Puntledge River Project Water Use Plan

Revised for Acceptance by the Comptroller of Water Rights

1 December 2004

BC hydro

Puntledge River Project
Water Use Plan

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BC hydro Generation

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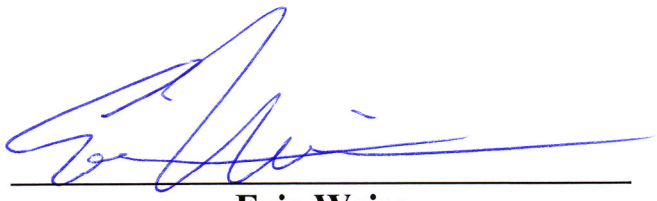

Eric Weiss
Manager, Plant Operations

Preface

The water use planning process for BC Hydro's Puntledge River facility was initiated in June 2001 and completed in June 2003.

The proposed conditions in this Water Use Plan, for the operation of BC Hydro's Puntledge River hydroelectric facility, reflect the recommendations of the Puntledge River 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 facilities 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 Puntledge River hydroelectric facility reflect the June 2003 consensus recommendations of the Puntledge River 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 Puntledge River hydroelectric facility are set out in this document. Future reference to the Puntledge River hydroelectric facility includes: the Comox Lake Reservoir, Comox Dam, Puntledge Diversion Dam, the Power Intake and Penstock, and the Puntledge River Powerhouse.

The proposed conditions will change current operations and are expected to affect fish, power generation, and recreation.

A monitoring program is proposed in order to study key uncertainties to enable improved operating decisions in the future. Refer to the *Puntledge River Water Use Plan: Consultative Committee Report* dated December 2003 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 Puntledge River System

The Puntledge River is located within the Regional District of Comox–Strathcona, and lies within the Puntledge River drainage basin located on the eastern side of the Vancouver Island Mountain Range. The Puntledge River hydroelectric facility is located approximately 9 km southwest of the City of Courtenay (Figure 2-1).

The Comox Dam is located on the Puntledge River 16 km upstream from the City of Courtenay and approximately 300 m downstream of the east end of Comox Lake Reservoir. A natural lake existed prior to impoundment. Comox Dam provides flow regulation for the downstream Puntledge River hydroelectric facility.

The Puntledge Diversion Dam is approximately 3.7 km downstream of Comox Dam. A 5 km long woodstave and steel penstock connects the power intake to the Puntledge River Powerhouse. Flows are also released from the Diversion Dam to maintain fish habitat in the Puntledge River.

Between 1965 and 1975, Fisheries and Oceans Canada constructed a 260 m long artificial spawning channel and a parallel rearing channel, together with two fishways, on the left bank of the river at Puntledge Diversion Dam. The Upper Hatchery water supply is provided by a pumphouse containing three pumps at the upstream end of the spawning channel.

Fisheries and Oceans Canada operates a second hatchery located on the right bank of the Puntledge River immediately downstream of the powerhouse. Water is supplied to the Lower Hatchery by pumps located in the river or by a pipe connected to BC Hydro's penstock.

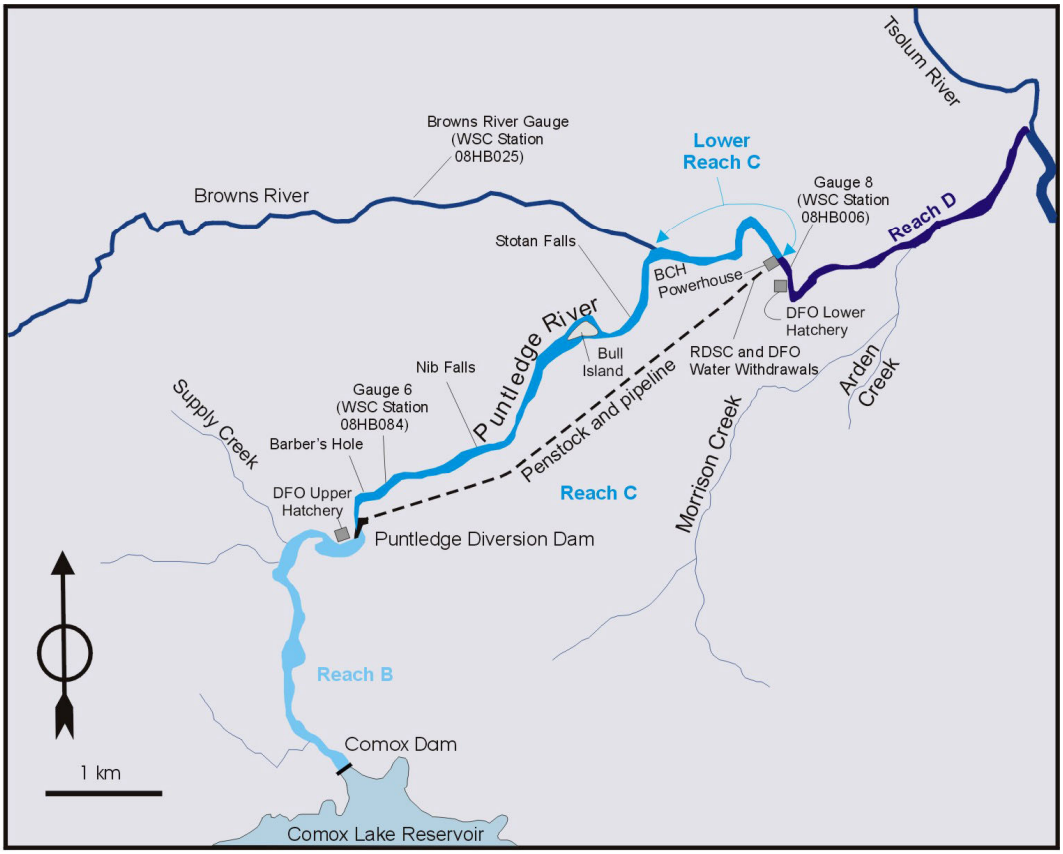

Figure 2-1: Place Names in Puntledge River Water Use Planning

2.2 Existing Works

2.2.1 Comox Lake Reservoir

Comox Dam impounds Comox Lake Reservoir, which covers approximately 1620 hectares and has a live, usable storage of 97.8 million m^3. The normal operating range of the reservoir is between 130.50 m and 135.33 m. At elevations above 135.33 m, water flows over the free crest weir.

2.2.2 Comox Dam

The Comox Dam is a concrete gravity dam, 142 m long, 10.7 m high with a crest elevation of 137.55 m. A fishway provides upstream passage past the dam for fish. There is no power generation at this dam. Water release facilities at Comox Dam consist of a two-bay gated sluiceway (with two vertical lift gates) and a free crest weir.

2.2.3 Puntledge Diversion Dam

The Puntledge Diversion Dam is a concrete buttress dam, 30.5 m long and 5.5 m high. The Diversion Dam forms the headpond for the intake and for the fishways on the left bank of the Puntledge River. The Diversion Dam also provides, along with flows from the Upper Hatchery, minimum flows down the Puntledge River.

2.2.4 Power Intake and Penstock

The power intake is located at the Puntledge Diversion Dam, with a 5 km long steel and woodstave penstock to the Puntledge River Powerhouse. The diversion capacity for power is 28.3 m^3/s. In 1993, permanent screens were installed in the penstock immediately downstream of the Diversion Dam to divert an additional 1.4 m^3/s for downstream migrating fish from the penstock flow and return them to the Puntledge River downstream of the dam.

