# Campbell River System

# Water Use Plan

Revised for Acceptance
by the
Comptroller of Water Rights

## November 21, 2012

BC hydro

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# Preface

BC Hydro's Campbell River Hydroelectric System ("Campbell River System") includes:

- Buttle and Upper Campbell Lake Reservoir ("Upper Campbell Reservoir"), Strathcona Dam, Strathcona Generating Station and Crest Diversion (and, previously, Heber Diversion);
- Campbell Lake Reservoir ("Lower Campbell Reservoir"), Ladore Dam, Ladore Generating Station, Salmon Diversion Dam, Quinsam Diversion Dam and Quinsam Storage Dam; and
- John Hart Lake Reservoir, John Hart Dam and John Hart Generating Station.

The Water Use Planning consultative report for the Campbell River System was completed in March 2004. The proposed conditions in this Water Use Plan, for the operation of the Campbell River System, reflect the March 2004 consensus recommendations of the Campbell River Water Use Plan Consultative Committee Report, the draft Water Use Plan Order referred in August 2007, and subsequent recommendations from the Comptroller of Water Rights. These conditions will replace operations previously governed by the Interim Flow Management Strategy ordered October 3, 1997 in addition to other orders under the *Water Act* regulating the diversion of water within the Campbell River System.

BC Hydro thanks all those who participated in the process that led to the production of this Water Use Plan. The proposed conditions for the operation of BC Hydro's facilities will not come into effect until implemented through an order issued by the Comptroller of Water Rights under the *Water Act* of British Columbia

# 1.0 INTRODUCTION

The conditions in this Water Use Plan, for the operation of BC Hydro's Campbell River Hydroelectric Projects (the "Campbell River System"), reflect the March 2004 consensus recommendations of the Campbell River Water Use Planning Consultative Committee Report, the draft Water Use Plan and Water Use Plan Order referred in August 2007, and subsequent recommendations from the Comptroller of Water Rights.

The proposed conditions, to be authorized under the British Columbia *Water Act*, for the beneficial use of water at the Campbell River System are set out in this document. For future reference, the Campbell River System includes:

- Buttle and Upper Campbell Lake Reservoir ("Upper Campbell Reservoir"), Strathcona Dam, Strathcona Generating Station and Crest Diversion (and, previously, Heber Diversion);
- Campbell Lake Reservoir ("Lower Campbell Reservoir"), Ladore Dam, Ladore Generating Station, Salmon Diversion Dam, Quinsam Diversion Dam and Quinsam Storage Dam; and
- John Hart Lake Reservoir, John Hart Dam and John Hart Generating Station.

The proposed conditions will change current operations of the Campbell River System and are expected to positively affect fisheries and wildlife habitat, shoreline conditions, flood control, and recreation interests. Impacts to power generation and cost of generation relative to operations under the Interim Flow Management Strategy ordered October 3, 1997 are expected to be minimal. These conditions will replace operations previously governed by the Interim Flow Management Strategy in addition to other orders under the *Water Act* regulating the diversion of water within the Campbell River System.

A monitoring program is proposed to evaluate key uncertainties to enable improved operating decisions in the future. Physical works in lieu of operational changes are also proposed to address environmental and recreational interests. Refer to the Campbell River Water Use Plan: Consultative Committee Report (March 2004) for details on the consultative process, interests, objectives, performance measures, operating alternatives, and details of the proposed monitoring program.

The proposed conditions for the operation of BC Hydro's facilities will not come into effect until ordered by the Comptroller of Water Rights under the British Columbia *Water Act*.

# 2.0 DESCRIPTION OF WORKS

## 2.1 General Description and Location

Campbell River is located on central Vancouver Island (Figure 2-1). Originating in Strathcona Provincial Park, Campbell River flows through Buttle Lake and Upper

Campbell Lake Reservoir, Campbell Lake Reservoir and John Hart Lake Reservoir, near the City of Campbell River, before discharging into Discovery Passage.

The three mainstem projects consist of Buttle Lake and Upper Campbell Lake Reservoir, Campbell Lake Reservoir and the John Hart Lake Reservoir. The upper and lower reservoirs provide flow regulation for the Strathcona (SCA), Ladore (LDR) and John Hart (JHT) Generating Stations, respectively.

The Campbell River System also has three diversion systems: Crest (and formally Heber), Salmon and Quinsam. The Crest Creek Diversion diverts additional flow into Buttle and Upper Campbell Lake Reservoir. The Salmon and Quinsam River Diversions may divert additional flow into Campbell Reservoir. See Figure 2-2 for a schematic on individual projects and water conveyance.

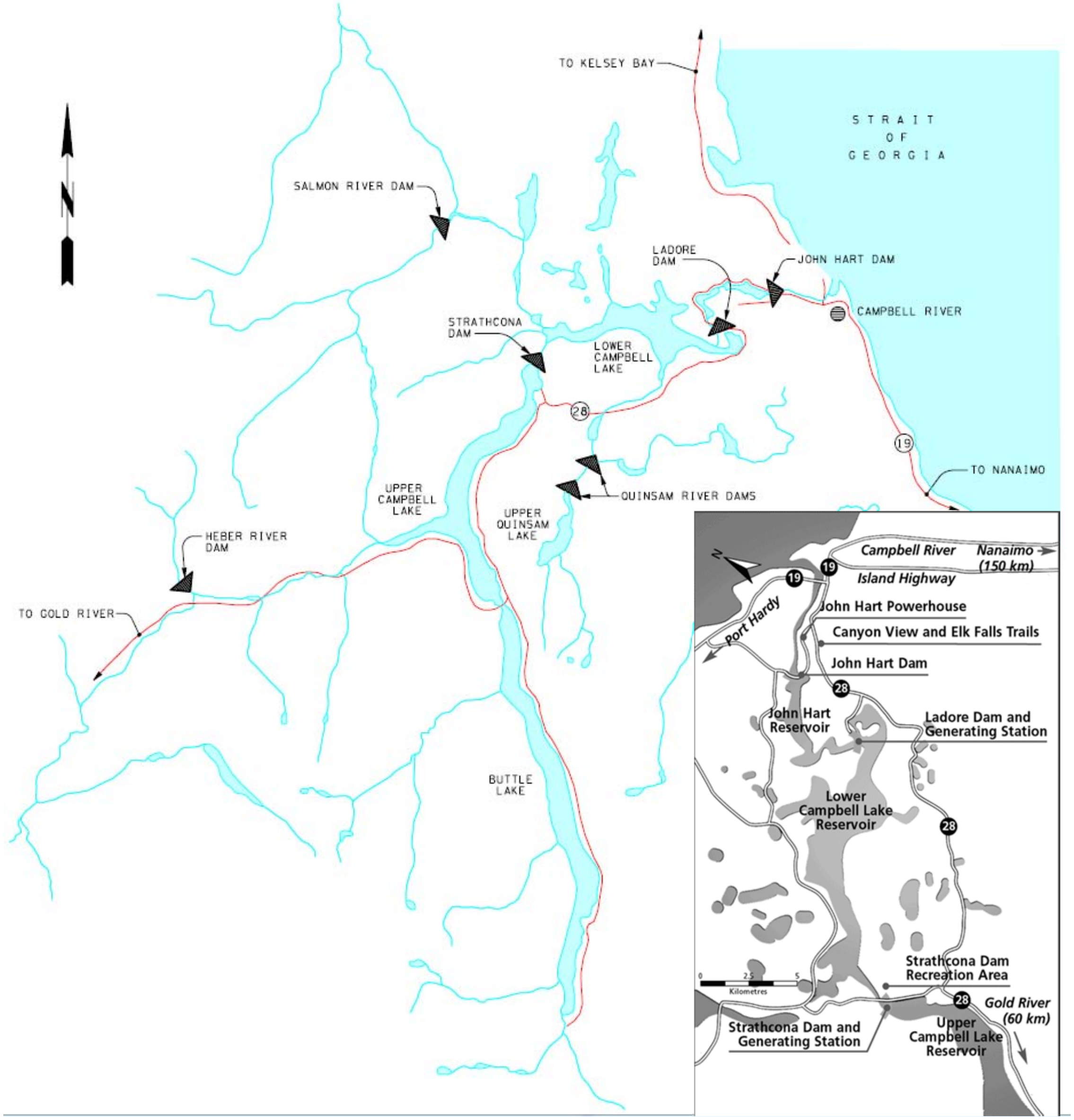


**Figure 2-1: Location Map for Campbell River Water Use Plan**

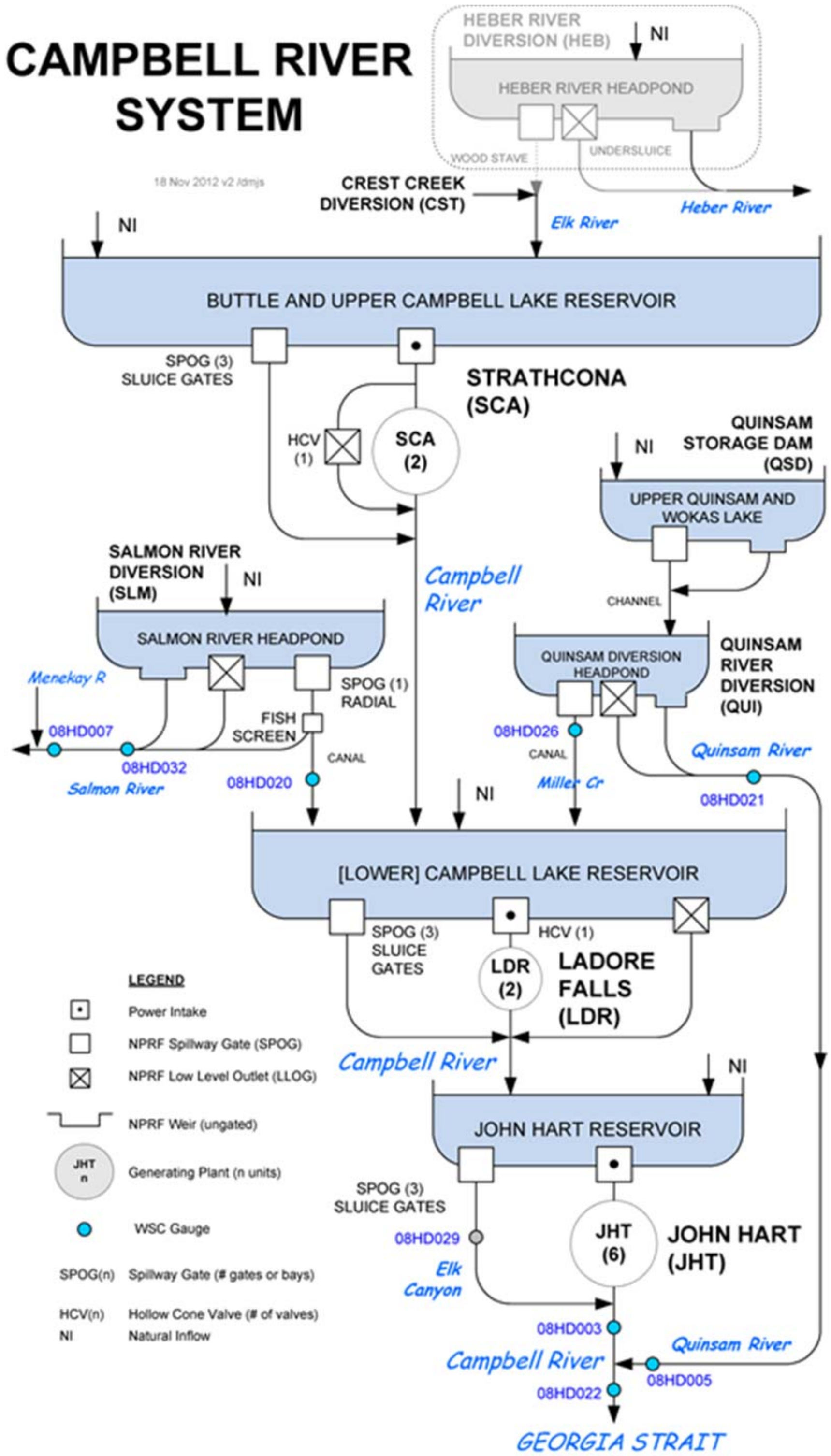


**Figure 2-2: Campbell River System: Water Conveyance Summary**

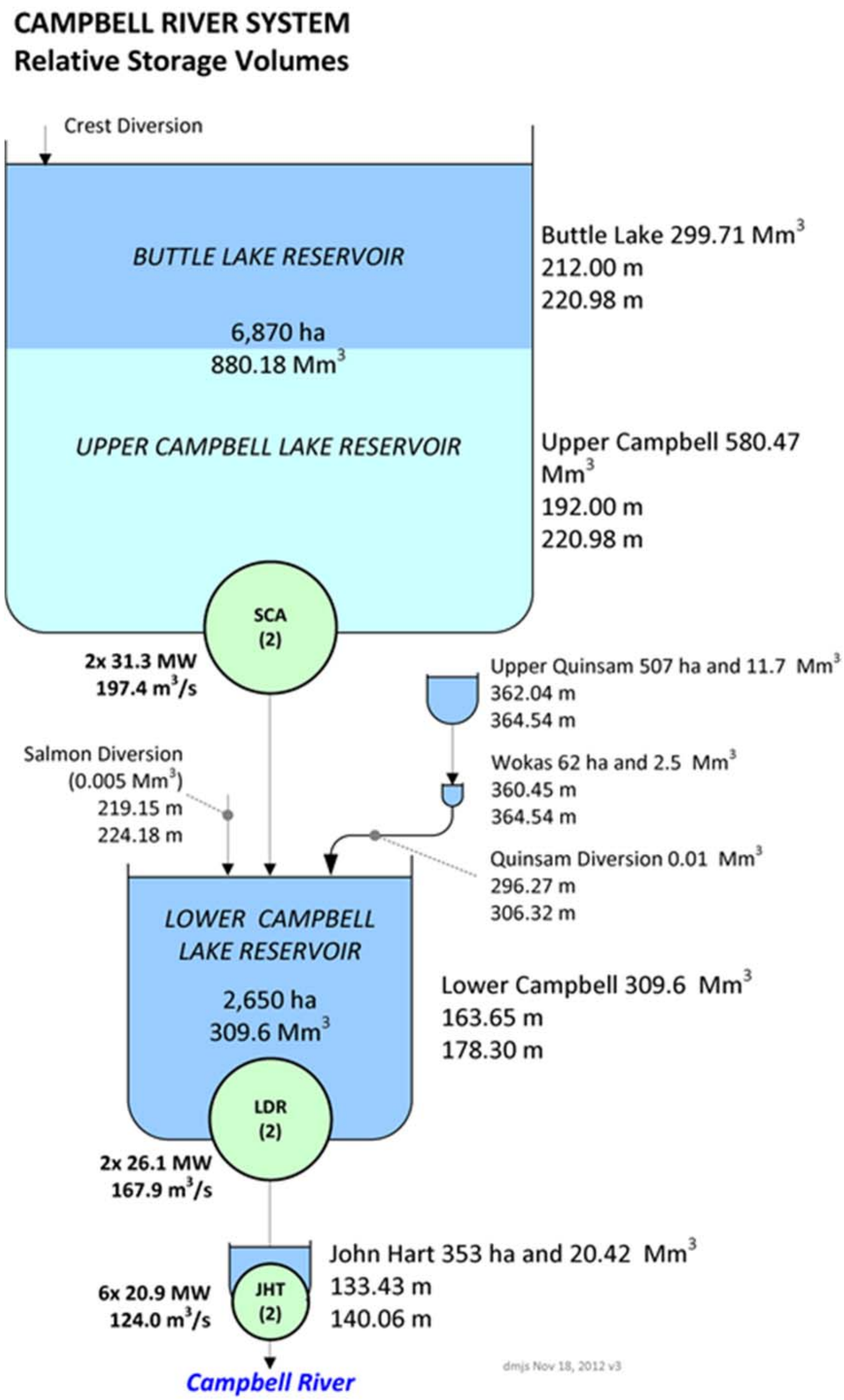


**Figure 2-3: Campbell River System: Relative Storage Volumes**

## 2.2 Description of System Projects

## 2.2.1 Mainstem Campbell River Projects

### 2.2.1.1 Strathcona Project

- **Background**: Strathcona Dam and Strathcona Generating Station are located on the Campbell River approximately 33 km west of the City of Campbell River. The dam impounds the largest reservoir in the system and provides the primary flow regulation for the Strathcona, Ladore, and John Hart Generating Stations. Strathcona Dam and the Strathcona Generating Station, with a single generation unit, were constructed between 1955 and 1958. A second generating unit was installed at Strathcona in 1968. The powerhouse is situated directly below Strathcona Dam on the north side.
- **Buttle and Upper Campbell Lake Reservoir ("Upper Campbell Reservoir")**: At full supply level, 220.98 m, the reservoir surface area is 6,870 ha with an estimated total storage of 2,459 million $m^3$. Both lakes are effectively a single reservoir at elevations above 212 m. Between 212 m and 208 m, Buttle and Upper Campbell Lake Reservoir begin to separate into two lakes. The storage licence for Buttle Lake and Upper Campbell Lake Reservoir, respectively, is set between 212.00 m to 220.98 m and 192.00 to 220.98. The active storage for the combined reservoirs, between storage licence levels, is estimated to be 880.18 $m^3$. The active storage estimate assumes Buttle Lake separates from Upper Campbell Lake at around 212 m. The historical operating range of Upper Campbell Reservoir has been between 221.0 m and 210.0 m.

