and 90\textsuperscript{th} percentile inflows are shown in bold.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{duncan_inflow.png}
\caption{Historical daily inflows to Duncan Lake Reservoir}
\end{figure}

The Lardeau River joins the Duncan River just downstream of Duncan Dam. Thus, the flow in the 10 km reach between the Lardeau confluence and Kootenay Lake is comprised of natural flow from the Lardeau River plus the regulated outflow from Duncan Dam. Figure 11 presents the historical daily discharge hydrographs for the Lardeau River.
**Figure 11: Historical daily discharge from Lardeau River upstream of Duncan River confluence**

Figure 12 and Table 1 summarize the daily inflows by month. Average monthly and maximum and minimum daily inflows are shown to highlight the variability of inflows to the project.

**Figure 12: Variability in Duncan Dam Project's daily inflows**
Table 1: Duncan Dam Project’s daily inflows (1963-1999)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>October</td>
<td>48</td>
<td>284</td>
<td>16</td>
</tr>
<tr>
<td>November</td>
<td>36</td>
<td>236</td>
<td>9</td>
</tr>
<tr>
<td>December</td>
<td>29</td>
<td>71</td>
<td>&lt;1</td>
</tr>
<tr>
<td>January</td>
<td>24</td>
<td>58</td>
<td>6</td>
</tr>
<tr>
<td>February</td>
<td>19</td>
<td>43</td>
<td>2</td>
</tr>
<tr>
<td>March</td>
<td>21</td>
<td>72</td>
<td>&lt;1</td>
</tr>
<tr>
<td>April</td>
<td>53</td>
<td>368</td>
<td>&lt;1</td>
</tr>
<tr>
<td>May</td>
<td>183</td>
<td>671</td>
<td>24</td>
</tr>
<tr>
<td>June</td>
<td>290</td>
<td>766</td>
<td>110</td>
</tr>
<tr>
<td>July</td>
<td>257</td>
<td>942</td>
<td>104</td>
</tr>
<tr>
<td>August</td>
<td>169</td>
<td>447</td>
<td>55</td>
</tr>
<tr>
<td>September</td>
<td>87</td>
<td>509</td>
<td>29</td>
</tr>
</tbody>
</table>

A “flow duration curve” indicates the percent of time that a flow is greater than a given discharge. Figure 12 shows a flow duration curve of daily inflows for the years 1963-1999. The figure again illustrates the large range and variability of inflows.

Figure 12: Duration curves of daily inflows to the Duncan Dam Project
Figure 13 shows a duration curve for annual flows.

**Figure 13: Duration curve of annual inflows to the Duncan Dam Project**

Figure 14 shows a comparison between the mean annual local inflow and total live storage available at a number of project reservoirs. The Duncan Dam Project is highlighted and shows that the average annual inflow is about 2 times the available storage.

The ratio of average annual inflow to available reservoir storage provides a qualitative indication of how the inflow regulation and spill management capability varies from project to project; the higher the ratio, the lower the regulation capability. Figure 14 also shows the relative contribution of Duncan Lake Reservoir to BC Hydro’s total reservoir storage capability.
Figure 14: Comparison of project annual inflows to reservoir storage throughout BC Hydro's system
6 Operational Inflow Forecasting

BC Hydro’s Resource Management produces two main types of hydrologic forecasts: daily inflow and seasonal volume inflow forecasts for the Duncan Dam project.

*Daily inflow forecasts*: Daily inflow forecasts are short-term forecasts that indicate the inflow expected over the next few days. An in-house conceptual watershed model, FLOCAST, is currently used to produce these forecasts. Each morning of each working day, Resource Management enters observed and forecast precipitation, temperature, and freezing level data into the model to forecast inflow over each of the next five days.

*Volume inflow forecasts*: Volume inflow forecasts estimate the volume of water that is expected to flow in to the Duncan Dam project during a given period. BC Hydro typically produces forecasts for the period February through September. The ability to forecast seasonal runoff for this period lies in the fact that much of the runoff during the forecast period is the product of snowmelt runoff. By measuring snow water equivalent in the mountain snowpack, as well as other parameters such as precipitation and streamflow up to the forecast date, a more accurate estimate of future runoff can be made than one based on historical inflow data alone. Volume inflow forecasts are issued beginning January 1 of each year and forecasts are updated on the first of each month until August 1.
7 Hydrometeorologic Network

Hydrometeorological data is required to plan, monitor, and operate facilities in the Duncan Dam project's watershed. Characteristics of the hydrometeorological data collection stations used for forecasting and operations are summarized in Table 2.

<table>
<thead>
<tr>
<th>Station</th>
<th>Type</th>
<th>ID</th>
<th>Elev (m)</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duncan Dam</td>
<td>AES</td>
<td>1142574</td>
<td>549</td>
<td>50.25</td>
<td>116.97</td>
<td>Climate</td>
</tr>
<tr>
<td>East Creek</td>
<td>DCP</td>
<td>EAC</td>
<td>2030</td>
<td>50.64</td>
<td>116.93</td>
<td>Climate &amp; Snow</td>
</tr>
<tr>
<td>Glacier NP Rogers Pass</td>
<td>AES</td>
<td>1173191</td>
<td>1323</td>
<td>51.28</td>
<td>117.52</td>
<td>Climate</td>
</tr>
<tr>
<td>Mount Revelstoke</td>
<td>MSRM</td>
<td>2A06</td>
<td>1630</td>
<td>51.03</td>
<td>118.15</td>
<td>Snow Course</td>
</tr>
<tr>
<td>Ferguson</td>
<td>MSRM</td>
<td>2D02</td>
<td>880</td>
<td>50.68</td>
<td>117.48</td>
<td>Snow Course</td>
</tr>
<tr>
<td>Duncan River below BB Creek</td>
<td>WSC</td>
<td>08NH119</td>
<td></td>
<td>50.64</td>
<td>117.05</td>
<td>River Level</td>
</tr>
</tbody>
</table>

Prepared by: M. Homenuke, PSE Co-op Student

Reviewed by: K. Groves, P. Eng.