2.2.5 Puntledge River Powerhouse

The Puntledge River Powerhouse is located on the Puntledge River and contains a single 24 MW capacity vertical shaft Francis turbine generator unit. Water released from the Comox Lake Reservoir travels 3.7 km to the Puntledge Diversion Dam, then 5 km through the penstock to the powerhouse. Water is discharged from the turbine back into the Puntledge River.

Water can be drawn from the penstock immediately above the powerhouse for consumptive use by the Regional District. Water can also be drawn from the penstock, routed through the lower fish hatchery and returned to the river below the powerhouse.

3.0 HYDROLOGY OF THE PUNTLEDGE RIVER BASIN

Appendix 1, the Puntledge River Water Use Plan Hydrology Memo, describes the physiography, climate, and hydrology of the Puntledge River basin.

The memo also describes daily inflow and seasonal volume inflow forecasting procedures. The supporting network of hydrometeorological stations in the area is described. A summary of the inflow hydrographs for the Comox Lake Reservoir is provided.

4.0 OPERATING CONDITIONS FOR FACILITY

4.1 Role of Facility in BC Hydro's System

The Puntledge River hydroelectric facility is described in *Making the Connection*, published by BC Hydro in April 2000.

The Puntledge River hydroelectric facility contributes approximately 5.3 per cent of BC Hydro's hydroelectric generation on Vancouver Island. It also provides voltage support for the Vancouver Island electricity transmission system.

4.2 Use of Water for Power Generation at the Puntledge River Facility

The Puntledge River hydroelectric facility is classified as a "coastal" system with the majority of inflow resulting from seasonal rainstorms and spring snowmelt. The generating plant is normally operated as a base load plant running at relatively constant output for days or weeks at a time. At maximum generating output of 24 MW, turbine discharge is 27 m^3/s under normal operating conditions. Spills occur when inflows exceed generation and storage capacity.

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. Dam safety requirements for operations are outlined in the *Puntledge River: Operation, Maintenance and Surveillance Requirements (OMS) for Dam Safety*, issued by BC Hydro's Director of Dam Safety.

4.4 Proposed Conditions for the Operation of Works for Diversion and Use of Water

BC Hydro proposes to operate the Puntledge River hydroelectric facility in accordance with the conditions outlined below. BC Hydro may not be able to operate within these conditions during extreme hydrological events.

4.4.1 Comox Lake Reservoir

From 15 October to 15 February, BC Hydro will operate Comox Lake Reservoir to a maximum normal level of 134.42 m. From 16 February to 14 October, BC Hydro will operate Comox Lake Reservoir to a maximum normal level of 135.33 m. Levels may be higher during the routing of high inflow events. Minimum level is controlled by the natural lake outlet.

4.4.2 Puntledge Diversion Dam Forebay

There are no special conditions for the operation of the forebay.

4.4.3 Minimum Flows in the Puntledge River between the Diversion Dam and the Powerhouse (Reach C)

BC Hydro will provide a minimum flow of 5.7 m^3/s in Reach C, measured at Gauge 6 on a three-day rolling average.

BC Hydro will provide a minimum flow of 5.1 m^3/s in Reach C, measured at Gauge 6 at all times.

BC Hydro will provide pulse flows in the Puntledge River between the Diversion Dam and the powerhouse for the benefit of fish as follows:

- From 15 January to 15 February, BC Hydro will provide minimum pulse flows of 12 m^3/s in Reach C, measured at Gauge 6, for 4 forty-eight hour periods, a minimum of five days apart. The minimum flow, including ramp up and ramp down at maximum allowable rates, will be initiated at midnight and conclude by midnight on the second day of each forty-eight hour period.

- From 15 March to 15 April, BC Hydro will provide minimum pulse flows of 12 m^3/s in Reach C measured at Gauge 6, for 4 forty-eight hour periods, a minimum of five days apart. The minimum flow, including ramp up and ramp down at maximum allowable rates, will be initiated at midnight and conclude by midnight on the second day of each forty-eight hour period.

- From 2 July to 15 August, BC Hydro will provide minimum pulse flows of 12 m^3/s in Reach C, measured at Gauge 6, for 5 forty-eight hour periods, a minimum of five days apart. The minimum flow, including ramp up and ramp down at maximum allowable rates, will be initiated at midnight and conclude by midnight on the second day of each forty-eight hour period. The summer pulse flow dates will be announced by BC Hydro two weeks prior to commencement, and will take place on the same two days of the week (not on statutory holidays) for safety and awareness issues. The minimum flow must be greater than the powerhouse flow.

- From 1 October to 31 October, BC Hydro will provide minimum pulse flows of 12 m^3/s in Reach C, measured at Gauge 6, for 4 forty-eight hour periods, a minimum of five days apart. The minimum flow, including ramp up and ramp down at maximum allowable rates, will be initiated at midnight and conclude by midnight on the second day of each forty-eight hour period.

BC Hydro will provide pulse flows in the Puntledge River between the Diversion Dam and the powerhouse for the benefit of kayaking as follows:

- From 15 May to 30 May, conditional on annual direction from the Comptroller of Water Rights, BC Hydro will provide minimum flows of 85 m^3/s, computed as the sum of Gauge 6 and Brown's River Gauge flows, for 2 eight-hour periods on two consecutive weekend days.

4.4.4 Minimum Flows in the Puntledge River below the Powerhouse (Reach D)

BC Hydro will manage operations to maintain a 95 per cent confidence level of providing a minimum flow of 15.6 m^3/s in the river below the powerhouse at all times. The minimum flow will be the sum of flow at Gauge 8 and the flow returned from the Lower Hatchery. Discretionary generation, which is generation above that necessary to provide the minimum flow, is permitted only when there is a 95 per cent confidence that a flow of 15.6 m^3/s can be maintained. During dry periods when the confidence level drops below 95 per cent, the minimum flow will be reduced below 15.6 m^3/s to the extent necessary to provide a 95 per cent confidence level of maintaining the new minimum flow. The minimum flow will be restored to 15.6 m^3/s as soon as possible. Confidence levels will be calculated weekly using historical inflow records. In the unlikely event that the minimum flow drops to 11.3 m^3/s, BC Hydro will consult with federal and provincial fisheries agencies and seek special direction on operations from the Comptroller of Water Rights.

From 21 September to 31 December, any discretionary power generation that increases flow at Gauge 8 above 15.6 m^3/s up to 20.7 m^3/s, must be maintained for the remainder of the period. Increases in discretionary flows when Gauge 8 flows are above 20.7 m^3/s need not be maintained.

BC Hydro will maintain the minimum flow, as calculated in the preceding paragraphs, on a three-day rolling daily average basis. Instantaneous minimum flows may be up to 0.5 m^3/s less than the minimum flow required at the time.

4.4.5 Spawning Gravel in the Headpond (Reach B) or in the Puntledge River between the Diversion Dam and the Powerhouse (Reach C)

The placement of spawning gravel in the Puntledge River Reaches B or C is recommended, in lieu of operational constraints that would maintain a minimum flow in the Puntledge River greater than that proposed in Section 4.4.3, as a means to improve fish habitat. It is recommended that the Comptroller of Water Rights direct BC Hydro to provide 2000 m^2 of spawning gravel in the Puntledge River Reaches B or C to be maintained and replaced up to once every five years. The details regarding this recommendation are provided in the *Puntledge River Water Use Plan: Consultative Committee Report*.

4.4.6 Fisheries and Oceans Canada Fish Hatcheries

Fisheries and Oceans Canada may draw up to 0.85 m^3/s from the BC Hydro penstock for the Lower Hatchery. The water will be routed through the hatchery and returned to the river below Gauge 8. The estimated withdrawal schedule is shown in Table 4-1.