**Figure 2-4: Strathcona Dam, Intake, Spillway, and Generating Station.**

- **Strathcona Dam and Spillway**: Located at the north east arm of Upper Campbell Reservoir, the earthfill dam is 550 m in length and 53 m high. Crest height is between 225.55 and 226.72 m. The concrete spillway structure, located on the right dam abutment, has three vertical lift steel gates with a combined discharge capability ~577 $m^3/s$ when the reservoir is at full pool. Sill elevation of the gates is 214.85, 214.88, and 214.86 m. The spillway discharge channel travels for ~400 m before joining the tailrace of the generating station on Campbell River.
- **Power Intake:** A single intake structure provides water to the generating station. A 122 m intake conduit divides into 2x ~50 m conduits, one for each generating unit, and

a ~38 m conduit to a low level outlet (hollow cone valve). The low level outlet is only intended for emergency use.

- **Strathcona Generating Station**: The generating station is located at the toe of the earthfill dam and houses two 42,000 hp (2x 31.3 MW) vertical shaft Francis turbines with generator nameplates of 2x 37.5 MVA. Total licence discharge for the purpose of power is 197.4 $m^3/s$. The turbines discharge directly into the channel of Campbell River and immediately thereafter into the Lower Campbell Reservoir.

#### 2.2.1.2 Ladore Project

- **Background**: The Ladore Dam (main dam) and the Loveland Bay and Big Slide Saddle Dams were completed in 1949, forming Lower Campbell Reservoir. The Ladore powerhouse with two generating units was added in 1957, ~500 m downstream of the dam. Ladore Dam is located approximately 15 km west of the City of Campbell River and is situated on the natural outlet on the west arm. Big Slide and Loveland Bay Saddle Dams are situated approximately 4 and 6 km northwest of Ladore Dam.
- **Campbell Lake Reservoir (**"Lower Campbell Reservoir"): The surface area is ~2,650 ha and has an estimated total storage of ~316 million $m^3$ at full supply level of 178.3 m. Between the storage licence limits for power, 178.3 m and 163.65 m, the reservoir has an estimated active storage of 309.6 million $m^3$. The historical operating range of the reservoir has been between 178.3 m and 174.0 m. In addition to Ladore Dam, the reservoir is impounded by two saddle dams.

**Figure 2-5: Ladore Spillway (top right) and Generating Station (bottom right).**

- **Loveland Saddle Dam**: The earthfill dam is 80 m long, 6 m high, and has a crest elevation of 179.8 m. At elevations greater than ~174 m, it prevents Campbell Lake Reservoir from overflowing to Mohun Creek which discharges to Menzies Bay.

- **Big Slide Saddle Dam**: The earthfill dam is 15 m long, 3 m high, and has a crest elevation of 179.8 m. At elevations greater than ~177 m, it prevents Campbell Lake Reservoir from overflowing directly into John Hart Lake Reservoir.
- **Ladore Dam and Spillway**: The concrete gravity dam is 94.5 m long and 37.5 m high. Crest elevation is 179.5 m. The concrete spillway is located on the left side of the dam and is controlled by 3 steel vertical lift gates, sill elevation of 168.86 m. Total discharge from the gates at full supply level is ~1,266 $m^3/s$.
- **Power Intake**: Two intake gates in the dam adjacent to the spillway gates, route water through the dam to a single 520 m concrete lined power tunnel. The tunnel trifurcates into three steel lined penstocks at the junction with the surge tank. The penstocks serve the two generating units and a single low level outlet.
- **Ladore Generating Station**: The generating station is located at the foot of the dam and houses two vertical 35,000 hp (2x 26.1 MW) shaft Francis turbine units with generator nameplates of 2x 30.0 MVA. Maximum licence discharge for the purpose of power is 167.9 $m^3/s$. Generation flows are discharged directly into Campbell River and the upper reach of John Hart Lake Reservoir

#### 2.2.1.3 John Hart Project

- **Background**: The John Hart Dam and a powerhouse with two generating units were constructed between 1945 and 1948. Generating units 3 and 4 and units 5 and 6 were added, respectively, in 1949 and 1953 to the powerhouse. The powerhouse lies ~1.7 km downstream from the dam structure. The dam is sited about 9 km upstream from the City of Campbell River.
- **John Hart Lake Reservoir:** The reservoir has a surface area of ~353 ha with a total estimated storage of 44.7 million $m^3$ at full supply level of 140.06 m. Between water licence elevations of 140.06 m and 133.43 m, the project has an active storage of 20.42 million $m^3$. The normal historical operating range of the reservoir has been between 139.60 m and 139.00 m.
- **John Hart Dam Structures**: The extended dam structures include, from northwest to southeast, the North Earthfill Dam, a concrete Main Dam, the Middle Earthfill, the Power Intake Dam, and the South Earthfill Dam. The main concrete dam is 201 m in length and 34 m high. Crest elevation is 141.73 m. The spillway is located in the central section of the main dam. The north, middle, and south earthfill dams are 205, 348, and 57 m long, respectively, and ~25 m high. Crest elevations are between 141.5 and142.0 m. The Power Intake dam is 56 m long and 10 m high with a crest elevation of 141.73 m and houses the intakes for the three powerhouse penstocks.
- **John Hart Spillway:** The central section of the main dam contains three vertical lift sluicegates, crest elevation 130.76 m. Discharge capacity is approximately 1,238 $m^3/s$ at full supply level of 140.06 m.
- **Power Intake to John Hart Generating Station**: The intakes are located at the Power Intake dam on the east shore of John Hart Lake Reservoir. From the dam, three 1,767 m long penstocks, each with a 1,100 m wood stave portion that joins a steel 670 m lower portion, bifurcate to provide water to each of the 6 generating units. Each of the three penstocks has a surge tower upstream of the bifurcation.

**Figure 2-6: John Hart Dam (left) and Generating Station (right).**

- **John Hart Generating Station**: The generating station has six 28,000 hp (6x 20.9 MW) vertical shaft Francis turbine units with generator nameplates of 6x 25 MVA. Maximum licence discharge for the purpose of power is 124.0 $m^3$/s. Generation flows are discharged into the Campbell River, just upstream of the confluence with Elk Falls Canyon.

## 2.2.2 Diversion Projects

### 2.2.2.1 Crest Creek and Heber Dam

- The Heber Diversion is scheduled for decommissioning commencing in 2012. The decommission project is to meet First Nation interests associated with the interbasin watershed diversion and to consider development criteria associated with Strathcona Provincial Park.
- The Heber Diversion Dam was located approximately 70 km west of the City of Campbell River. The Heber works, along with Crest, were constructed in 1958.

Downstream of the Heber Diversion Dam, the river naturally flows southwest for ~14 km before joining the Gold River. The Heber Diversion used to divert a portion of water, when available, through a wood stave into Crest Lake. Downstream of the Heber Diversion, all of Crest Creek is diverted into Crest Lake and its natural outlet is closed permanently with a dyke. A canal at the east end of Crest Lake connects with Mud Lake. Mud Lake flows into the Upper and Lower Drum Lakes before joining Elk River and, ultimately, Upper Campbell Reservoir. Note that the Heber Diversion has not been in service since 2007 and, as part of the Water Use Plan recommendations, is in the process of decommissioning.

- **Heber Diversion Dam**: The rockfill timber crib dam was ~120 m in length and 9.8 m high with a crest elevation of 355.1 m. The structure used to divert water, when available, from the Heber River via a 3.6 km woodstave pipeline to Crest Lake. The woodstave had the capacity to divert up to 9 $m^3/s$ and was limited to an annual licenced limit of 111.0 $Mm^3/yr$. From Crest Lake, the water would flow through the Drum lakes and into Upper Campbell Reservoir via Elk River.
- **Crest Creek Diversion Dam**: The Crest Creek diversion is located downstream of the Heber Diversion. An earthfill berm diverts all Crest Creek flows into Crest Lake. On average, this is 35 $Mm^3/yr$. From Crest Lake, the water flows through the Mud and Drum lakes and into Upper Campbell Reservoir via the Elk River. The diversion works also captures the smaller Menzies Creek.

#### 2.2.2.2 Salmon Diversion

- **Salmon Diversion Dam**: The Salmon River works are located about 30 km west of the City of Campbell River. From the headwaters, the Salmon River flows north to the Salmon Diversion Dam and then northeast before discharging into Discovery Passage near Sayward. The diversion structure diverts a portion of water, when available from the natural course of Salmon River, via a canal and channel to Brewster Lake and then into Lower Campbell Reservoir. The works were constructed in 1958. In 1986 and 1992, the provincial Ministry of Environment and the Department of Fisheries and Oceans (DFO) added a fish screen and fishway, respectively.
- **Salmon Diversion Dam**: The rockfill timber crib dam is ~69 m in length with an additional ~28 m long trimming weir. Dam crest is 228.30 m. The dam has a negligible active storage ( ~5,000 $m^3$). Main spillway crest elevation is 224.18 m and the trimming weir elevation is between 223.72 m and 223.78 m. Water is returned to the natural course of the Salmon River via i) the main spillway, ii) an undersluice (sill elevation 219.15 m), iii) the trimming weir, and the iv) fishway. Water is diverted into Lower Campbell Reservoir via a diversion canal.
- **Salmon Diversion Canal:** An intake gate (221.36 m) and a downstream radial gate (221.22 m) controls diversion, when available, into a canal. Canal capacity is estimated to be 45 $m^3/s$. Water is diverted through the canal and then through a flume over Paterson Creek to Brewster Lake. Discharge into Brewster ultimately discharges into Lower Campbell Reservoir. Annual diversion to Campbell Reservoir is limited by licence to 493.39 million $m^3$. Overall canal length is approximately 3 km.
- **Salmon Diversion Fishway and Fish Screen:** A fish screen and a fishway were added in 1986 and 1992, respectively, to provide fisheries benefits. The fish screen is located ~400 m downstream of the dam on the canal and diverts fish smolts, when operational, back into the natural course of the Salmon River. Efficient operation of the fish screen

has historically limited the maximum canal diversion rate. The fishway (fish ladder) was added at the downstream end of the trimming weir to permit fish from the natural course of the Salmon River to travel above the diversion dam.

#### 2.2.2.3 Quinsam Diversion

- **Background:** The Quinsam Storage Dam and Diversion Dam are located approximately 25 km southwest of the City of Campbell River. Inflows are partially regulated by the Quinsam Storage Dam which impounds Upper Quinsam Lake and the smaller Wokas Lake. Flows from the Quinsam Storage Dam may be diverted into Lower Campbell Reservoir or returned back to the natural course of the Quinsam River at the Quinsam Diversion Dam, ~3 km downstream of the storage dam. Downstream of the diversion dam, the natural course of the Quinsam River generally parallels the Campbell River to the south and naturally joins Campbell River between the John Hart Dam and Discovery Passage. Both dams were completed in 1957.
- **Quinsam Storage Dam**: The concrete gravity dam is 57 m long with a crest elevation of 368.2 m and a free spill weir at 364.54 m. It impounds Wokas Lake (62 ha) and Upper Quinsam Lake (507 ha). There is ~14.2 million $m^3$ of active storage between full supply level of 364.54 m and the sill level of 360.45 m, of which 11.7 million $m^3$ is associated with Upper Quinsam. The lakes are believed to separate at elevations below 362 m. Normal historical operating range has been between 365 and 361 m. The storage dam regulates flows to the downstream Quinsam Diversion Dam.
- **Quinsam Diversion Dam**: The diversion dam is a concrete gravity dam 65 m long with a crest elevation between 309.68 and 309.35 m. The diversion structure may route water into the natural course of the Quinsam River via an undersluice gate (296.27 m) or the free crest weir (306.32 m). Water, when available, is also be diverted into the Quinsam Diversion Canal which eventually flows into Lower Campbell Reservoir. The canal runs for ~1.7 km between the diversion dam and Gooseneck Lake. Gooseneck Lake drains into Snakehead Lake and Miller Creek, before draining into Lower Campbell Reservoir. The canal intake has the capacity to divert 8.5 $m^3/s$. Annual diversion is limited, by licence, to less than 100 $Mm^3/yr$.

# 3.0 HYDROLOGY OF THE CAMPBELL RIVER BASIN

## 3.1 Drainage Basin

The Campbell River basin is in the transition zone between the wet West Coast and drier East Coast climates of Vancouver Island. The basin is affected by frontal systems arriving southwest off the Pacific Ocean. The systems often arrive in a series of storms separated by hours or days, with each storm bringing strong moist winds and heavy precipitation that last for a few hours to several days.

The west facing mountain slopes of Vancouver Island are usually cloud covered and wet during the winter due to prolonged and heavy rains formed by the orographic lifting of warm moist air from Pacific cyclones flowing inland. The east faces of these mountains experience the spillover effect of the moisture laden winds which lift precipitation over the mountain barrier. The climate tends to be drier on the East Coast of the island because the descending air disperses cloud and lessens the cyclonic rainfall.

The basin area upstream of Strathcona Dam (the Elk River basin) is 1,176 $km^2$, excluding the Heber and Crest Diversions. The Ladore and John Hart basins, downstream of Strathcona Dam are 245 $km^2$ and 25 $km^2$ respectively, excluding their associated diversions. With all diversion basins included, the total system drainage area is ~1,856 $km^2$ (See Table 3-1).

**Table 3-1: Mean annual inflow (MAI) (1984-1999) and drainage area (DA).**

| | **Project Area** | MAI ($m^3/s$) | DA ($km^2$) |
|---|---|---|---|
| HEB | Heber Diversion Outflow | 2.3 | 55 |
| CST | Crest Diversion Outflow | 1.1 | 18 |
| SCA | Strathcona Local Inflow | 77.5 | 1,176 |
| SLM | Salmon Diversion Outflow | 6.8 | 253 |
| QUI | Quinsam Diversion | 1.3 | 84 |
| LDR | Ladore Local Inflow | 10.2 | 245 |
| JHT | John Hart Local Inflow | < 1.0 | 25 |
| | Total | ~100 | 1,856 |
| | | | |
| | Heber River Inflow* | 4.8 | |
| | Crest Inflow* | 1.1 | |
| | Upper Quinsam Inflow* | 3.1 | |
| | Salmon Inflow* | 13.6 | |

* Difference between Diversion Inflow and Diversion Outflow is the MAI to the natural course of those rivers.