Table 4-1: Estimated Monthly Average Withdrawals from BC Hydro Penstock by Fisheries and Oceans Canada

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Quantity (m^3/s)	0.40	0.42	0.57	0.57	0.74	0.14	0.14	0.48	0.57	0.57	0.48	0.34

4.4.7 Ramping Rates

The following ramping rates apply to the release of water from the Puntledge Diversion Dam year-round.

- The maximum rate of change of flow, increasing or decreasing, is 2.8 cubic metres per second per hour, when the flow is in the range 5.1 to 19.8 cubic metres per second. There is no maximum rate of change of flow, when the flow is greater than 19.8 cubic metres per second.

The following ramping rates apply to the release of water from the powerhouse.

- The Powerhouse must be operated such that the maximum rate of increase of flow, as measured at the location of Water Survey of Canada gauge 08HB006, is:

    a. 1 August to 30 September for flows less than 21.3 cubic metres per second,

        i. 2.8 cubic metres per second per hour when releases from powerhouse facilities are between 0 to 11.3 cubic metres per second;

        ii. 8.5 cubic metres per second per hour when releases from powerhouse facilities are between 11.3 to 15.6 cubic metres per second;

        iii. There is no maximum rate of increase of discharge when releases from powerhouse facilities are greater than 15.6 cubic metres per second.

    b. 1 October to 31 July for flows less than 25.5 cubic metres per second,

        i. 7.1 cubic metres per second per 15 minutes when releases from powerhouse facilities are less than 19.8 cubic metres per second,

ii. There is no maximum rate of increase of discharge when releases from powerhouse facilities are greater than 19.8 cubic metres per second.

- There is no maximum rate of reduction of discharge from the powerhouse.

5.0 PROGRAMS FOR ADDITIONAL INFORMATION

Development of the proposed conditions for the Puntledge River hydroelectric facility was complicated by uncertainties and information gaps. The June 2003 consensus 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.
- Provide improved information for future operating conditions.

Details and costs of the proposed monitoring program are provided in the *Puntledge River 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 Key Questions

Component	Key Questions
Puntledge River Adult Chinook and Steelhead Migration Monitoring	Will pulse flow releases in the Puntledge River Reach C allow adult steelhead and chinook to successfully migrate?
Puntledge River Spawning Habitat and Incubation Monitoring	Will increases in the minimum flow increase the effective spawning habitat?
Puntledge River Steelhead Production	Will minimum flow increase juvenile and adult steelhead abundance?
Puntledge River Ramping Rates and Stranding Monitoring	Will the ramping rates provide adequate protection to fish?
Puntledge River Kayaking Economic Cost–Benefit Monitoring	What are the economic costs and benefits of the planned kayaking event?

BC Hydro's Puntledge River hydroelectric facility is located within the claimed traditional territory of the Comox, Sliammon and Homalco First Nations. First Nations have an interest in:

- Opportunities for study and traditional use in the Comox Lake Reservoir
- Traditional use in the Puntledge River

BC Hydro will work with the First Nations as required under the *BC Heritage Conservation Act*.

6.0 IMPLEMENTATION OF RECOMMENDATIONS

The proposed conditions and the monitoring program 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 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 First Nations Considerations

The proposed conditions in this Water Use Plan are not expected to affect First Nations' interests beyond those mentioned below.

7.2 Archaeological Considerations

The proposed conditions are not expected to affect archaeological conditions.

7.3 Fisheries

The proposed conditions in this Water Use Plan are expected to increase rearing and spawning habitat and opportunities for fish to migrate past natural barriers in the Puntledge River through the provision of minimum flows, pulse flows, and the placement of spawning gravel.

7.4 Flood Routing

The proposed conditions in this Water Use Plan are not expected to affect flood frequency or severity on Comox Lake Reservoir or the Puntledge River.

7.5 Industrial Use of Water

The proposed conditions in this Water Use Plan are not expected to affect industrial use of water associated with Comox Lake Reservoir or the Puntledge River below the facilities.

7.6 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 Comox Lake Reservoir or the Puntledge River below the facilities. However, some constraints may be required on new licences, particularly withdrawals for consumptive use.

7.7 Power Generation

The proposed conditions in this Water Use Plan are expected to decrease power generation associated with the Puntledge River hydroelectric facility.

7.8 Recreation

The proposed conditions in this Water Use Plan are expected to increase opportunities for recreational kayaking in the Puntledge River diversion reach and provide economic benefits to the community. The pulse flows in the Puntledge River during the summer months may decrease opportunities for recreational swimmers and bathers in the Puntledge River diversion reach. Recreation on Comox Lake Reservoir is not expected to be affected.

7.9 Riparian Rights

The proposed conditions in this Water Use Plan are not expected to affect riparian rights associated with Comox Lake Reservoir or the Puntledge River below the facilities.

7.10 Water Quality

The proposed conditions in this Water Use Plan are not expected to affect water quality associated with Comox Lake Reservoir or the Puntledge River below the facilities.

7.11 Wildlife Habitat

The proposed conditions in this Water Use Plan are not expected to affect wildlife associated with Comox Lake Reservoir or the Puntledge River below the facilities.

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:

- Comox Lake Reservoir elevation
- Gauge 6 flows, Gauge 8 flows and Brown's River flows as required
- Turbine discharges
- Lower Hatchery flows

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, if not triggered earlier. Five years after the implementation of this Water Use Plan, BC Hydro will review the results of the monitoring studies and assess the need to review the Puntledge River Water Use Plan. A review of the Puntledge River 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 *Puntledge River Dam Emergency Planning Guide* and the *Power Supply Emergency Plan (PSEP) for the Puntledge River Project*. Both these documents are filed with the Office of the Comptroller of Water Rights.

Appendix 1
Puntledge River Water Use Plan Hydrology Memo

Inter-office memo

TO: Eric Weiss 1 December 2003

FROM: Kathy Groves File: PSE 151.0
C-PUN-151.0

SUBJECT: Puntledge Water Use Plan
Hydrology of Puntledge River Basin Upstream of Comox Dam REVISED

Originally issued 7 Nov 2002; revised to include corrections to Figures 8 & 9.

1 INTRODUCTION

The Puntledge project is a single reservoir / two dam hydroelectric project with the following general characteristics:

- Comox Dam impounds Comox Lake and provides flow regulation for the downstream Puntledge facilities. There are no power generation facilities at Comox Dam. Water release facilities at Comox Dam consist of a two-bay gated sluiceway, a free crest overflow weir, and a fish ladder.
- All flow releases from Comox Dam discharge into the Puntledge River.
- Puntledge Diversion Dam is located approximately 4 km downstream of Comox Dam and forms the headpond for the power intake.
- At the Puntledge Diversion Dam, power releases (turbine discharge) are diverted via a 5 km penstock to the Puntledge Generating Station (one unit, typical maximum output ~ 24 MW). The remaining water passes downstream via the free crest overflow spillway sections.
- Discharge from the Puntledge Generating Station re-enters the Puntledge River.
- The Browns River joins the Puntledge River between Puntledge Diversion Dam and the Puntledge Generating Station tailrace.
- The Tsolum River joins the Puntledge River downstream of the Puntledge Generating station.

This report highlights the hydrology of the Puntledge hydroelectric system. Physiography and climatology are reviewed for the Puntledge River watershed upstream of Comox Dam. 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 Puntledge system referred to in this report were used in power studies

conducted for the Puntledge Water Use Plan. Procedures used to provide daily and seasonal volume inflow forecasts are also described.

2.1 Physiography[1]

The Puntledge River basin lies on the eastern side of the Vancouver Island ranges approximately midway along the length of the island. The drainage basin for the Puntledge River system upstream of Comox Dam is shown in Figure 1.

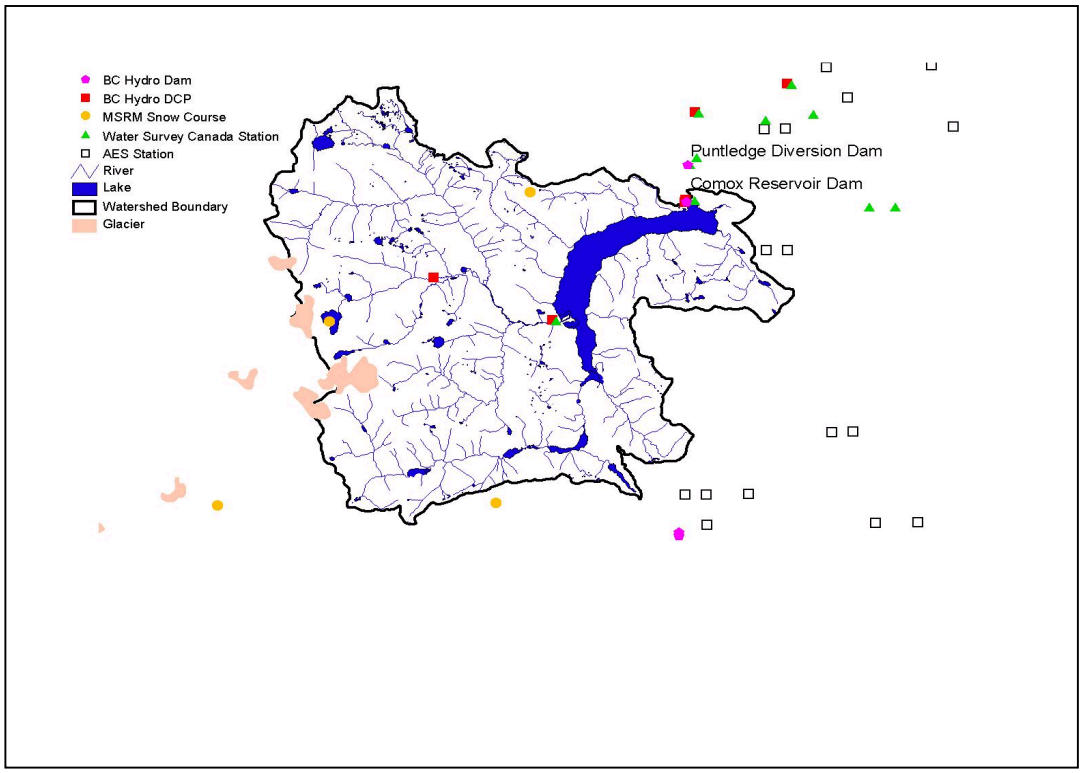

Figure 1: Watershed Map and Hydrometeorological Stations

The basin above Comox Lake Storage Dam is approximately rectangular in shape with Comox Lake at the northeast corner. The basin is very rugged with mountain peaks rising to El. 2134 m. Glaciers cover ~ 4 km^2 of the basin and are located above El. 1310 m.

Comox Lake is a natural lake fed by two primary sources, the Puntledge River and the Cruikshank River, near the southwest end of the lake. These tributary channels are approximately 22.5 km in length, and drop over an elevation range of

about 150 m. Most of the lake is surrounded by relatively steep terrain except for the northeast end where the terrain is relatively low and flat.

The basin hypsometric curve (basin area vs elevation) is shown in Figure 2.

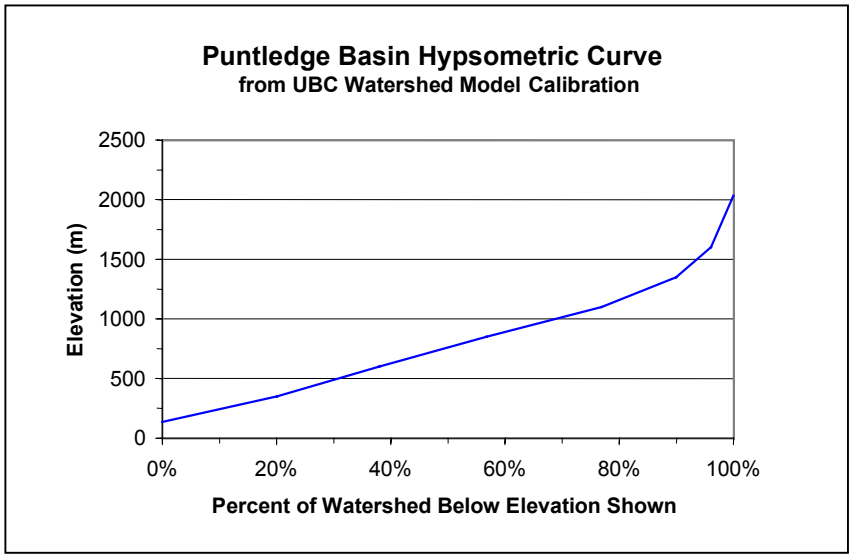

Figure 2: Hypsometric curve for the Puntledge Watershed upstream of Comox Dam

Figure 3 shows the elevation-storage relationship for Comox Lake Reservoir within its normal reservoir operating ranges. Between its normal maximum and minimum operating elevations Comox Lake has a storage capacity of approximately 1000 cms-days (86.4 Mm^3).

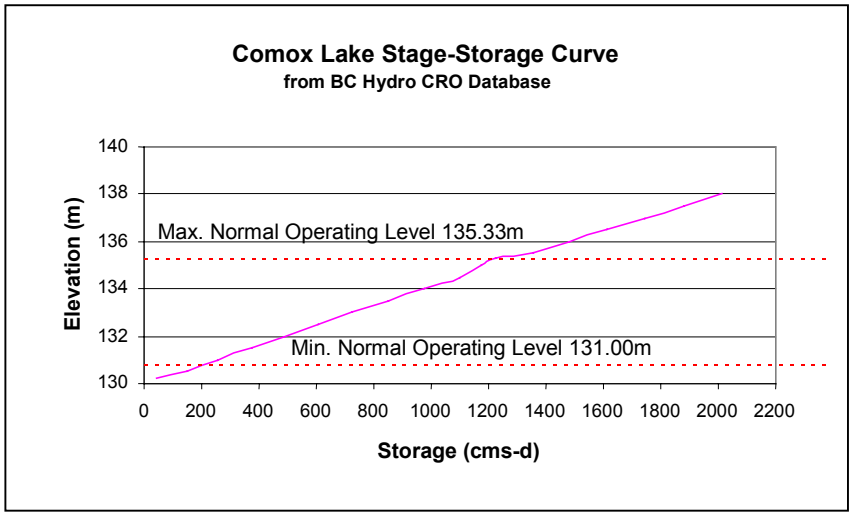

Figure 3: Stage-storage relationship for Comox Lake Reservoir

[1] Basin information obtained from BC Hydro, "Comox Lake Storage Dam Probable Maximum Flood", Hydroelectric Engineering Division report no. H1224A, January 1985

2.2 Climatology[2]

The westward mountain slopes of Vancouver Island are usually cloud covered and wet during the winter because of the lifting of warm, moist air flowing inland from the Pacific Ocean. The eastward faces of these mountains experience a resultant "spill-over" effect. Precipitation formed by the lifting of moisture-laden air on the west side is carried over the mountain barrier by strong high level winds. The climate tends to be less rainy on the east coast of the island because the descending air tends to disperse clouds and lessen the cyclonic rainfall.