## 3.2 Run Off Distribution

Annual inflow, typical of coastal reservoirs is characterized by peak inflows that occur between October and March associated with seasonal rainstorms and spring snowmelt (Figure 3-1 and Figure 3-2). It is typical for periods of cooler weather, in which snowpack increases, to be followed by large short-term Pacific disturbances with higher temperatures that melt portions of the snowpack. During large winter storms, the air temperature may even be above freezing at all basin altitudes.

Table 3-1 summarizes the mean annual inflow to each component of the Campbell River System. See Appendix B, for a complete description of daily inflow and seasonal volume forecasting procedures. A description of the supporting network of hydrometeorological stations and inflow for the system is provided in Appendix B.

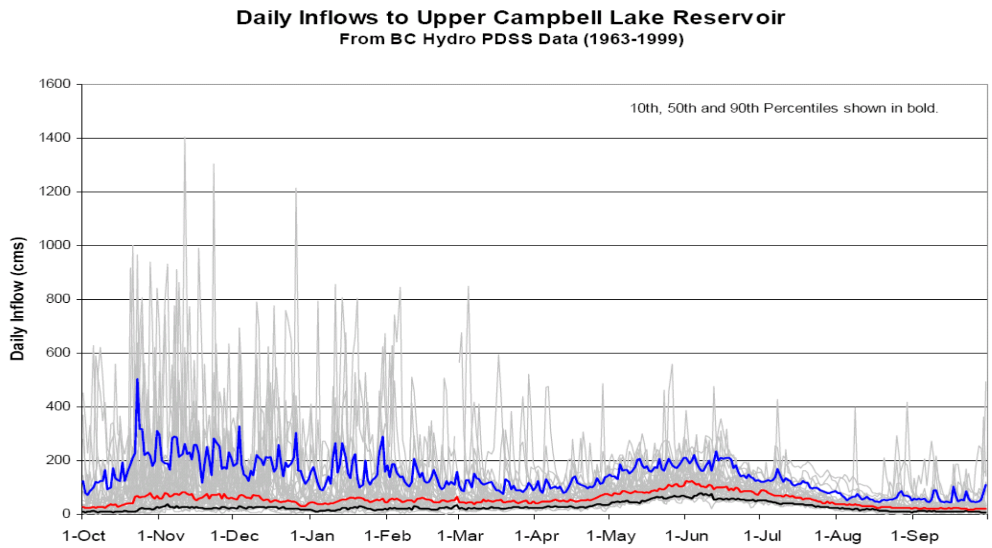


**Figure 3-1: Historical inflows to Buttle and Upper Campbell Lake Reservoir.**

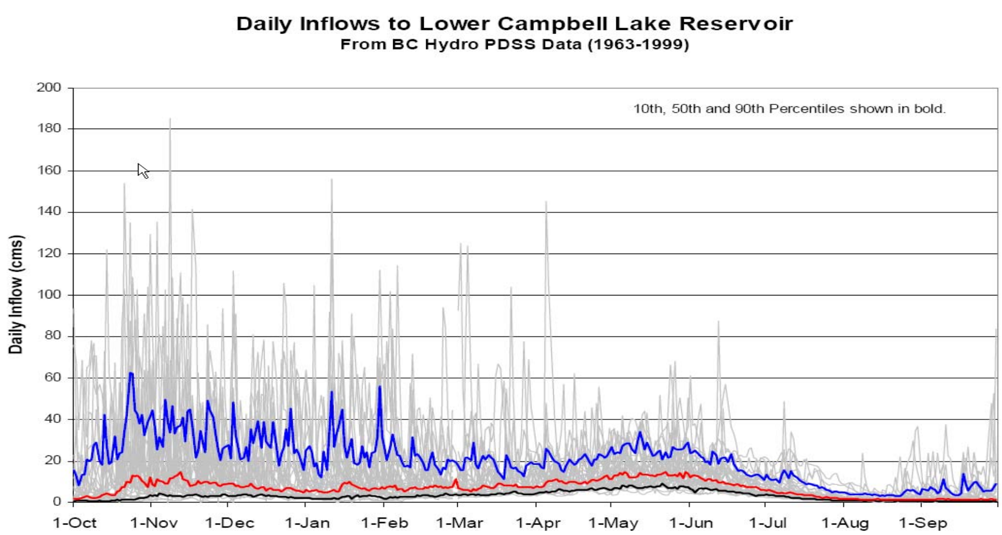


**Figure 3-2: Historical inflows to Lower Campbell Reservoir.**

# 4.0 OPERATING CONDITIONS FOR FACILITY

## 4.1 Role of Campbell River System in BC Hydro's System

The Campbell River System is part of BC Hydro's integrated generation system and plays an important role in generation reliability on Vancouver Island. On average, the Campbell River System generates about 1,230 GWh annually. This is approximately 2.5% of BC Hydro's total hydroelectric generation or 68% of BC Hydro's Vancouver Island hydroelectric generation.

Annual generation needs for Vancouver Island (~11,000 GWh) are met by BC Hydro projects (Jordan River, Ash River, Puntledge River, and the Campbell River System), transmission from the mainland, and independent thermal and hydro resources. The Campbell River System, itself, can provide on average up to 11% of Vancouver Island's annual energy demand and up to 10% of peak daily capacity. This makes the Campbell River System a critical component in maintaining electricity reliability for Vancouver Island.

## 4.2 General Water Use and Power Generation

Total average annual inflow to the Campbell River system is estimated to be 3,310 $Mm^3$. Of this, the majority of the inflow, 2,550 $Mm^3$ or ~82%, is received into the upper basin of Buttle and Upper Campbell Lake Reservoir (Mean Annual Inflow: Table 4-1). The Crest Diversion contributes only a small fraction of inflow to the upper basin: 35 $Mm^3$/yr, respectively

As noted in Section 3.2, seasonal inflow is punctuated by peak rainstorms and spring snowmelt events that occur primarily between October and March. Typically, water surplus to energy demand is stored in the summer and drafted over periods of higher demand over the winter. The Upper Campbell Reservoir manages the bulk of the system storage. Inflows are seasonally shaped into regulated discharges using an average storage volume of 660 $Mm^3$/yr for release to Strathcona and the other downstream generation projects of Ladore and John Hart.

**Table 4-1: Relative Comparison of Inflows, Working Storage, and Generation.**

| Project | Mean Annual Inflow ($Mm^3$/yr) | Mean Storage Volume ($Mm^3$/yr) | Mean Generation (GWh/yr) |
|---|---|---|---|
| Strathcona | 2,550 | 660 | 225 |
| Ladore | 580 | 105 | 230 |
| John Hart | <1 | 2 | 775 |
| Total | 3,130 | 767 | 1,230 |

Average local and diversion inflow to Lower Campbell Reservoir, ~580 $Mm^3$/yr, is significantly less than that for the Upper Campbell basin. Of the diversion inflows, Salmon and Quinsam contribute an average of ~214 and ~41 $Mm^3$/yr, respectively. This inflow, with that from Upper Campbell Reservoir (total of ~3,130 $Mm^3$/yr), is managed in Lower Campbell Reservoir using only 1/6$^{th}$ the working volume available to Upper Campbell and Buttle Reservoir under normal inflow conditions.

John Hart Lake Reservoir has negligible local inflow and working storage (2 $Mm^3$). Discharge from Lower Campbell Reservoir (average of ~3,130 $Mm^3$/yr) is passed, without storage attenuation in John Hart Lake Reservoir, through the John Hart turbines and, to a lesser extent, Elk Falls Canyon for fish habitat (<130 $Mm^3$/yr). Under normal operations discharge from Lower Campbell Reservoir is balanced with the lesser turbine capability of John Hart. On the infrequent occasions where reservoir discharge from Lower Campbell Reservoir is in excess of John Hart turbine capability, the additional water is routed through Elk Falls Canyon as spill.

Discharge capability of the three Generating Stations is dependent on reservoir elevations and is limited by the water licence limit for power generation. Within the normal operating ranges, maximum discharges are as follows:

- Maximum turbine discharge Strathcona ranges from 175.0 to 197.4 $m^3/s$;
- Ladore has a maximum turbine discharge between 160.0 and 167.9 $m^3/s$; and
- John Hart has a maximum turbine discharge between 122.0 and 124.0 $m^3/s$.

Generation capability of each project is primarily a function of the difference in elevation between the reservoir and the powerhouse tailrace. John Hart, having the highest head of the three projects, can produce ~4 times the energy as Ladore and ~3 times the energy of Strathcona per unit of water. As John Hart also receives the cumulative inflow from both the Strathcona and Ladore drainage basins, it produces ~2x as much energy as the Strathcona and Ladore projects combined (Table 4-1).

Within the storage and generation limits of the facilities, BC Hydro normally endeavours to use all the available inflow for generation, less that required for fisheries flows. During spring runoff and during seasonal storms, operations may require cessation of diversion flows from Salmon and Quinsam and initiation of system spills past all three reservoirs. This event may occur under high inflow scenarios, when the storage and generation capacities of Upper Campbell Reservoir and Strathcona Generating Station and Lower Campbell Reservoir and Ladore Generating Station near their maximum normal limits.

## 4.3 Emergencies and Dam Safety

Emergencies and dam safety requirements take precedence over the operational constraints outlined in this Water Use Plan. Emergencies include, but are not limited to, actual and potential loss of power to customers, mechanical failures, public safety and environmental incidents.

Dam safety requirements for operations are outlined in the Operation, Maintenance and Surveillance (OMS) Manuals for each of the John Hart, Ladore, Strathcona, Quinsam Storage, Quinsam Diversion, and Salmon projects filed with the Comptroller of Water Rights. Operational instructions for surcharging the reservoirs and undertaking drafts above and below the water licence for dam safety purposes are also described in the OMS.

Community notification procedures are documented in the current Emergency Planning Guide for the Campbell River System provided to the province and the local authorities.

## 4.4 Conditions for the Operation of Works and Water Use

BC Hydro proposes to operate the Campbell River hydroelectric facilities in accordance with the conditions outlined in this section. These conditions will replace operations previously governed by the *Interim Flow Management Strategy* (IFMS) ordered October 3, 1997 and other ancillary orders associated with the diversions. The constraints identified in Section 4.4 and in Appendix A recognize the complexity and interdependence of the Campbell River System, the numerous social and environmental interests, and the extreme variability of inflows.

### 4.4.1 Priority of Operations

During average conditions the system is managed with the intent to maintain all components within the specified constraints and "Preferred Zones". To meet the constraints, operating decisions require adjustments across multiple control points (Figure 2-2) and must consider both current conditions and the likelihood of being able to meet future constraints. BC Hydro may not be able to operate within these constraints during unusual hydrological events or when other events such as maintenance or unplanned outages occur. When conflicts arise the following, from highest priority to lowest, will guide operating decisions:

- Dam safety requirements defined in the Operation, Maintenance and Surveillance Manuals for Strathcona, Ladore and John Hart Dams, Salmon River and Quinsam River Diversion Dams and Quinsam Storage Dam;
- When flows are naturally available, maintain minimum fisheries flow requirements for Salmon and Quinsam Rivers and for Elk Falls Canyon;
- Manage high flow and reservoir routing criteria according Appendix A of this Water Use Plan;
- Operate Strathcona, Ladore and John Hart Generating Stations to manage the flow in Lower Campbell River to the Preferred Zone (Table 4-2);
- Maintain all specified ramping rates;
- Operate Strathcona, Ladore and John Hart Generating Stations to manage the level of the Upper Reservoir to the Preferred Zone (4.4.2); and
- Operate Strathcona, Ladore and John Hart Generating Stations to manage the level of the Lower Campbell Reservoir to the Preferred Zone (4.4.3).

Appendix A of the Water Use Plan provides additional guidance for operating the Campbell River System to meet the constraints articulated in Sections 4.4.2 to 4.4.4 and for operations outside the Preferred Zones for the reservoirs and John Hart discharges. During specified operations outside the Corrective Zones, BC Hydro will engage in regular communication with the agencies and other interested parties.

## 4.4.2 Strathcona Project

### 4.4.2.1 Buttle and Upper Campbell Lake Reservoir ("Upper Campbell Reservoir")

- The maximum and minimum operating levels for Upper Campbell Reservoir to meet fisheries, recreation, shoreline and flood mitigation interests, as measured[1] at Strathcona Dam are:

| Date | Maximum (m) | Minimum (m) |
|---|---|---|
| Jan 1 to Dec 31 | 220.5 | 212.0 |

- Within the range of operating levels specified above is a Preferred Zone, which is shown in Figure 4-1 and in Appendix A. Specifically for summer recreation, the upper and lower bounds of the reservoir Preferred Zone are:

| Date | Preferred Maximum (m) | Preferred Minimum (m) |
|---|---|---|
| Jun 21 to Sep 10 | 220.5 | 217.0 |

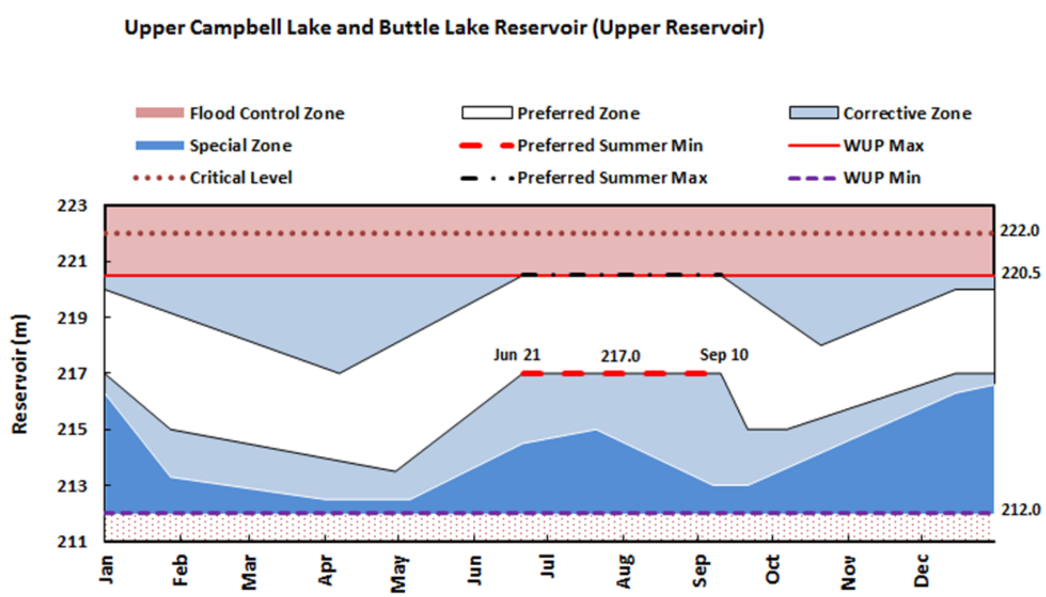


**Figure 4-1: Upper Campbell Reservoir Operation Zones**

### 4.4.2.2 Strathcona Generating Station Ramp Rate

- There is no ramp rate required for the turbine units.

[1] All elevations in this section are relative to Geodetic Survey of Canada (GSC) datum.

#### 4.4.2.3 Strathcona Dam Spillway Ramp Rate

- To reduce potential for fish stranding downstream of Strathcona Dam, the following ramp down rates are required for spill discharge:

| Strathcona Dam Spill ($m^3/s$) | Maximum Spillway Ramp Down Rate ($m^3/s/hr$) |
|---|---|
| > 5.0 | n/a |
| 5.0 to 0.0 | 2.5 |

- There are no constraints on the rate of spill increase.
- Flow changes and the ramp rate will be based on the current gate discharge curves.

#### 4.4.2.4 Strathcona Discharge

- Maximum turbine discharge for the purpose of power is limited by water licences.
- Other than design and dam safety, there is no restriction on maximum spill discharge from the Strathcona project.
- There is no minimum discharge requirement from the spillway or generating station.