The critical months of the year for heavy precipitation in the Puntledge River basin are October through March. In this period frontal storms arriving from the southwest off the Pacific Ocean are associated with strong, moist winds that bring heavy precipitation for durations of a few hours to 4 days. Very often a series of cyclonic storms are carried in the flow of air, with each storm event being separated by hours or days.

During these large winter storms the air temperature may be above freezing at all altitudes in the basin. Consequently, the accumulated snowpack may vary appreciably, especially at low elevations. Typically, a period of cooler weather in which the snowpack increases may be followed by a larger pacific disturbance that raises temperature and melts a portion of the snowpack.

[2] Climate information obtained from BC Hydro, "Comox Lake Storage Dam Probable Maximum Flood", Hydroelectric Engineering Division report no. H1224A, January 1985

Forecasting and watershed modelling procedures have determined that the precipitation within the Comox Basin is best represented by a weighted average computed from the Comox Dam Forebay, Comox Airport, and Eric Creek precipitation stations (see Table 2). The resulting precipitation record is referred to as the Comox Indexed station. Figure 4 shows the maximum, mean, and minimum daily precipitation for the basin as represented by the Comox Indexed Station.

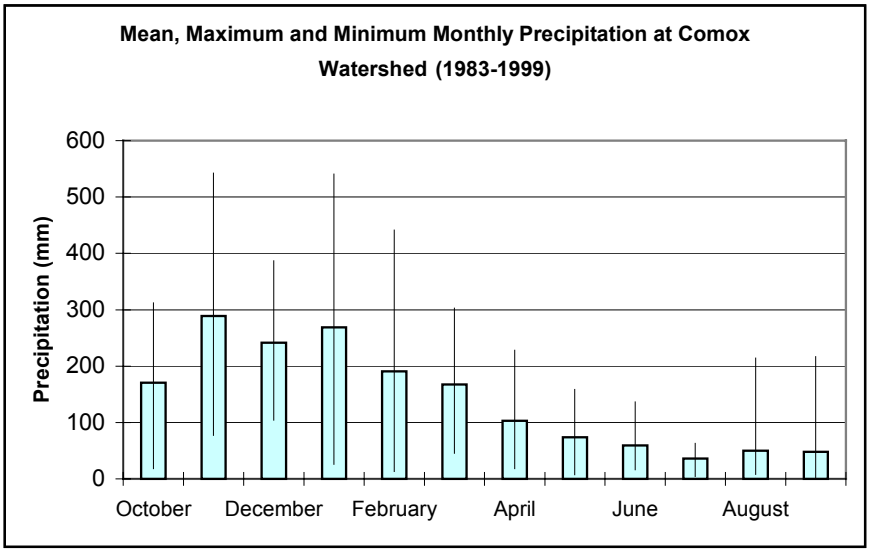

Figure 4: Maximum, mean and minimum monthly precipitation at Comox Indexed Station

Figure 5 shows the maximum, mean, and minimum daily temperatures for the Comox Watershed as represented by the Comox Dam Forebay DCP station.

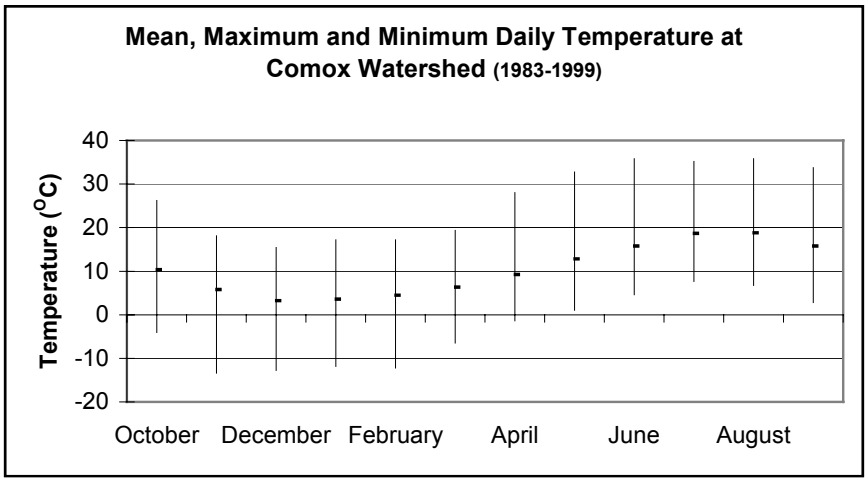

Figure 5: Maximum, mean and minimum daily temperature at Comox Dam Forebay DCP

There is no snow course located within the Comox Watershed. Figure 6 shows the monthly snow water equivalents recorded at the Forbidden Plateau (3B01), El. 1130 m and Wolf River (3B17P), El. 1490 snow courses which are both used for forecasting purposes in the Comox Watershed.

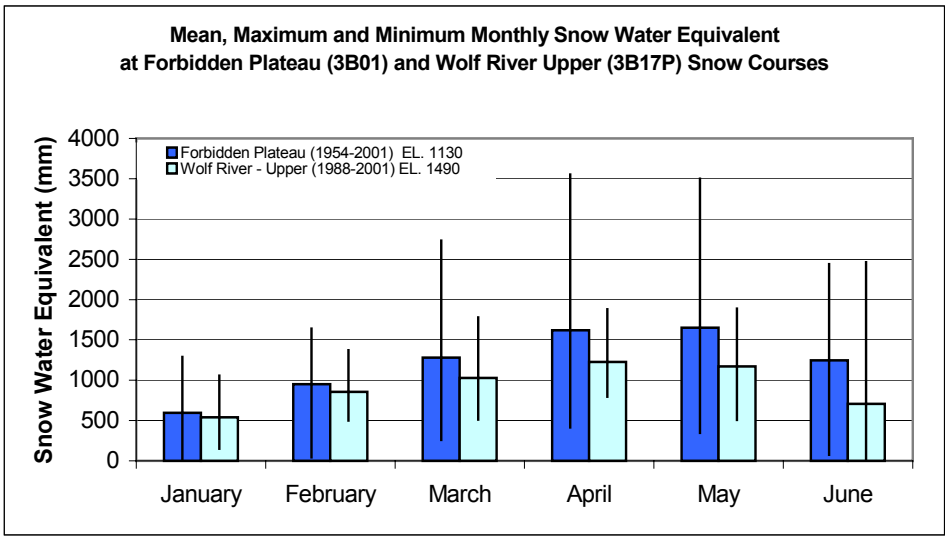

Figure 6: Maximum, mean and minimum monthly snow water equivalent at Forbidden Plateau and Wolf River (Upper) snow courses

3.1 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:

$$INFLOW = OUTFLOW + \Delta\ STORAGE \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where INFLOW = average inflow over a one - day period

OUTFLOW = average outflow over a one - day period

Δ STORAGE = S2 - S1, where

S2 = reservoir storage at the end of the day

S1 = 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 Comox Lake Reservoir is shown in Figure 3.

Outflow relationships: Flow through turbines at the Puntledge powerhouse is computed based on megawatt output and hydraulic head. “Hydraulic head” is a measure of the vertical distance between the water level in the reservoir and the water level immediately below the turbine outlet. Power output is proportional to head and turbine discharge. A generic relationship between these variables is shown in Figure 7.

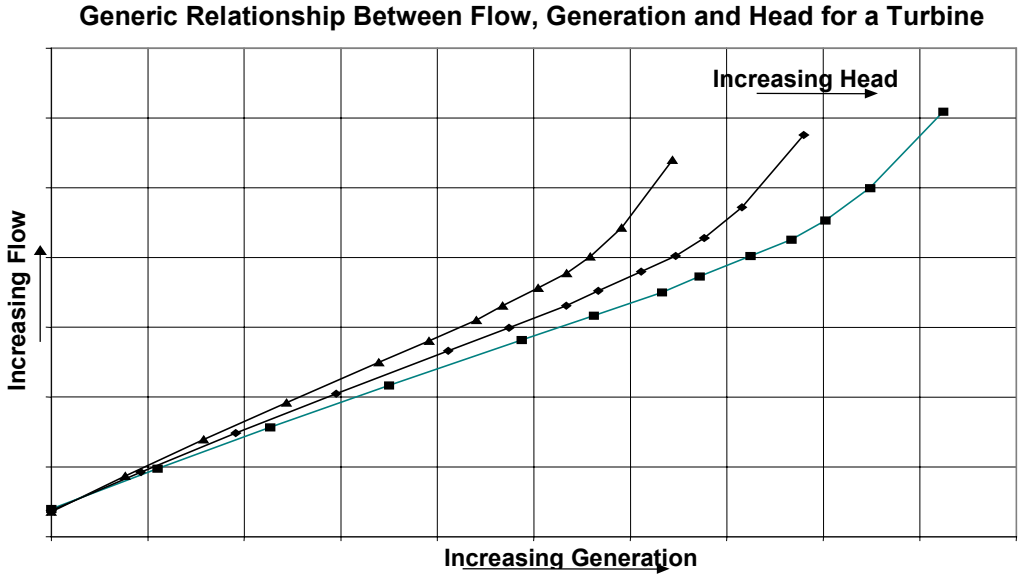

Figure 7: Generic relationship between flow, generation, and head for a turbine

"Rating curves" show the relationship between flow, opening, and elevation for a given release device. A maximum discharge rating curve for the combined operation of all discharge facilities fully open is shown for Comox Dam in Figure 8.

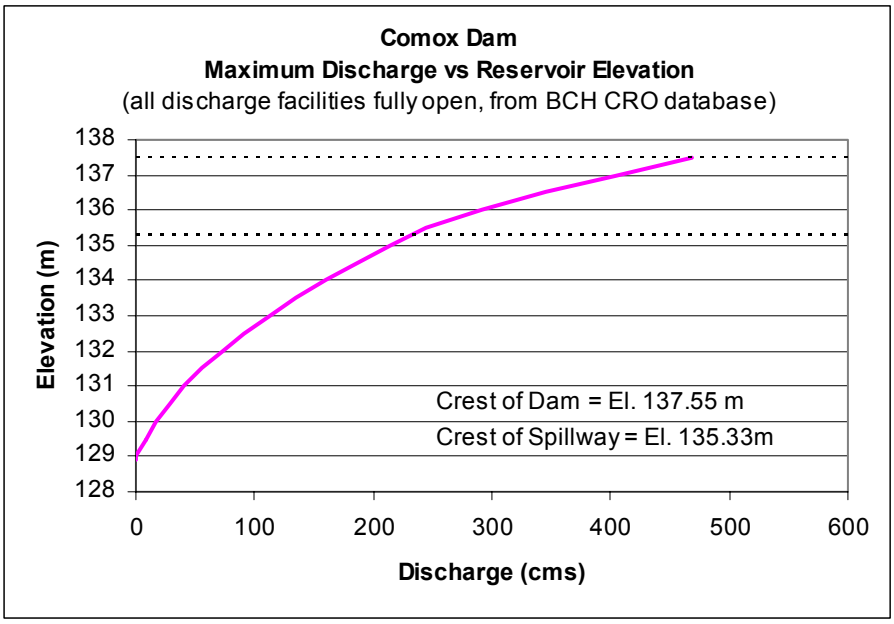

Figure 8: Discharge Rating curve for Comox Dam with all discharge facilities open

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

Various information, including gate openings, reservoir and tailwater elevations, generation, spill, turbine flows, and inflows are stored in FLOCAL. The FLOCAL configuration for the Comox / Puntledge system is shown in Figure 9.

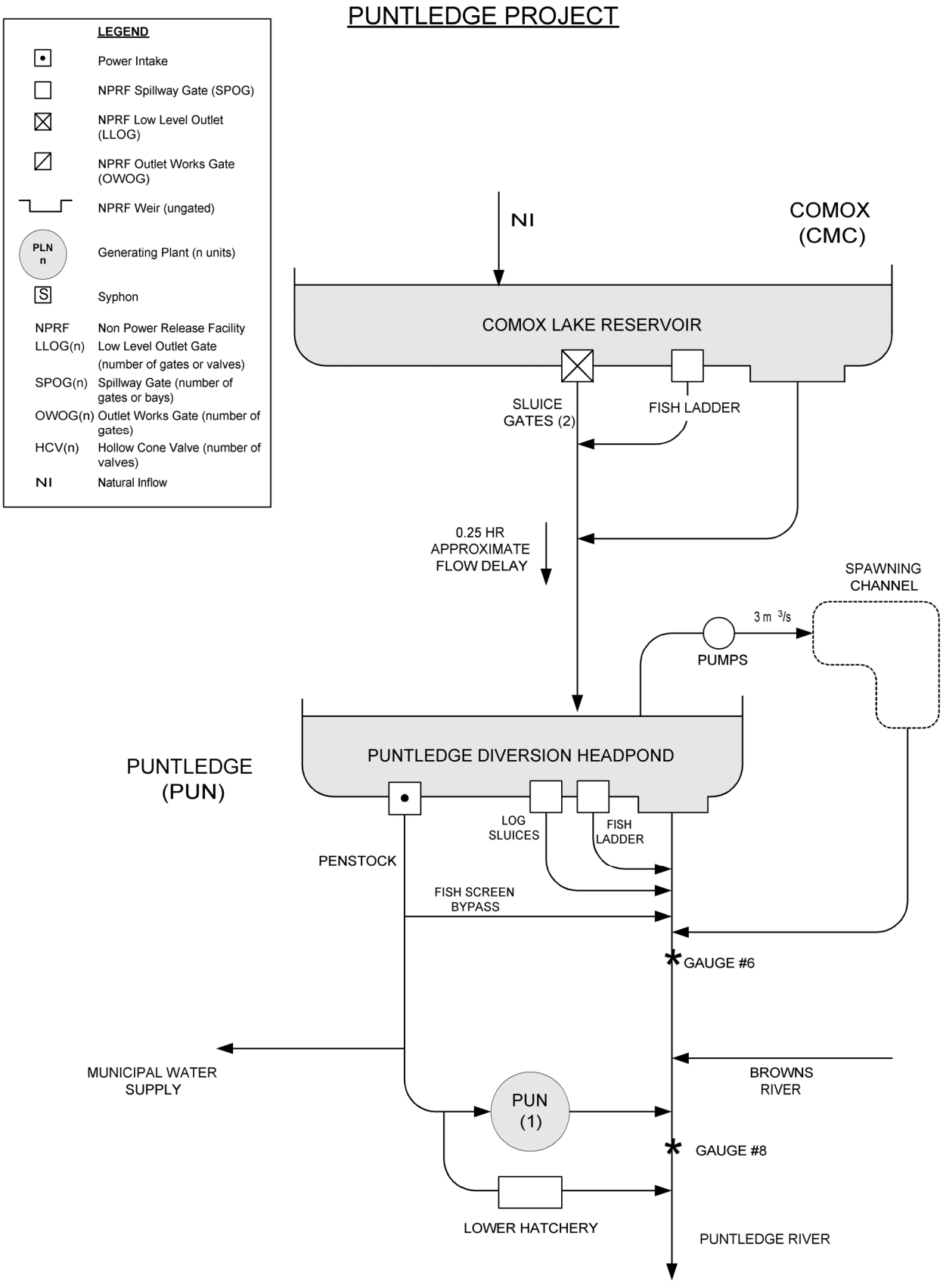

Figure 9: Schematic of the FLOCAL configuration for the Puntledge system

3.2 Reservoir inflow characteristics

Figure 10 shows "spaghetti plots" of historical inflows to Comox Lake Reservoir. The 10th, 50th and 90th percentile inflows are shown in bold.