### 4.4.3 Ladore Project

#### 4.4.3.1 Campbell Reservoir ("Lower Campbell Reservoir")

- The maximum and minimum operating levels for Lower Campbell Reservoir to meet fisheries, recreation, shoreline and flood mitigation interests, as measured at Ladore Dam are:

| Date | Maximum (m) | Minimum (m) |
|---|---|---|
| Jan 1 to Dec 31 | 178.3 | 174.0 |

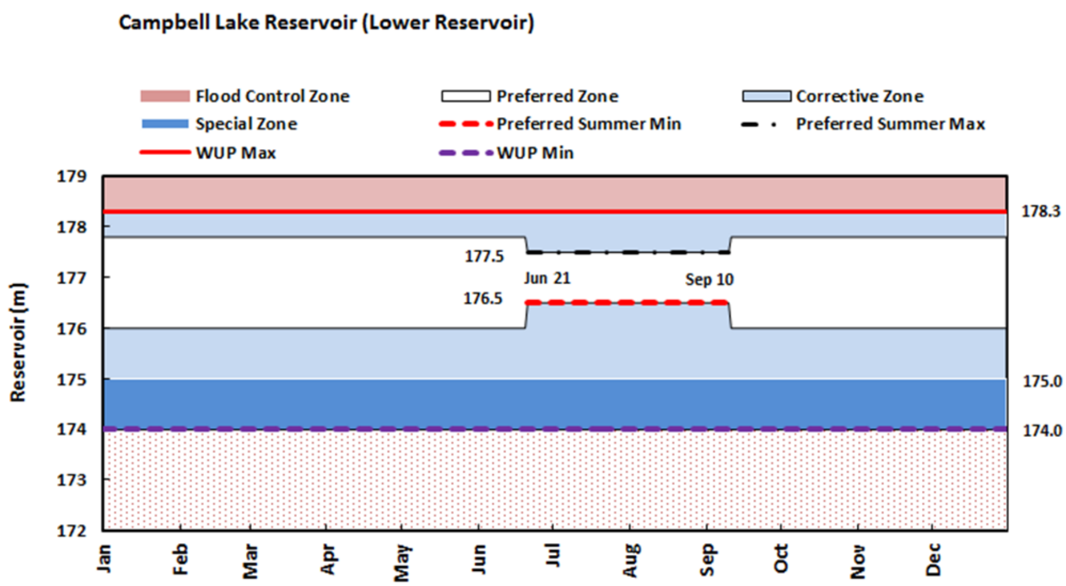


**Figure 4-2: Lower Campbell Reservoir Operation Zones**

- Within the range of operating levels specified above is a Preferred Zone for Lower Campbell Reservoir, which is shown Figure 4-2 and in Appendix A. Specifically for recreation, the upper and lower bounds of the reservoir Preferred Zone are:

| Date | Preferred Maximum (m) | Preferred Minimum (m) |
|---|---|---|
| Jun 21 to Sep 10 | 177.5 | 176.5 |

- In the event that Lower Campbell Reservoir is expected to enter (or has entered) the Flood Control Zone (>178.3 m: Appendix A), Salmon (Section 4.4.7.2) and Quinsam (Section 4.4.8.2) diversion flow to Lower Campbell Reservoir must be stopped.
- Guidelines for the operation of the Campbell River System to manage Lower Campbell Reservoir in and outside the Preferred Zone are set out in Appendix A.

#### 4.4.3.2 Ladore Dam Spillway Ramp Rate

- To reduce potential for fish stranding during a spill at Ladore, the following ramp down rates are required:

| Ladore Dam Spill ($m^3/s$) | Spillway Max Ramp Down Rate ($m^3/s/hr$) |
|---|---|
| > 8.0 | n/a |
| 8.0 to 0.0 | 2.0 |

- There are no constraints on the rate of spill increase.
- Flow changes and the ramp rate will be based on the current gate discharge curves.

#### 4.4.3.3 Ladore Generating Station Ramp Rate

- There is no ramp rate required for the turbine units.

#### 4.4.3.4 Ladore Discharge

- Maximum turbine discharge for the purpose of power is limited by water licences.
- Other than design and dam safety, there is no restriction on maximum spill discharge from the Ladore project.
- There is no minimum discharge requirement from the spillway or generating station.

### 4.4.4 John Hart Project

#### 4.4.4.1 John Hart Lake Reservoir

- The Preferred Operating range for John Hart Lake Reservoir is 139.60 m and 139.00 m.

#### 4.4.4.2 Elk Falls Canyon Flows

- Minimum fisheries flow from the John Hart spillway to Elk Falls Canyon are:

| Date | Minimum Flow ($m^3/s$) |
|---|---|
| Apr 16 to Mar 31 | 4.0 (habitat) |
| Apr 1 to Apr 15 | 7.0 (habitat and spawning) |

- In addition to the minimum flows, a series of pulse flows for fisheries interests from the John Hart spillway to Elk Falls Canyon are:

| Date | Minimum Pulse ($m^3/s$) | Requirements |
|---|---|---|
| Feb 15 to Apr 15 | 10.0 | 5 x 48hr, minimum 5 days apart, and once every two weeks. |
| Sep 15 to Nov 15 | 7.0 | 9 x 48hr, minimum 3 days apart, and once every week. |

- The minimum flow for Elk Falls Canyon is included in the minimum pulse flow.[1]
- The ramp up and ramp down time, at the maximum allowable ramp rate, is included in the 48 hour pulse duration.[2]
- The Elk Falls Canyon minimum flow and pulse flows may be included as part of or in addition to the Lower Campbell River flow in Table 4-2, Section 4.4.4.4.
- The flows are to be reported as the calculated discharges from Elk Falls Canyon based on the current spillway discharge curve.

#### 4.4.4.3 John Hart Spillway and Elk Falls Canyon Ramp Rates

- To reduce potential for fish stranding and to avoid impacting habitat during ramp ups, the following ramp rate restrictions are applied to the John Hart Spillway:

| Spill Discharge ($m^3/s$) | Maximum Spill Ramp Down Rate ($m^3/s/hr$) |
|---|---|
| > 8.0 | n/a |
| 8.0 to 4.0 | 1.0 |

| Spill Discharge ($m^3/s$) | Maximum Spill Ramp Up Rate ($m^3/s/hr$) |
|---|---|
| > 100 | n/a |
| 4.0 to 100 | 20.0 |

- The ramp down rate is implemented using at least four discrete changes per hour to graduate the hourly flow change. While four changes within the hour are possible, for flows < 1.0 $m^3/s$ the infrastructure prohibits making these changes in equal steps.
- The ramp up rate is implemented by using at least four discrete and approximately equal changes per hour to graduate the hourly flow change.[3]
- Flow changes and the ramp rate will be based on the current gate discharge curves.
- The ramp up and ramp down time, at the maximum allowable ramp rate, is included in the 48 hour pulse duration specified in 4.4.4.2.

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1 For example, the minimum pulse between April 15 and Feb 15 requires 6.0 $m^3/s$ or more in addition to the minimum flow of 4.0 $m^3/s$ to achieve the 10 $m^3/s$ or more requirement.

2 For example, within the 48 hr period, transition between the min flow (e.g. 4.0 $m^3/s$ in Sep) to the min pulse flow (e.g. 10.0 $m^3/s$ in Sep) to accommodate Elk Falls Canyon ramping (e.g. <1 $m^3/s/hr$ when discharge < 8.0 $m^3/s$) is permitted.

3 For example, if a gate was required to open 40 cm to ramp up from ~80 to 100 $m^3/s$ when JHT reservoir was at ~139 m, this could be achieved by 4 x 10 cm changes once every ~15 min or 8 x 5 cm changes once every ~7.5 min, etc…

- There is no ramp down rate for emergency situations requiring the cessation of flows into Elk Falls Canyon.
- The ramp up rate is not in effect in the event of an unexpected outage at John Hart Generating Station. In this scenario, flows may be ramped up faster than the limits specified above to restore the Campbell River minimum flow in Section 4.4.4.4.
- If the Lower Campbell River flows required under Section 4.4.4.4 are being provided in full by the John Hart spillway via Elk Falls Canyon and not by the John Hart Generating Station, the John Hart spillway must ramp down according to the John Hart Generating Station requirements in Section 4.4.4.5.[1]

#### 4.4.4.4 Lower Campbell River Flows

- Lower Campbell River is defined as the portion of Campbell River downstream of the John Hart Generating Station and the confluence with Elk Falls Canyon. Under normal operations the majority of the flow to Lower Campbell River will be provided by discharge from the John Hart Generating Station.
- Within the range of downstream discharges, is a Preferred Zone for the Lower Campbell River, which is shown in Table 4-2, Figure 4-3, and Appendix A, to balance upstream reservoir recreation and flood control with downstream fisheries interests.
- Specifically to enhance fisheries habitat, spawning and rearing success, the upper and lower bounds of the Lower Campbell River Preferred Zone is provided in Table 4-2.

**Table 4-2: Lower Campbell River Preferred Flow Range ($m^3/s$)**

| Date | Preferred Low | Fisheries Target | Preferred High |
|---|---|---|---|
| January 1 to February 15 | 80 | 122 | 124 |
| February 16 to February 28 | 80 | 106 | 124 |
| March 1 to April 14 | 60 | 100 | 104 |
| April 15 to April 30 | 80 | 80 | 124 |
| May 1 to June 30 | 100 | 100 | 124 |
| July 1 to July 19 | 28 | 40 | 124 |
| July 20 to September 14 | 28 | 40 | 124 |
| September 15 to September 21 | 28 | 40 | 124 |
| September 22 to October 14 | 28 | 100 | 104 |
| October 15 to November 15 | 80 | 122 | 124 |
| November 16 to December 31 | 80 | 106 | 124 |

- The Elk Falls Canyon minimum and pulse flow (Section 4.4.4.2) may be included as part of or in addition to the Lower Campbell River flow requirements in Table 4-2.[2]

---

1 Consider that on June 30 JHT GS is out of service for maintenance. JHT spillway must now provide 96 $m^3/s$ in addition to the 4 $m^3/s$ min flow to Elk Falls Canyon to meet the June 30 min flow of 100 $m^3/s$. On July 1, the minimum flow for Lower Campbell River changes to 26 $m^3/s$. In order to ramp down to 26 $m^3/s$, the spillway must meet the ramp down criteria for the JHT GS. In this example, the spillway would have to ramp down from 100 to 80 $m^3/s$ at 42.0 $m^3/s/hr$, from 80 to 60 $m^3/s$ at 7.0 $m^3/s/hr$ and then from 60 to 28 $m^3/s$ at 2.0 $m^3/s/hr$ subject to a maximum of 6.0 $m^3/s/day$.

2 For example, a pulse flow in the week of April 15 of 10 $m^3/s$ may be delivered as part of the requirement to meet the 80 $m^3/s$ minimum flow in the Campbell River (i.e.10 $m^3/s$ from spill and 70 $m^3/s$ from JHT GS) or may be delivered in addition to the JHT GS 124 $m^3/s$ maximum, for a total of 134 $m^3/s$ in the Lower Campbell River.

- The John Hart Generating Station is normally run at a relatively constant output (base loaded) over several consecutive days for fisheries interests. Within the Preferred Flow Ranges (Table 4-2), operations should consider an ancillary target objective of stable flows (5+ days) to sustain the downstream fisheries habitat.
- In addition to the Preferred Low and High range for Lower Campbell River, targets within the Preferred Range were also identified specifically for fisheries objectives. The Fisheries Target flows (Table 4-2), are those considered to best meet the needs of fish in the Lower Campbell River, second in priority to providing stable flows between the Preferred Low and High limits.
- Stable flows (5+ days) at non Fisheries Target flows, but within the Preferred Operating ranges in Table 4-2, are preferable to short term (hourly or daily) fluctuations in an attempt to intermittently meet the Fisheries Target flows.
- Changes between stable flows and across the Fisheries Target flows, within the aforementioned Preferred Operating ranges, are expected under normal operations.
- Between January 1 and February 15 the John Hart Generating Station may operate freely (load factor) with frequent changes to the turbine discharge between 76 and 124 $m^3/s$. These operations are not restricted by either ramp rate restrictions (see Section 4.4.4.5) or the ancillary target objective to maintain a stable flow.
- When the John Hart Generating Station cannot provide sufficient flows to meet the Preferred Low requirements in Table 4-2, releases from the John Hart spillway via Elk Falls Canyon will be increased to meet or exceed the Preferred Low flow requirement. Under this scenario, ramp down rates in Elk Falls Canyon are restricted to the same requirements as the John Hart Generating Station in Section 4.4.4.5.
- Guidelines for operating the Campbell River System to manage the flow of the Lower Campbell River within and outside the Preferred Zone are set out in Appendix A.

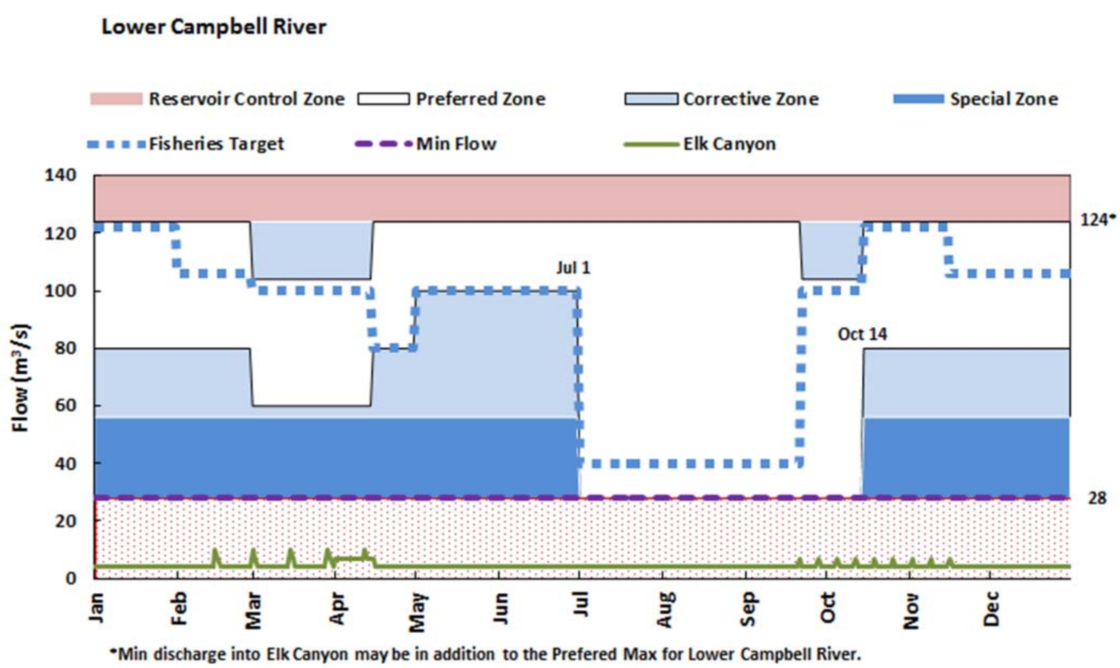


**Figure 4-3: Lower Campbell River Operation Zones**

#### 4.4.4.5 Ramp Rates for John Hart Generating Station

- To minimize the risk of stranding fish during ramp downs the following rates are applied based on the total flow in the Lower Campbell River:

| Turbine Flow ($m^3/s$) | Maximum Generation Ramp Down Rate ($m^3/s/hr$) | Min # of changes per hour |
|---|---|---|
| > 76.0 | 42.0 | 4 |
| 76.0 to 60.0 | 7.0 | 2 |
| < 60.0 | 2.0 (maximum 6.0 $m^3/s/d$) | 1 |

- To avoid impacting habitat during ramp ups, the following ramp rates are applied based on the total flow in the Lower Campbell River:

| Turbine Flow ($m^3/s$) | Maximum Generation Ramp Up Rate ($m^3/s/hr$) | Min # of changes per hour |
|---|---|---|
| > 76.0 | 42.0 | 4 |
| ≤ 76.0 | 14.0 | 2 |

- The ramp rates are implemented using several discrete and approximately equal changes per hour to graduate the hourly flow change.
- Changes to flow and the resulting ramp down or up rates will be based on the current turbine discharge curves.
- Between January 1 and February 15, ramp rate restrictions for the John Hart Generating Station are not in effect when turbine discharge is greater than 76.0 $m^3/s$. Load factoring (frequent within day changes) between the ranges of 76.0 and 124.0 $m^3/s$ is permitted during this period and operations do not have to consider the target objective of maintaining a longer term stable flow.
- There is no ramp down rate for emergency situations requiring the cessation of flows into Lower Campbell River.
- The ramp up rate is not in effect in the event of an unexpected outage at John Hart Generating Station. In this scenario, flows may be ramped up in excess of the above limits to restore the minimum flow.