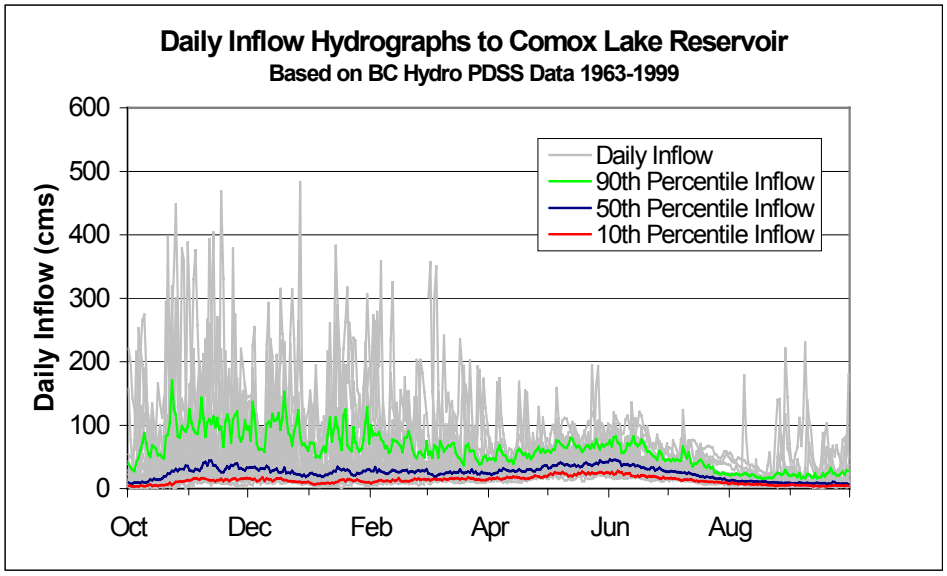

Figure 10: Historical Daily Inflows to Comox Lake Reservoir

Figure 11 and Table 1 summarizes the daily inflows by month. Average monthly and maximum and minimum daily inflows are shown to highlight the variability of inflows to the project.

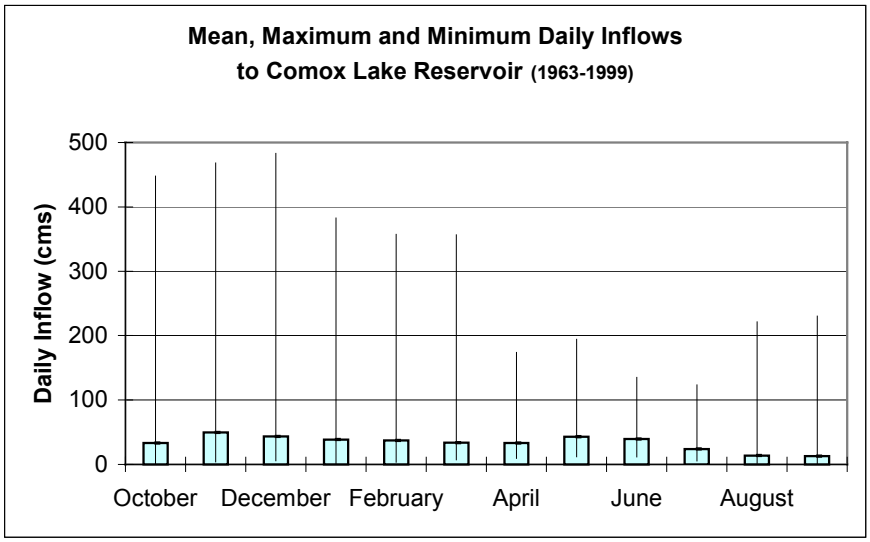

Figure 11: Variability in Comox Reservoir daily inflows

Table 1: Comox Reservoir daily inflows (1963-1999)

	Mean (cms)	Maximum (cms)	Minimum (cms)
October	33	448	0
November	50	468	4
December	43	483	6
January	38	383	1
February	37	358	4
March	34	356	7
April	33	174	9
May	43	194	12
June	40	135	11
July	24	124	5
August	14	221	2
September	13	230	1

For reference, Tables 2 and 3 show the average monthly, maximum daily and minimum daily inflows recorded for the Browns River and the Tsolum River.

Table 2: Browns River daily flow (WSC 08HB025) 1985-2000

	Mean (cms)	Maximum (cms)	Minimum (cms)
October	5.8	183	0.1
November	8.2	104	0.2
December	7.1	101	0.6
January	7.1	91	0.1
February	6.1	147	0.5
March	5.3	85	0.6
April	7.3	52	1.4
May	10.4	51	0.9
June	6.1	53	0.2
July	2.4	25	0.1
August	0.9	38	0.0
September	0.9	55	0.0

Table 3: Tsolum River daily flows, WSC 08HB011 (1965-2000)

	Mean (cms)	Maximum (cms)	Minimum (cms)
October	7.3	165	0.1
November	18.1	184	0.3
December	21.4	164	0.8
January	18.1	192	0.1
February	17.6	180	0.1
March	15.8	161	1.8
April	10.9	88	1.2
May	7.2	57	0.7
June	3.8	45	0.1
July	1.9	19	0.0
August	0.8	43	0.0
September	1.5	60	0.0

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; this again illustrates the large range and variability of inflows.

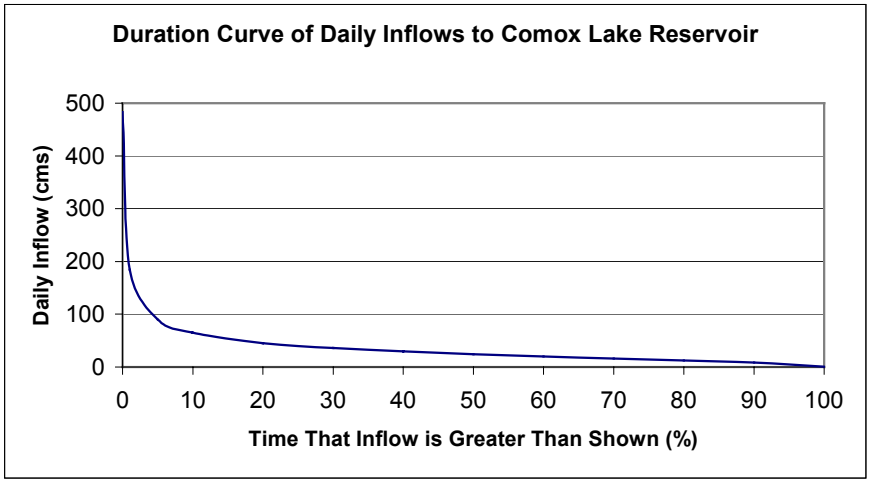

Figure 12: Duration curve of daily inflows to Comox Lake Reservoir

Figure 13 is a duration curve that highlights the variations in total annual inflow to the project.

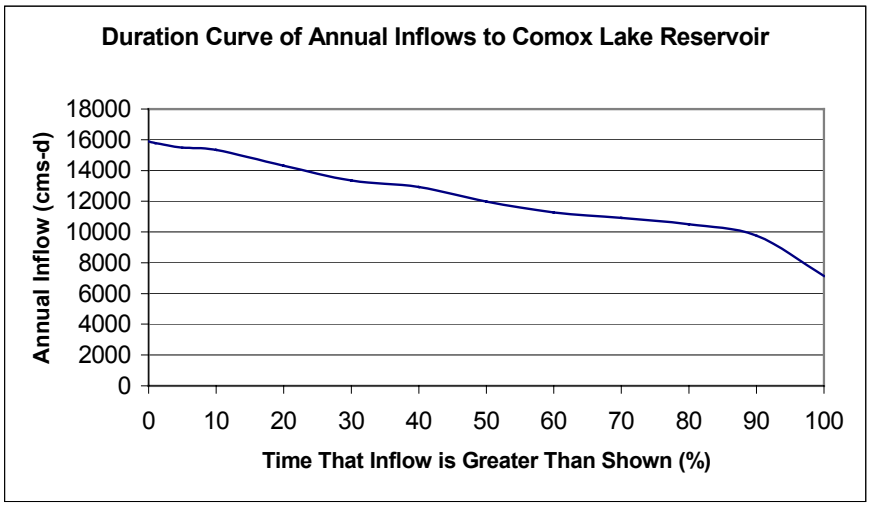

Figure 13: Duration curve of annual inflows to Comox Lake Reservoir

For reference, Figure 14 shows a comparison between the mean annual local inflow and total live storage available for selected BC Hydro and other hydroelectric projects. Comox Lake Reservoir is highlighted and shows that the average annual inflow is approximately 12 times greater than the available project 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 Comox Lake Reservoir to BC Hydro's total reservoir storage capacity.

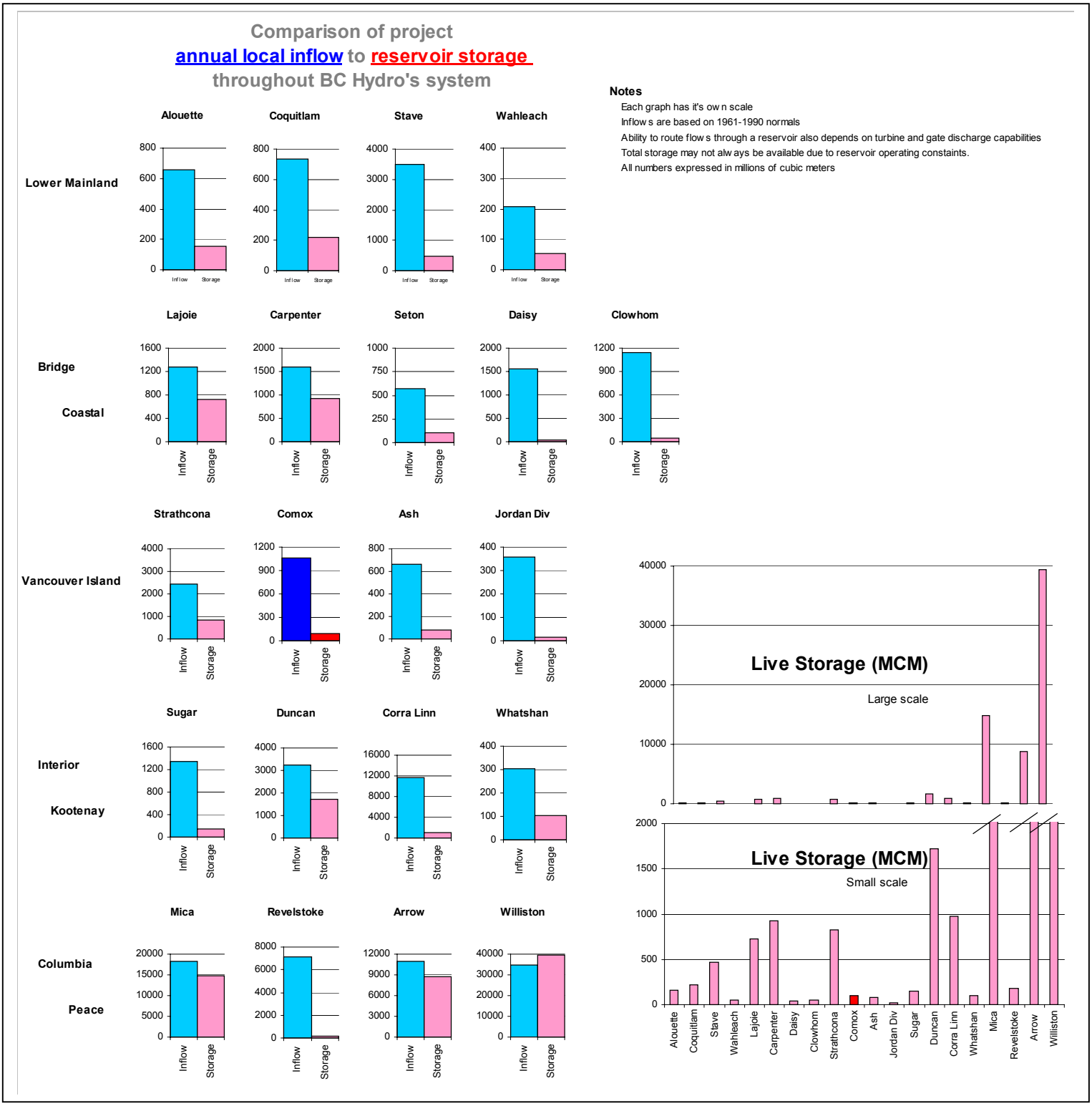

Figure 14: Comparison of project annual inflows to reservoir storage throughout BC Hydro's system

4 Operational Inflow Forecasting

BC Hydro's Resource Management produces two main types of hydrologic forecasts: daily inflow and seasonal volume inflow forecasts for the Comox / Puntledge projects.

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 Puntledge system 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 are updated on the first of each month until August 1.

5 Hydrometeorologic Network

Hydrometeorological data is required to plan, monitor, and operate hydroelectric facilities in the Puntledge system watershed. Characteristics of the hydrometeorological data collection stations referenced for operation purposes are summarized in Table 4.

Table 4: Hydrometeorological stations referenced for operations planning

Station	Type	ID	Elev (m)	Latitude	Longitude	Characteristics
Comox Airport	AES	1021830	24	49.72	124.90	Temp/Precip.
Campbell River Airport	AES	1021261	106	49.95	125.27	Temp/Precip.
Port Alberni Airport	AES	1036206	2	49.15	124.50	Temp/Precip.
Elk River	DCP	ELK	270	49.86	125.81	Temp/Precip.
Wolf (Upper) River	DCP	WOL	1490	49.68	125.74	Temp/Precip.
Comox Dam Forebay	DCP	CMX	135	49.38	125.06	Temp/Precip.
Eric Creek	DCP	ERC	280	49.36	125.18	Temp/Precip.
Cruickshank River	DCP	CRU	150	49.58	125.20	Temp/Precip.
Comox Lake at Courtney	DCP	COX	140	49.39	125.06	Temp/Precip.
Elsie Forebay	DCP	ASH	340	49.93	125.14	Temp/Precip.
Forbidden Plateau	MWLAP	3B01	1130	49.39	125.13	Snow Course
Wolf River Upper	MWLAP	3B17P	1490	49.42	125.40	Snow Course
Wolf River Middle	MWLAP	3B18	1070	49.42	125.41	Snow Course
Wolf River Lower	MWLAP	3B19	640	49.44	125.42	Snow Course
Mount Cokely	MWLAP	3B02A	1190	49.15	124.36	Snow Course
Upper Thelwood Lake	MWLAP	3B10	980	49.32	125.42	Snow Course
Sproat Lake	MWLAP	3B20	1220	49.18	125.09	Snow Course
Tennent Lake	MWLAP	3B22	950	49.33	125.38	Snow Course

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