### 4.4.5 Heber Diversion and Heber River

#### 4.4.5.1 Heber Diversion Project Life

- The Heber Diversion is scheduled for decommissioning commencing in 2012. The decommission project is to meet First Nation interests associated with the interbasin watershed diversion and to consider development criteria associated with Strathcona Provincial Park.
- The decommissioning of the dam and pipeline for the diversion of water from Heber River shall follow the process set out in Section 9 of the *Water Act British Columbia Dam Safety Regulation*. This process is separate from the implementation of the remainder of the recommendations of the Campbell River Water Use Plan.

#### 4.4.5.2 Heber River Flow Requirements

- The diversion of flow from the natural course of the Heber River to Upper Campbell Reservoir has effectively ceased since 2007.
- Prior to and after facility decommissioning, Heber inflows may no longer be diverted into Upper Campbell Reservoir.

### 4.4.6 Crest Creek Diversion

#### 4.4.6.1 Diversion Flows

- Crest Creek Diversion will continue to operate separate and independent of the Heber decommissioning project.
- All of Crest Creek is diverted into Upper Campbell Reservoir. There are no means to control regulation.
- Other than design and dam safety, there is no restriction on maximum diversion.

### 4.4.7 Salmon River and Salmon Diversion

#### 4.4.7.1 Salmon River Flow Requirements

- The minimum flow requirements for the protection of fisheries habitat in the Salmon River, when flows are naturally available, are:

| Date | Minimum Flow ($m^3/s$) |
|---|---|
| Jan 1 to Dec 31 | 4.0 |

- The flows can be delivered by any combination of releases from the under-sluice gate and diversion structures such as the fish ladder and fish screen outflow pipe.
- The flows are to be measured in the vicinity of the Water Survey Canada gauge 08HD032, downstream from the dam.

#### 4.4.7.2 Salmon Diversion Canal Flows

- Subject to available inflow and the maintenance of flows required under Section 4.4.7.1, a portion of the inflow to the Salmon Diversion Dam may be diverted to Lower Campbell Reservoir.
- Diversion of flow from Salmon River via the canal into Lower Campbell Reservoir is restricted below the design capacity to 43.0 $m^3/s$ between April and December to increase the fish screen efficacy:

| Date | Maximum Diversion ($m^3/s$) | Fish Screen |
|---|---|---|
| Jan 1 to Mar 31 | 43.0 | n/a |
| Apr 1 to Dec 31 | 15.0 | On |

- Upon completion of the identified fish screen improvements (Section 4.5.3), the maximum diversion flow into the canal from April 1 to 31 December 31 can be increased to 30.0 $m^3/s$.
- In the event that Buttle and Upper Campbell Lake Reservoir (4.4.2.1) or Lower Campbell Reservoir (Section 4.4.3.1) is expected to enter or has entered a Flood Control Zone, Salmon diversion flows to Lower Campbell Reservoir must be stopped.
- Diversion flows are to be measured in the vicinity of Water Survey Canada gauge 08HD020.

#### 4.4.7.3 Salmon Diversion Ramp Rates

- Flow to the Salmon River downstream of the Diversion Dam can be reduced by i) closing the under-sluice to the Salmon River and ii) opening the radial gate to the diversion canal. The following ramp down limits for the Salmon River are expected to reduce fish stranding in the Salmon River:

| Salmon River Flow ($m^3/s$) | Salmon River Maximum Ramp Down ($m^3/s/hr$) |
|---|---|
| > 10.0 | 10.0 |
| 10.0 to 8.0 | 2.0 |
| < 8.0 | 1.0 |

- The following ramp down limits are expected to reduce impacts to fish habitat in the Salmon River and downstream of the canal:

| Salmon Diversion Flow ($m^3/s$) | Canal Maximum Ramp Down ($m^3/s/hr$) |
|---|---|
| 43.0 to 0.0 | 10.0 |

- The ramp rates are to be implemented by using at least four discrete and approximately equal changes per hour to graduate the hourly flow change.
- Flow changes and the ramp rate will be based on the current gate discharge curves.

#### 4.4.7.4 Salmon Diversion Debris Management

- Woody debris builds up on the Salmon Diversion trash rack and in the forebay. The debris needs to be periodically flushed for dam safety reasons. Flushing is achieved by filling the headpond and then opening the under-sluice to maximum capacity. The objective is to complete the debris removal within two hours. The inflow volume and debris load, however, will affect the completion time.
- For this operation, the Salmon River ramp rates in Sections 4.4.7.3 are not applicable.
- The downstream minimum flow into the Salmon River, Section 4.4.7.1, will be met during this operation.

## 4.4.8 Quinsam Diversion and Quinsam River

### 4.4.8.1 Quinsam Storage Dam and Quinsam River

- When flows are naturally available at the Quinsam Storage Dam, the Quinsam Diversion Dam shall be operated to release flow to the natural course of the Quinsam River for fisheries interests:

| Date | Minimum Flow ($m^3/s$) |
|---|---|
| Jan1 to Apr 30 | 2.0 |
| May 1 to Oct 31 | 1.0 |
| Nov 1 to Dec 31 | 0.6 |

- The minimum flow to Quinsam River, May 1 to October 31, may be reduced from 1.0 $m^3/s$ upon consultation with federal and provincial fishery agencies and approved by the Comptroller of Water Rights to ensure flow continuity for fishery interests.
- The flows are to be measured in the vicinity of the Water Survey Canada gauge 08HD021, downstream from the dam.

### 4.4.8.2 Quinsam Diversion

- Subject to available inflow and the maintenance of flows required under Section 4.4.8.1, a portion of the inflow to Quinsam Diversion Dam may be diverted to Lower Campbell Reservoir.
- The flows are to be measured in the vicinity of the Water Survey Canada gauge 08HD026, in the diversion canal upstream of Gooseneck Lake.
- In the event that Buttle and Upper Campbell Lake Reservoir (4.4.2) or Lower Campbell Reservoir (4.4.3) is expected to enter or has entered a Flood Control Zone, Quinsam diversion flows to Lower Campbell Reservoir must be stopped.

### 4.4.8.3 Quinsam River and Quinsam Diversion Ramp Rates

- The ramp down limits at Quinsam Diversion Dam are expected to allow fish in the waters downstream of both the diversion canal and in Quinsam River to adjust to the new conditions The maximum ramp down rates for Quinsam Diversion are:

| Quinsam Diversion Flow ($m^3/s$) | Quinsam Diversion Maximum Ramp Down ($m^3/s/hr$) |
|---|---|
| > 2.0 | n/a |
| ≤ 2.0 | 1.0 |

- The Quinsam River ramp rates are expected to reduce fish stranding in the Quinsam River. Flow to Quinsam River, downstream of Quinsam Diversion Dam, can be reduced by i) closing the under-sluice to Quinsam River and ii) opening the gate to the diversion canal. The maximum ramp down rates for Quinsam River flows are:

| Quinsam River Flow ($m^3/s$) | Quinsam River Maximum Ramp Down ($m^3/s/hr$) |
|---|---|
| > 4.0 | 8.5 |
| ≤ 4.0 | 1.0 |

- Both ramp up and ramp downs are to be implemented by using at least four discrete and approximately equal changes per hour to graduate the hourly flow change.
- Flow changes and the ramp rate will be based on the current gate discharge curves.

## 4.5 Recommended Non-Operating Alternatives

In lieu of other operational constraints, the following non-operating or physical work alternatives are recommended. It is expected that the non-operating alternatives could further improve fisheries and wildlife habitat, recreation, shoreline conditions, or other interests at costs less than additional operating restrictions.

### 4.5.1 Buttle and Upper Campbell Lake Reservoir

- **Erosion Control Works**: Sites with erosion concerns will be identified and selected sites will be "soft engineered" (i.e. vegetation planting, log boom wave breaks, etc...) to improve conditions. The specific areas of interest are at Cedar Creek Subdivision, Strathcona Park Subdivision and Strathcona Park Lodge. These works are in lieu of implementing a lower maximum elevation on Upper Campbell Lake Reservoir.
- **Recreation Facility Improvements**: The lower Corrective Zone levels are expected to make beaches and boat ramps incrementally less accessible. To address this concern, existing boat ramp and beach recreation facilities in the Provincial Park and Forest Recreation sites will be prioritized and the feasibility assessed for upgrades to improve usability under the new reservoir range.
- **Re-vegetation:** The lower Corrective Zone levels are expected to incrementally expose additional areas. To improve terrestrial habitat, it is recommended that the sites be identified and highly visible reservoir perimeter sites, within the drawdown zone, be prioritized for re-vegetation efforts. Site selection is to be confirmed before work commences.

### 4.5.2 Lower Campbell Reservoir

- **Recreation Facility Improvements**: The lower corrective operating level is expected to make beaches and boat ramps less accessible. To improve this concern, existing boat ramp and beach recreation facilities in the Provincial Park and Forest Recreation sites will be prioritized and the feasibility assessed for upgrades to improve usability under the new reservoir range.

### 4.5.3 Salmon Diversion

- **Sayward Canoe Route Signage**: To improve public safety and reduce hazards expected from higher flows, a program to improve access and signage along the Salmon Diversion portage routes of the Sayward Canoe Route is proposed.
- **Sayward Canoe Route Erosion Control**: To improve erosion control and public safety expected with higher diverted flows, it was recommended to install bank protection along the Salmon Diversion portion of the Sayward Canoe Route.

- **Salmon Fish Screen Upgrade**: It was recommended that an upgrade or redesign of the fish screen at the Salmon Diversion be undertaken to improve the fish screen efficiency at higher diversion flows.

### 4.5.4 Implementation of Ramping Rates

- **Ramping Rate Deficiencies**: The ability to reliably and accurately deliver the new ramping rates for the mainstem plants and the diversion works remains to be tested. Over the first year of implementation, a summary of feasibility and monitoring deficiencies will be produced. Recommendations to improve infrastructure or modify the operational constraints to meet the original fisheries objectives will be made.

# 5.0 PROGRAMS FOR ADDITIONAL INFORMATION

Development of the proposed conditions for the Campbell River hydroelectric system was complicated by uncertainties and information gaps. The recommendations of the Consultative Committee were contingent on the implementation of the non-operating alternatives and monitoring programs to reduce these uncertainties.

The monitoring programs are designed to address key questions that affected decision making throughout the consultative process. Accordingly, it is recommended that BC Hydro undertake a monitoring program that will:

- Assess expected outcomes of the operational changes and non-operational programs (physical works) being proposed; and
- Provide improved information for future operations.

Additional details and estimated costs of the proposed monitoring program are provided in the Campbell River Water Use Plan: Consultative Committee Report. Table 5-1 to Table 5-5 provide a summary.

**Table 5-1: Recreation and Shoreline Conditions Monitoring**

| Component | Objectives |
|---|---|
| **Recreation Hazard Assessment**<br><br>Upper Campbell & Lower Campbell Reservoirs | Assess boating related recreation hazards and develop a bathymetric map using a Digital Elevation Model (DEM). The DEM will determine whether there is a correlation between static submerged hazards and reservoir elevations for Upper Campbell and Lower Campbell Reservoirs. DEM data will also be used for the reservoir spawning success and littoral productivity studies. |
| **Recreation & Perception**<br><br>Upper Campbell & Lower Campbell Reservoirs and Lower Campbell River | Measure public response to the proposed operating regime through public use and perception surveys. The information is intended to correlate between system operations (i.e., flow rates, reservoir elevations) and recreation use and public perceptions. These data would be valuable for future operating reviews. |
| **Erosion Monitoring**<br><br>Upper Campbell Reservoir and Salmon Diversion | Monitor rates of erosion at selected sites including areas where private property is at risk to determine whether the lower normal maximum elevations reduces the rate of erosion on Upper Campbell Reservoir. The information would also be used to prioritize and design physical works at sites where erosion is determined to be putting private property at risk. Monitor rates of erosion at selected sites on the Salmon Diversion associated with the proposed erosion improvement works. |

**Table 5-2: Wildlife Monitoring: Upper Campbell and Lower Campbell Reservoir**

| Component | Objectives |
|---|---|
| **Amphibian Habitat Inventory/Use** | The monitoring will assess whether amphibians are impacted by operations. The work will also assess the response of amphibians to the flow regime. |
| **Shoreline Vegetation Model Validation** | Shoreline vegetation will be monitored to validate the model used to predict vegetation community structure in response to reservoir operations. |

**Table 5-3: Reservoir Fisheries Monitoring**

| Component | Objectives |
|---|---|
| **Fish Population Response to Reservoir Spawning Habitat**<br>Upper Campbell & Lower Campbell Reservoirs | Monitor spawning success in tributaries. This information will assist in determining if spawning success is sufficient to fully seed reservoir fish populations and thus maintain genetic diversity with the proposed operating regime. |
| **Littoral Productivity of Reservoirs**<br>Upper Campbell & Lower Campbell Reservoirs | Monitor littoral productivity in the reservoirs to validate the use of the Effective Littoral Zone performance measure as an indicator of littoral productivity change. This monitoring will also confirm whether the new operating regime results in the expected increase in littoral productivity. |
| **Energy Flows to Fish (Main Stem Reservoirs)**<br>Upper Campbell & Lower Campbell Reservoirs | Assess fish productivity in relation to littoral and pelagic productivity and residence time. Also evaluate the extent to which more stabilized reservoir levels benefit the fish resource. |
| **Energy Flows to Fish (Diversion Lakes)**<br>Salmon & Quinsam. | Assess fish productivity in relation to littoral and pelagic productivity and residence time. Develop an understanding of the importance of water residence time to fish productivity in the diversion lakes. Study results are intended to confirm the proposed operations or lead to alternative future operations. |

**Table 5-4: Lower Campbell River Fisheries Monitoring**

| Component | Objectives |
|---|---|
| **Physical State Monitoring** | Assess primary and secondary productivity with respect to habitat quality in the Lower Campbell River System. It will provide base diagnostic information to help determine the effectiveness of selected operating regimes. |
| **Habitat Flow Relationships** | Monitor the correlation between instream flow and fish habitat. This study will use transect analysis in diversion streams, including an assessment of diversion stream passage barriers, and 2D model in Campbell River. The data would confirm expected benefits of the proposed operating regime or lead to alternative future operations. |
| **Fish Response to Rearing Habitat** | Monitor the correlation between flow, rearing habitat and behavioural response in fish. The data are expected to confirm the benefits of proposed operating flow changes or lead to alternative future operations. |
| **Physical Modelling of Ramping and Tripping** | Correlate the quantity and quality of spawning and rearing habitat with John Hart ramp rates and tripping events. The data are expected to confirm the benefits of John Hart Generating Station ramp rates or lead to alternative future operations. |
| **Fish Response to Load Factoring** | Measure the effects of proposed load factoring on spawning behaviour and spawning success. The data are expected to validate habitat-based performance measures and confirm the benefits of proposed operation restrictions. This could lead to a more flexible load factoring regime if expected benefits are not realized. |
| **Limits to Fish Production**<br>Elk Falls Canyon | Monitor the spawner and smolt abundance in Elk Falls Canyon. The data are expected to determine whether the proposed flow regime is effective in minimizing impacts to fish or to provide alternative operating regimes. |

**Table 5-5: Fisheries Monitoring Program: Quinsam and Salmon Diversions**

| Component | Objectives |
|---|---|
| **Smolt and Spawner Abundance** | Monitor the spawner and smolt abundance in each of Quinsam and Salmon Rivers. The data are expected to validate the benefits associated with the minimum flow provisions. |
| **Limits to Fish Production** | Assess habitat productivity. In addition to the proposed spawner and smolt abundance monitoring, determine whether the proposed flow regime is effective in improving fish productivity. If the regime proves ineffective, the data would facilitate the development of alternative operating regimes, if deemed necessary. |

# 6.0 IMPLEMENTATION OF RECOMMENDATIONS

The operating conditions, physical works and monitoring programs 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 provincial interests that were considered during the preparation of this Water Use Plan are expected outcomes 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 and implementation requirements, but not for achieving the expected outcomes.

## 7.1 Other Licenced Users of Water

The proposed conditions in this Water Use Plan are expected to improve or not affect other current licenced uses of water associated with the Campbell River System, associated diversions, or the Campbell River below John Hart Generating Station.

## 7.2 Riparian Rights

The proposed conditions in this Water Use Plan are not expected to affect riparian rights. The proposed physical works are expected to reduce erosion on Upper Campbell Reservoir and adjacent to the Salmon Diversion.

## 7.3 Fish Habitat

The proposed operating conditions in this Water Use Plan are expected to improve rearing and spawning habitat as well as other life stage conditions for fish in all components of the Campbell River System.

## 7.4 Wildlife Habitat

The proposed conditions in this Water Use Plan are not expected to impact, positively or negatively, wildlife habitat associated within Upper Campbell Lake Reservoir and Lower Campbell Reservoir. The proposed monitoring programs will provide information to determine the type, if any, and extent of impacts. No effects are expected downstream of the John Hart Generating Station.

## 7.5 Flood Management

The proposed conditions in this Water Use Plan are expected to decrease the frequency and duration of local flooding associated with the reservoirs and the river below the facilities.

## 7.6 Recreation

The proposed conditions in this Water Use Plan are expected to improve the recreation experience on the Upper Campbell and Lower Campbell Reservoirs. A slight negative impact for recreational angling (but not the fish) is expected as a result of the increased flows through Elk Falls Canyon.

## 7.7 Water Quality

The proposed conditions in this Water Use Plan are not expected to affect water quality associated with the reservoirs or the river below the facilities.

## 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 river below the facilities.

## 7.9 First Nations Considerations

BC Hydro’s Campbell River System lies within the traditional territory claimed by We Wai Kai Nation, We Wai Kum First Nation, K'omoks First Nation, Mowachaht/Muchalaht First Nation, Xwemalhhwu (Homalco) First Nation, Members of the Laich-kwil-tach Treaty Society, and Members of the Nanwakolas First Nations Referrals Office. The First Nations have an interest in:

- Opportunities for study and traditional use in the Heber River, Crest Creek, Campbell River, Salmon River and Quinsam River watersheds; and
- Traditional use in the watershed.

The Water Use Plan is expected to:

- Eliminate an inter-basin water transfer issue with the decommissioning of the Heber Diversion in 2012;
- Improve the knowledge of traditional use in the Campbell River System; and
- Improve conditions for fish in the Campbell River System.

## 7.10 Archaeological Considerations

BC Hydro's Campbell River System lies within the traditional territory claimed by We Wai Kai Nation,We Wai Kum First Nation, K'omoks First Nation, Mowachaht/Muchalaht First Nation, Xwemalhhwu (Homalco) First Nation, Members of the Laich-kwil-tach Treaty Society, and Members of the Nanwakolas First Nations Referrals Office. First Nations interests included:

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

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

## 7.11 Power Generation

The proposed operations in the Water Use Plan are expected to result in a loss of power benefits relative to water licence rights. However, when compared to recent operations restricted under the 1997 Interim Flow Management Strategy, additional impacts to energy generation and value of energy are expected to be minimal under the proposed Water use Plan.

# 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:

- Elevations of the Buttle and Upper Campbell Lake Reservoir, Lower Campbell Reservoir, and John Hart Lake Reservoir;
- Spillway discharge from Strathcona Dam, Ladore Dam and John Hart Dam;
- Discharge from Strathcona, Ladore and John Hart Generating Stations;
- The combined flow release into Campbell River from Elk Falls Canyon and John Hart Generating Station;
- Campbell River flow downstream of Quinsam River;
- Diversions at Salmon River, Quinsam River; and Crest Creek; and
- Flow into the natural courses of Salmon River and Quinsam River.

## 8.2 Non-compliance Reporting

Non-compliance with operating conditions required by the water licences or associated orders, 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 mid-term technical review of all operating, physical works and monitoring results is proposed approximately five years after the start of implementation.

A formal review is recommended after 10 years. A review of the 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 Dam Safety Operation, Maintenance, and Surveillance manuals for each project. These documents are filed with the Office of the Comptroller of Water Rights.

Emergency Planning Guides (EPG's) are public documents that define the roles and responsibilities of BC Hydro and emergency response agencies. EPG's describe hazards associated with BC Hydro dams, and the corresponding notifications that would be issued by BC Hydro to downstream responders in the event of an emergency.

# Appendix A

# Operating Zones and Guidance for Implementing Operations

Nov 21, 2012 v4

# 1.0 INTRODUCTION

This Appendix provides planning guidelines to meet the *Preferred Zones* specified in this Water Use Plan and for managing operations outside the specified constraints. It also includes provisions for returning Buttle and Upper Campbell Lake Reservoir (“Upper Reservoir”), Campbell Lake Reservoir (“Lower Campbell Reservoir”) and Lower Campbell River back to the *Preferred Zones* when abnormal hydrological or other unplanned events have caused a deviation.

# 2.0 OPERATING ZONES

Achieving reservoir levels, flow requirements, and ramp rates contained in the Water Use Plan requires dynamic adjustments at multiple control points during the year. An “operating zone” method was developed during the Campbell River Water Use Plan to demonstrate how operation planners could manage constraints that may conflict under different inflow scenarios.

Operating zones were developed for the Upper Campbell Reservoir and Lower Campbell Reservoirs (collectively the “Reservoirs”) and the Lower Campbell River. The purpose of the zones is to identify when the mainstem system conditions may require operational actions to minimize or manage competing impacts to other system interests (e.g. fish, recreation, flood risk reduction, etc…). Guidance is provided to return the Campbell System components back to the *Preferred Zones*.

## 2.1 Reservoir Operating Zones

Reservoir operating zones were developed to increase the likelihood of meeting the reservoir recreation targets while ensuring adequate storage for fish flows and maintaining flood risk reduction under normal and abnormal hydrological scenarios (Figures A1 and A2).

- ***Preferred Zone***: The Reservoirs are expected to be in this range most of the time. The variability of the inflow throughout the year requires the operator to plan and prepare in advance for spring freshet, maintenance outages and other inflow events.
- ***Corrective Zone***: When one reservoir elevation approaches the *Corrective Zone*, reasonable efforts are expected to keep within the *Preferred Zone* by adjusting the other reservoir. If both the reservoirs enter the *Corrective Zone*, John Hart discharges will be initially reduced within the Lower Campbell River *Preferred Zone* and then, if this is insufficient, within the Lower Campbell River *Corrective Zone*.
- ***Special Zone***: Operating within the *Special Zone* could occur during periods of extended low inflows. When both reservoirs enter the *Special Zone*, reasonable efforts are expected to return to the *Corrective Zone* by initially reducing John Hart discharges within the Corrective Zone and then, if this is insufficient, within the Lower Campbell River *Special Zone*.

- ***Flood Control Zone***: When the reservoir elevations enter the *Flood Control Zone*, flood routing principles will be implemented. Reasonable efforts will be made to return to the Reservoir *Corrective Zone* and ultimately the *Preferred Zone* by adjusting the John Hart discharges within the *Reservoir Control Zone* and by ceasing diversions.
- ***WUP Minimum Levels***: Operating below these levels should be strongly avoided. Consultation with federal and provincial fisheries agencies and the Comptroller in advance of such operations is required.

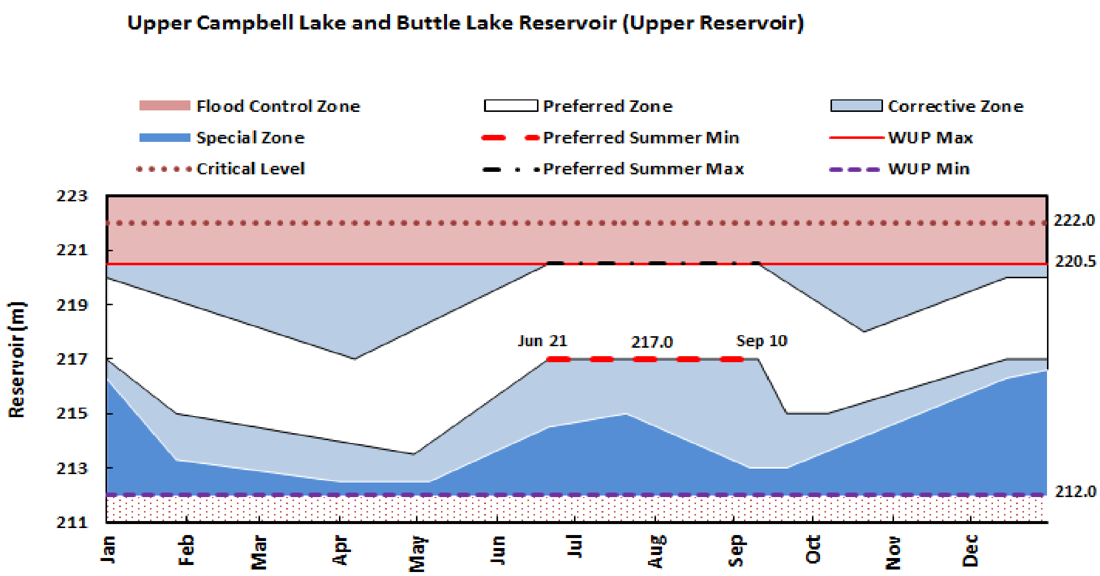


**Figure A- 1 Upper Campbell Reservoir Operating Zones**

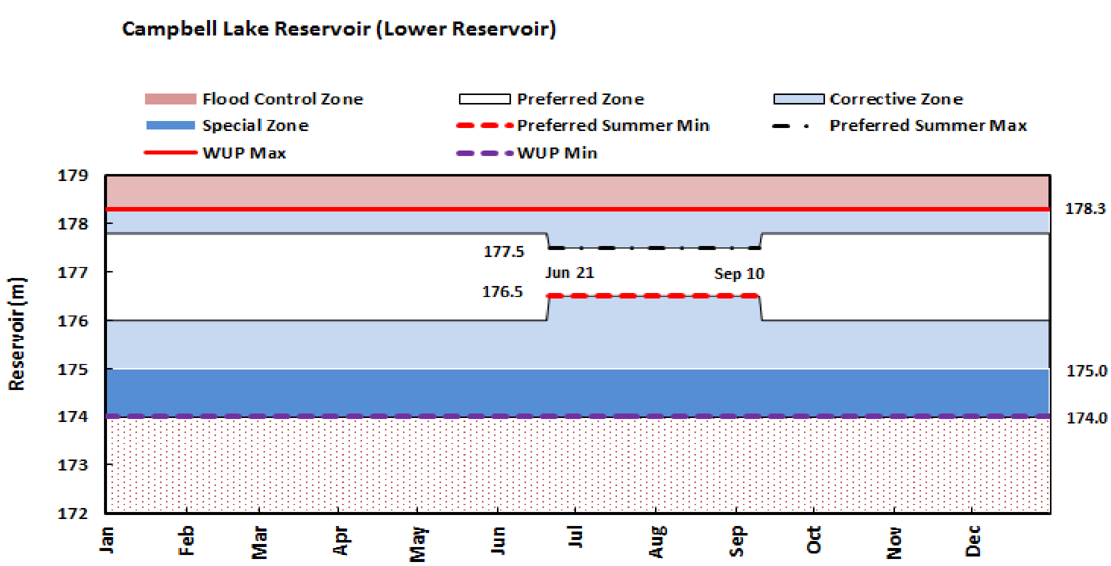


**Figure A- 2 Lower Campbell Reservoir Operating Zones**

## 2.2 Lower Campbell River Operating Zones

Operating zones were developed to increase the likelihood of operating within the flow ranges established for the river below John Hart[1] and to resolve conflicts between reservoir level management and Lower Campbell River flows under unusual hydrological scenarios (Figure A3).

- ***Preferred Zone*:** River flows are expected to be in this range most of the time. The variability during the year recognizes the need to plan in advance for spring freshet.
- ***Corrective Zone***: River flows may enter the *Corrective Zone* in an attempt to return the Reservoirs from their *Corrective Zones* to the *Preferred Zones*. There is no *Corrective Zone* in the river during the summer low flow period.
- ***Special Zone***: During low inflows, Lower Campbell River flows may enter the *Special Zone* in an attempt to return the Reservoirs from their *Special Zones* to their *Corrective Zones*. There is no *Special Zone* during the summer low flow period.
- ***Flood Control Zone*:** John Hart may regulate the Lower Campbell River flows into the *Flood Control Zone* when flood routing (see Appendix Sections 3.4) is implemented. After the high inflows have passed, BC Hydro will make reasonable efforts to return all system states back to the *Preferred Zones*.
- ***Minimum Flow*:** The minimum river flow is 28 $m^3/s$. Operation below that can only be considered when both reservoirs are also below their *Minimum Levels*. Consultation with fisheries agencies and the Comptroller in advance of such operations is required.
- **Elk Falls Canyon:** Minimum, spawning, and pulse flows (approximate timing) are plotted in Figure A3 for completeness. The pulses may deviate from plan during unusual hydrologic events or to accommodate planned or unplanned outages.

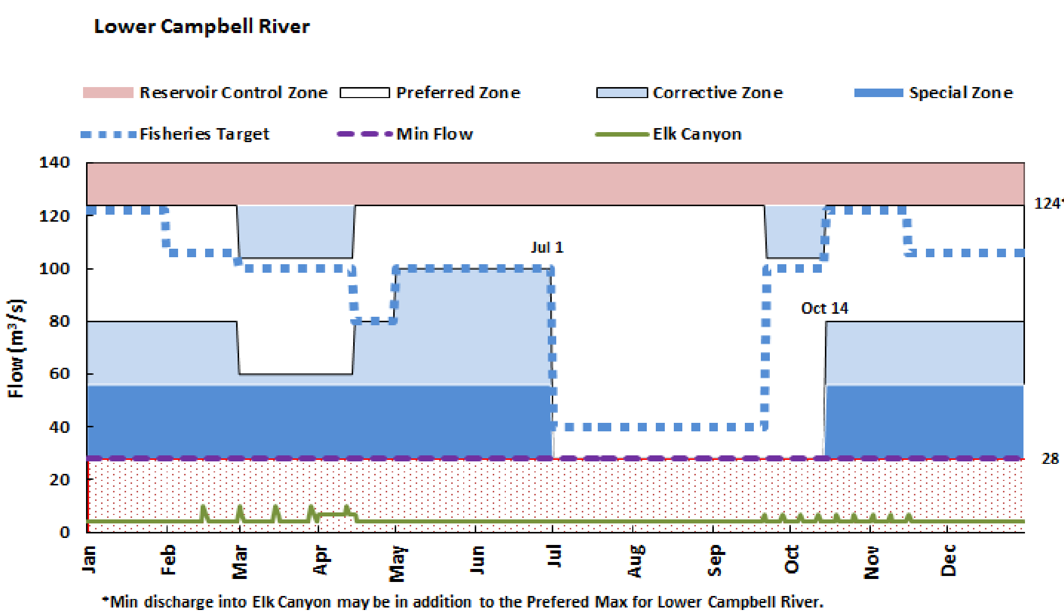


**Figure A- 3 Lower Campbell River Operating Zones**

[1] Lower Campbell River flows can be provided from the John Hart Generating Station (JHT GS), by spilling water at the John Hart dam through Elk Falls Canyon, or any combination thereof.

# 3.0 OPERATING GUIDELINES

## 3.1 Operating Priorities

Conflicts may arise between managing constraints between the Reservoirs and the Lower Campbell River flows. This may occur during periods of normal or abnormal hydrological conditions or resulting from other events such as maintenance or unplanned outages. When conflicts arise, the following will guide operating decisions from highest to lowest priority within and outside the *Preferred Zones*:

- Dam safety requirements defined in the Operation, Maintenance and Surveillance Manuals for Strathcona, Ladore and John Hart Dams, Salmon River and Quinsam River Diversion Dams and Quinsam Storage Dam;
- When flows are naturally available, maintain minimum fisheries flow requirements for Salmon and Quinsam Rivers and for Elk Falls Canyon;
- Manage high inflow and reservoir routing criteria defined in section 3.4 below;
- Operate Strathcona, Ladore and John Hart Generating Stations to manage the flow in Lower Campbell River to the Preferred Zone;
- Maintain all specified ramping rates;
- Operate Strathcona, Ladore and John Hart Generating Stations to manage the level of the Upper Reservoir to the Preferred Zone; and
- Operate Strathcona, Ladore and John Hart Generating Stations to manage the level of the Lower Reservoir to the Preferred Zone.

The use of short term and long term weather and inflow forecasts, historic operating records, planned outage schedules, and other best available operational information are necessary to plan operations within and outside the *Preferred Zones* at the system level.

## 3.2 Normal Operations

### 3.2.1 Lower Campbell River: *Preferred Zone*

The Reservoirs and the Lower Campbell River should be operated with the objective of staying in the *Preferred Zones*. Deviations outside the *Preferred Zone*, however, are still expected. When outside the *Preferred Zones,* the system should be managed with the aim to return to the *Preferred Zones.*

- Holding all other factors equal, operations should pursue the soft objective of stable Fisheries Target flows, within the *Preferred Zone,* in the Lower Campbell River.
- Maintaining a stable flow, within the *Preferred Zone,* downstream of John Hart is preferable to intermittently deviating and returning to a specified Fisheries Target flow.
- The Lower Reservoir *Preferred Zone* and then the Upper Reservoir *Preferred Zone* will be used to absorb system inflow variability before changing stable John Hart releases.

- From 1 January to 15 February load factoring is permitted at John Hart Generating Station. The plant is exempt from ramp rate restrictions when the John Hart Generating Station is discharging above 76 $m^3/s$ during this period.
- Diversions shall be used, as required, to meet the goal of operating above the Lower Campbell River *Preferred Zone* subject to first meeting the minimum flow constraints in the natural rivers associated with the diversions.

### 3.2.2 Reservoir Management: *Corrective Zones*

Natural events such as high or low system inflows on a weekly or monthly basis will necessitate operations outside of the *Preferred Zone*. Other factors such as equipment failure or maintenance activity could also require operating outside of the *Preferred Zone*. The following provide guidance for operating outside of the *Preferred Zone* during these conditions.

- Typically, storage between the Reservoirs shall be balanced to maintain the Reservoirs within their *Preferred Zones* prior to adjusting the Lower Campbell River flows.
- In the event that the elevations of the Reservoirs are forecast to enter the *Corrective Zone* (high or low) within the next five days and remain there for seven days or more, John Hart releases will be changed within the *Preferred Zone* to avoid this.[1]
- In the event that the elevations of the Reservoirs have entered the *Corrective Zone*, John Hart releases will be operated in such a manner to restore the reservoirs to the *Preferred Zone* by permitting operation within the Lower Campbell River *Corrective Zone* to restore the Reservoirs to the *Preferred Zones*.[2]
- John Hart releases will be gradually adjusted back towards the *Preferred Zone* when the Reservoir elevations also begin to trend towards their *Preferred Zone*, but only when the forecast for the next five days confirms the system conditions are improving. The overall intent is to keep all three components of the main stem system in the same operating zone whenever possible.
- Preventative measures will be taken to avoid bringing any system component into the *Special Zone*. Consultation with federal and provincial fisheries agencies and the Comptroller in advance of such planned operations is required.

---

1 Consider on Mar 15, JHT GS discharge is 100 $m^3/s$ and the Reservoirs are forecast to enter their lower *Corrective Zone* in the next 5 days. JHT GS flows should be dropped from 100 $m^3/s$ to a lesser flow within the Lower Campbell River *Preferred Zone* (104 to 60 $m^3/s$). If forecasts suggest that a reduction to 75 $m^3/s$ will raise the reservoirs from the *Corrective Zone* to the *Preferred Zone* within 7 days, any JHT GS discharge between 60 to 75 $m^3/s$ would be viable.

2 Consider on Mar 15, JHT GS discharge is 100 $m^3/s$ and the Reservoirs have entered their upper *Corrective Zones*. JHT GS flows should be increased from 100 $m^3/s$ to a flow within the Campbell River *Corrective Zone* (104 to124 $m^3/s$). If forecasts suggest that an increase to 115 $m^3/s$ will lower the reservoirs back to the *Preferred Zone* within 7 days, any JHT GS discharge between 115 to 124 $m^3/s$ would be acceptable. If forecasts suggest that an increase to the upper bound of 124 $m^3/s$ will still result in reservoir rise, JHT GS flows would be increased to 124 $m^3/s$, but no additional discharge from the JHT spillway (in excess of the 4 $m^3/s$ minimum Elk Canyon flow) would be required until the Reservoirs enter the *Flood Control Zone*.

## 3.3 Low Inflow Operations

### 3.3.1 Reservoir and Lower Campbell River: *Special* and *Minimum Zone*s

Extended periods of low inflow could cause the need to operate below the *Corrective Zone* for both the Reservoirs. The following guidance is provided:

- The Comptroller will be notified in advance of planned operations entering the *Special Zone* or below the *Minimum Level.*
- Regardless of reservoir levels, a minimum flow of 4 $m^3/s$ shall be maintained from the John Hart Spillway into Elk Falls Canyon at all times.
- In the event that the elevation of both reservoirs are in the *Special Zone*, John Hart will operate in such manner as to restore the reservoirs back to their *Corrective Zones* by allowing the flow regime at John Hart to enter the Lower Campbell River *Special Zone*.[1]
- In the event that both reservoirs are operating below their *Minimum Level*, John Hart will operate in such manner to restore the reservoirs to their *Corrective Zone* by allowing the flow regime at John Hart to discharge less than 28 $m^3/s$ into the Lower Campbell River. Consultation with provincial and federal fisheries agencies and the Comptroller of Water Rights is required to determine what this lesser flow should be.

## 3.4 High Inflow Operations

### 3.4.1 Reservoirs and Lower Campbell River Management: *Flood Control Zones*

Flood management for the Campbell system is generally addressed by maintaining a flood buffer below the *Critical Level* on the Upper Reservoir. The *Critical Level* is a level below the top of Strathcona Dam lock blocks 226.32 m. The *Critical Level* is currently set at 222.0 m.

The following are guiding principles to manage the Upper Reservoir in a manner that will reduce the probability of significant downstream flow events:

- Within the *Preferred Zone*, draft the Upper Reservoir before the spring freshet and before the fall storm season to create room to absorb high inflows without encroaching into the *Flood Control Zone*.
- In the event that the Upper Reservoir is forecast to enter the *Flood Control Zone* (220.5 m) within the next five days, Quinsam and Salmon diversions into storage should be shut off.

[1] Consider on Mar 15, JHT GS discharge is 60 $m^3/s$ and the Reservoirs have entered their *Special Zones*. The combined discharge from the JHT GS and the JHT spillway will be reduced to a lesser flow within the *Special Zone* (58 to 28 $m^3/s$). If forecasts suggest that a reduction to 45 $m^3/s$ will raise the reservoirs to the *Special Zone* within 5 days, JHT discharge between 45 to 28 $m^3/s$ would be viable.

- In the event that the Upper Reservoir enters the *Flood Control Zone* (> 220.5 m) John Hart will operate in such manner to return the Upper Reservoir below the *Flood Control Zone* in seven days or less by allowing the Lower Campbell River flow regime to operate into the *Reservoir Control Zone* up to a maximum[1] of 453 $m^3/s$, as measured downstream of the Quinsam River.
- If inflows continue to increase, Campbell River flows as measured downstream of the confluence of Quinsam River (generation, spill, and Quinsam flows) will be kept at 453 $m^3/s$ and Upper Campbell Reservoir will be allowed to rise into the *Flood Control Zone*.
- When managing downstream John Hart releases, several benchmarks should be considered in planning. Onset of erosion of the banks is expected between 300 and 453 $m^3/s$ downstream of the Quinsam River and flows are expected to exceed bankfull at 453 $m^3/s$. Flows in excess of 530 $m^3/s$ are expected to cause significant inundation of properties.
- In the event that the Upper Reservoir reaches or exceeds the *Critical Level* of 222.0 m, the spill through the system will be increased to pass inflows until maximum spillway capacity is reached.
- Comptroller of Water Rights will be notified in advance of any operations into the *Flood Control Zone* or above the *Critical Level*.

## 4.0 OPERATING DURING EMERGENCY CONDITIONS

Emergency situations include those required to address dam safety, actual or potential loss of power supply to customers, dam breach or potential dam breach, extreme flood flows, fire or explosion, environmental incidents, major equipment failure or threat to employee or public safety. These situations are usually of short duration and occur unexpectedly. Actions to resolve emergency situations take priority over the regular operating regime as described in this document.

The protocols to address emergency situations are documented in the following:

- Operation, Maintenance and Surveillance Manuals for Dam Safety;
- Generation Operating Orders;
- Local Operating Orders; and
- Emergency Planning Guides.

These documents provide the process to be followed to resolve the various emergency situations. During such events, the Campbell River system operations may deviate significantly from the normal operating regime, as required by the needs of the specific case, until the emergency is over.

[1] Consider on Mar 15, JHT GS discharge is 124 $m^3/s$, JHT spill is 4 $m^3/s$ and the Upper Reservoir has exceeded 220.5 m. JHT GS flows should be maintained at 124 $m^3/s$ and JHT spill increased from 4 to an amount no greater than 329 $m^3/s$ (total 453 $m^3/s$) less the contribution from the Quinsam River. If forecasts suggest that an increase in spill of 100 $m^3/s$ or more will lower the reservoir below 220.5 m within 5 days, river flows between 100 and 329 $m^3/s$ would be viable.

**APPENDIX B**

**HYDROLOGIC OVERVIEW**

# BC Hydro Campbell River System Strathcona, Ladore and John Hart Basins

January 16th, 2013

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**hydrology & technical services**

# Executive Summary

This report summarizes the hydrology of the basins comprising BC Hydro's Campbell River hydroelectric system and updates the Campbell River Water Use Plan report of the Hydrology of the Campbell River Basin (Groves 2003). For background, an overview of the hydroelectric system, physiography, stream and lake network, geology, climatology and vegetation of the region are provided. The hydroclimatic station network and inflow forecasting procedures are briefly described.

The BC Hydro Campbell River system consists of three projects: Strathcona, Ladore and John Hart. The Salmon and Quinsam Rivers are also partially diverted into Upper Campbell Lake Reservoir in the Ladore basin. The projects are located in central Vancouver Island and drain into the Strait of Georgia near the city of Campbell River.

Tables 1 and 2 and the following are a summary of the key characteristics of the basins and its water resources:

- The Strathcona basin is the largest of BC Hydro's basins in the Campbell River system and contains the majority of the system storage in its Upper Campbell and Buttle Lake Reservoirs.
- Mean annual inflows into the Strathcona basin are much higher than those into the Ladore basin due to its larger drainage area and higher annual precipitation. Annual flows into John Hart are minimal.
- Inflows to the system exhibit a dual annual peak of rainfall in the winter months and a snowmelt freshet in the spring, characteristic of a pluvio-nival hybrid regime. Peak flows occur from October-March during intense rainfall-runoff events, often augmented by snowmelt.
- The Campbell River system is in the Coastal climate region, which is mainly influenced by moisture-laden frontal storms off the Pacific in the winter resulting in high annual precipitation totals. In the summer, the Pacific High is dominant, bringing warm and relatively dry weather to the region.
- The area is dominated by dense mountain forests of hemlock, fir and cedar, typical of the BC west coast.
- Global Climate Model predictions indicate that the 2050s will be warmer across all seasons and possibly wetter overall. Specifically, winters will likely be wetter, while summers will be drier. Studies to date suggest that the effect on flow timing will likely be larger than the effect on the magnitude of total annual inflow. It is expected that winter flows will increase, the snowmelt freshet will start and end earlier, the duration of the summer low flow period will be longer and the magnitude of late summer flows will be lower.

**Table 1** Campbell River system basin summary

| Basin | Strathcona[1] | Ladore | John Hart |
|---|---|---|---|
| Drainage area ($km^2$) | 1194 | 245 | 25 |
| Glaciated area (% of drainage area) | <1 | 0 | 0 |
| Mean annual precipitation (mm) | 2596 | 1438 | 1602 |
| Mean annual inflow (mm) | 2048 | 1316 | N/A |
| Mean annual inflow ($m^3/s$) | 77 | 10 | <1 |
| Reservoir storage ($Mm^3$) | 880 | 310 | 20 |

**Table 2** Campbell River system diversion summary

| Diversion | Salmon | Quinsam | Heber[2] |
|---|---|---|---|
| Drainage area ($km^2$) | 253 | 84 | 55 |
| Mean annual inflow (mm) | 1696 | 1165 | 2754 |
| Mean annual inflow ($m^3/s$) | 14 | 3 | 5 |
| Average inflow diverted (%) | 50 | 42 | 48 |

[1] Includes the 18 $km^2$ Crest Creek Diversion with a mean annual inflow of ~1.1 $m^3/s$, as it is permanently fully diverted and effectively functions as part of the Strathcona natural inflow.

[2] Heber Diversion was closed in 2007 and permanently decommissioned in 2012.

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# 1 Location

BC Hydro's Campbell River hydroelectric system is located in central Vancouver Island southwest of the city of Campbell River. Figure 1 shows the general location of the Campbell River basins in BC.


**Figure 1** Location of the Campbell River system in British Columbia.

# 2 Physiography and Stream/Lake Network

The Campbell River system is located on the east side of the Vancouver Island Ranges, a sub-range of the Insular Mountains which extends along the length of Vancouver Island, and drains to the north and east into the Strait of Georgia. The Campbell River is impounded by Strathcona Dam, Ladore Dam and John Hart Dam in succession before draining into the Strait of Georgia near the city of Campbell River. The three basins have respective local drainage areas of 1194 $km^2$, 245 $km^2$ and 25 $km^2$. The Salmon and Quinsam diversions, which both flow into the Ladore basin, have drainage areas of 253 $km^2$ and 84 km2, respectively. Figure 2 shows the location of the basins, hydroelectric facilities and hydroclimatic stations within the Campbell River system.

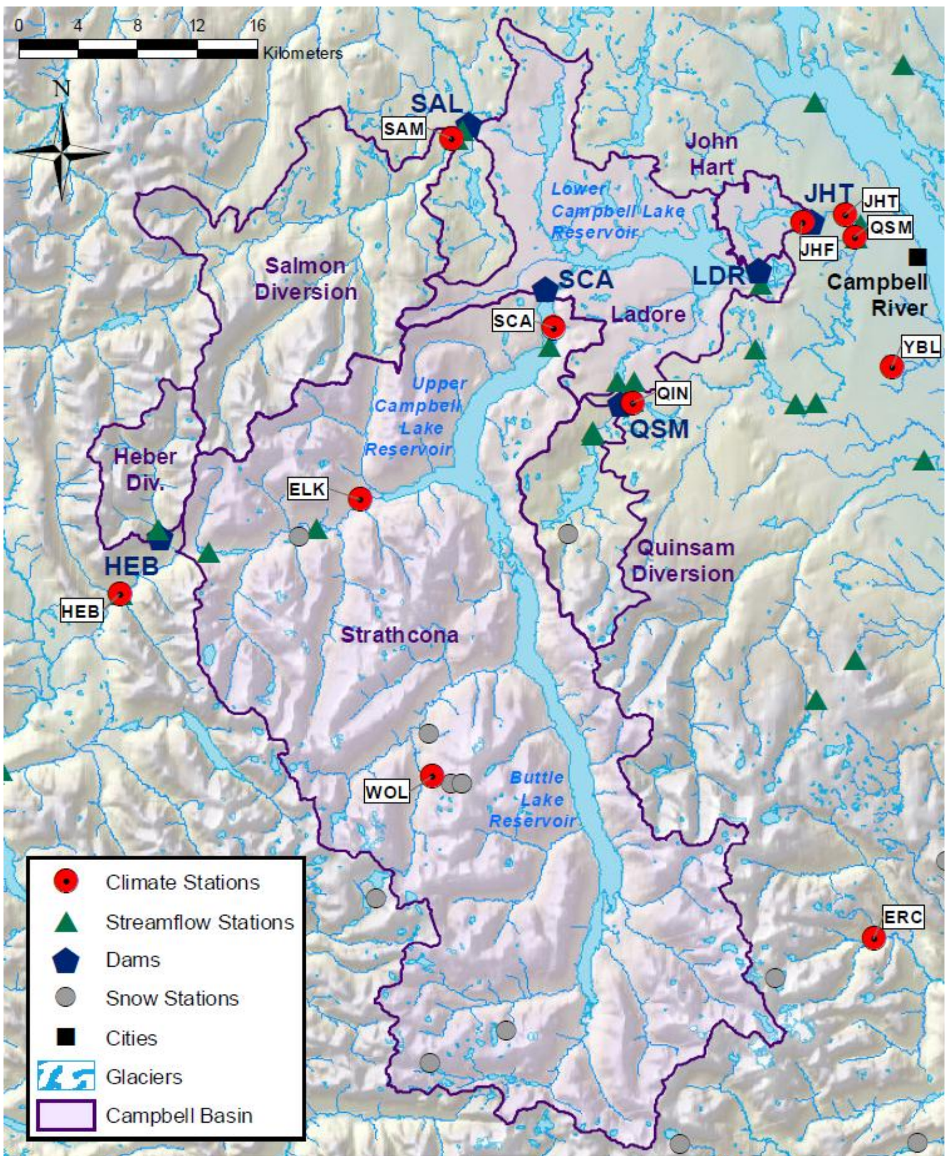


**Figure 2** BC Hydro watersheds, diversion watersheds, facilities and hydroclimatic stations in the Campbell River system.

## 2.1 Strathcona Basin

The watershed above Strathcona Dam is primarily made up of the rugged slopes of the Elk River Mountains descending into the valley containing Upper Campbell and Buttle Lake Reservoirs. The elevation of the Strathcona basin ranges from 134 m to the summit of the Golden Hinde at 2201 m. The median elevation of the basin is 974 m. There is about 4 $km^2$ of glaciers and permanent snowpack, making up only 0.3% of the basin area. The hypsometric curve[3] for the basin is shown in Figure 3.

The local drainage area of 1194 $km^2$ includes the Crest Creek Diversion, which is fully diverted and effectively functions as a natural tributary of the Elk River. The 55 $km^2$ Heber River Diversion once flowed through the Crest Creek Diversion and into the Strathcona basin as well, but that diversion was closed in 2007 and completely decommissioned in 2012.

The reservoir formed by joining Upper Campbell and Buttle Lakes is about 50 km long and up to 5 km wide. The creeks feeding the reservoir tend to be short and steep due to the mountainous terrain. The Elk River, which is 24 km long and falls roughly 760 m, is the longest watercourse in the basin.

## 2.2 Ladore and John Hart Basins

Below Strathcona Dam, the terrain is much less rugged and mainly comprised of lakes and heavily forested rolling hills. Flow into Lower Campbell Lake Reservoir and John Hart Reservoir from the Strathcona basin is augmented by local inflow from small streams draining those hills and by the Salmon and Quinsam Rivers, which are both partially diverted into the Ladore basin. The 270 $km^2$ combined area of the Ladore and John Hart basins ranges in elevation from near sea level to 1370 m, with a median elevation of 262 m.

[3] A ***hypsometric curve*** is a graph that shows the fraction of a watershed's land area that lies at or above a given elevation.

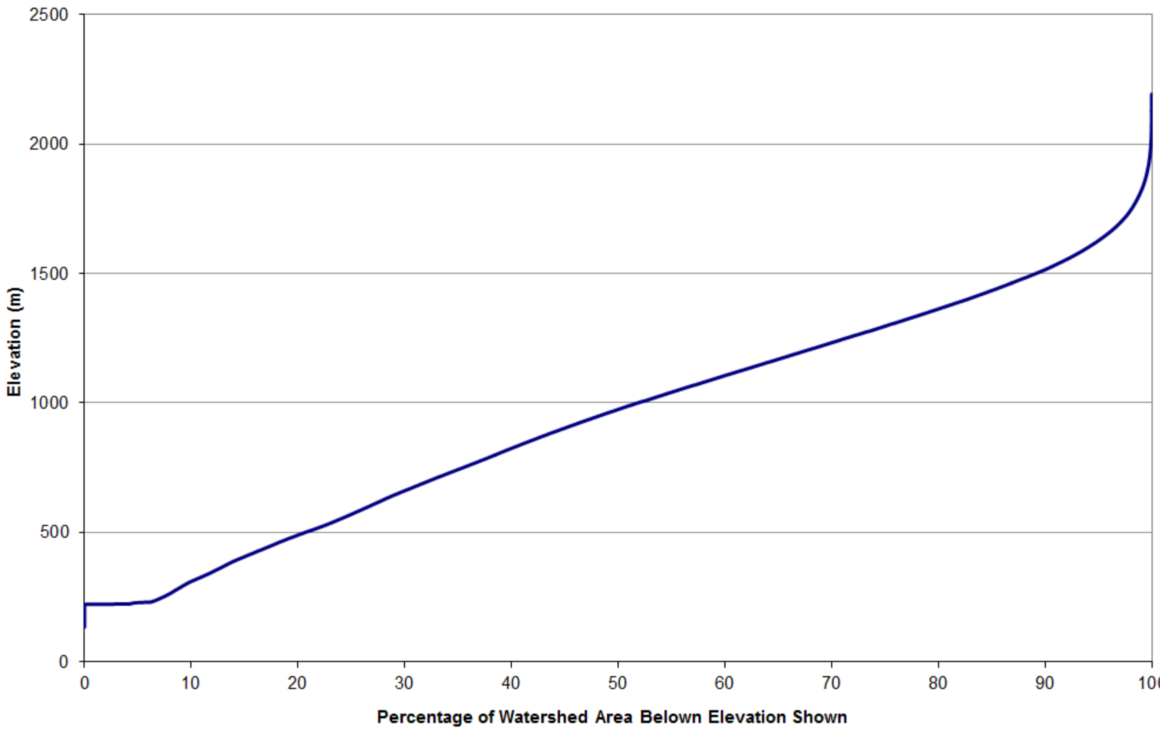


**Figure 3** Hypsometric curve for the Strathcona basin.

# 3 BC Hydro Project Infrastructure

## 3.1 BC Hydro Project Characteristics

The Campbell River system encompasses three hydroelectric projects. A schematic of the system is shown in Figure 4. Key features of the projects are listed below.

### *3.1.1 Strathcona Project*

- Strathcona Dam impounds Upper Campbell and Buttle Lake Reservoirs, which together form the main storage reservoir for the Campbell River system.
- The Strathcona Generating Station contains two units (64 MW total).
- Power releases and non-power releases from Strathcona Dam are discharged into Lower Campbell Lake Reservoir.
- Inter-basin diversions from Heber Diversion Dam once flowed into Upper Campbell Lake Reservoir, but the diversion was closed in 2007 and permanently decommissioned in 2012.

### *3.1.2 Ladore Project*

- Ladore Dam impounds Lower Campbell Lake Reservoir.
- The Ladore Generating Station contains two units (52 MW total).
- Releases from Ladore Dam are discharged into John Hart Lake Reservoir.
- Inter-basin diversions from the Salmon and Quinsam River Diversion Dams flow into Lower Campbell Lake Reservoir.

### *3.1.3 John Hart Project*

- John Hart Dam impounds John Hart Lake Reservoir, which provides daily pondage for the generating station.
- The John Hart Generating Station contains six units (126 MW Total).
- Spill and other non-power releases from John Hart Dam are discharged into the Lower Campbell River at John Hart Dam with power releases also joining the river downstream of Elk Falls.

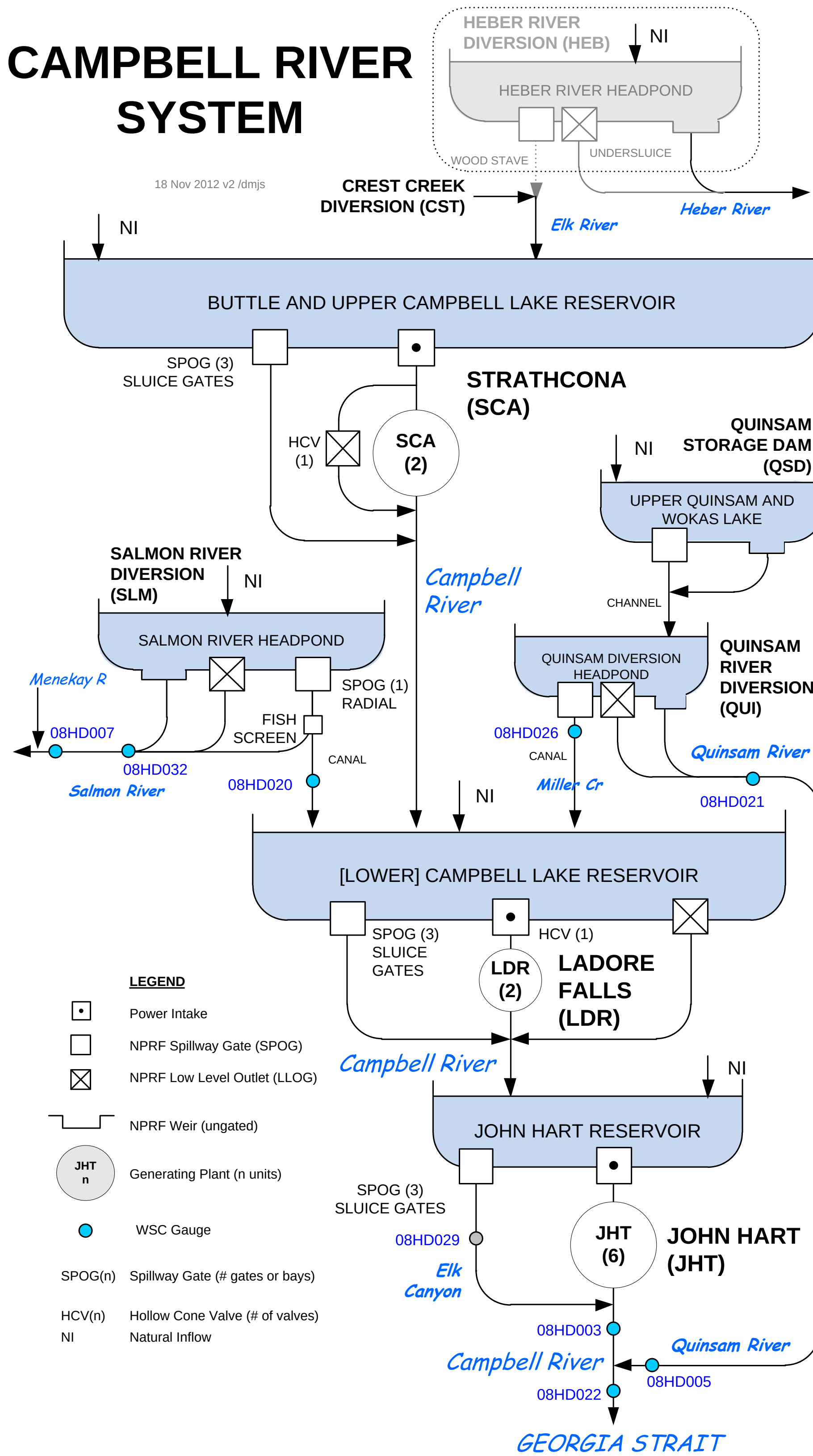


**Figure 4** Schematic of the BC Hydro Campbell River hydroelectric system.

## 3.2 Hydroclimatic Data Collection

### *3.2.1 Hydroclimatic Data*

A network of weather, snow and streamflow stations was established to collect hydroclimatic data in support of planning, monitoring, and operating the BC Hydro Campbell River system facilities. The variables collected include precipitation, air temperature, snow water equivalent, snow depth and streamflow. Weather and snow stations in the region of interest are funded by BC Hydro. Weather stations are automated for both data collection and transmission. Snow data are collected using two types of stations: manual snow surveys[4] and automated snow pillows[5]. Automated hydrometric stations in the Campbell River watersheds are operated by the Water Survey of Canada and funded by BC Hydro. Key hydroclimatic stations in the Campbell River region are summarized in Table 3. Locations of hydroclimatic stations are shown in Figure 2.

Climate data are quality controlled in several stages using outlier, plausibility and consistency checks and various automated and manual estimation techniques. A similar procedure is employed for monthly snow water equivalent data. Streamflow data are not quality controlled in real-time. Instead they are quality controlled several months after they have been collected by the Water Survey of Canada.

[4] ***Manual snow surveys*** are conducted at predetermined times of the year (up to a maximum of eight times per year) using the Federal Snow Sampler (a specific type of snow corer).

[5] ***Automated snow pillows*** measure the displacement of antifreeze solution from a bladder in response to the weight of the snow exerted on it. Snow pillows transmit snow water equivalent data in real-time.

**Table 3** Key hydroclimatic stations in the Campbell River region.

| Station Name | ID | Elev (m) | Lat. (º) | Long. (º) | Station Type |
|---|---|---|---|---|---|
| Crest Lake near Highway 28 DCP | CST | 329 | 49.84 | 125.90 | Hydrometric |
| Elk R ab Campbell Lk DCP[6] | ELK | 270 | 50.85 | 125.80 | Climate/Hydrometric |
| Eric Creek DCP | ERC | 280 | 49.60 | 125.30 | Climate |
| Gold R below Ucona R DCP | GLD | 10 | 49.70 | 126.10 | Climate/Hydrometric |
| Heber Div near Gold R DCP | HBD | 361 | 49.85 | 125.95 | Hydrometric |
| Heber River near Gold River DCP | HEB | 215 | 49.82 | 125.98 | Climate/Hydrometric |
| John Hart Substation DCP | JHT | 15 | 50.05 | 125.31 | Climate |
| Quinsam R at Argonaut Br DCP | QIN | 280 | 49.93 | 125.51 | Climate/Hydrometric |
| Quinsam Div nr Campbell R DCP | QSD | 297 | 49.95 | 125.51 | Hydrometric |
| Quinsam R bl Quinsam Lk DCP | QSL | 149 | 49.93 | 125.33 | Hydrometric |
| Quinsam R nr Campbell R DCP | QSM | 15 | 50.03 | 125.30 | Climate/Hydrometric |
| Salmon R ab Campbell Div DCP | SAM | 215 | 50.09 | 125.67 | Climate/Hydrometric |
| Strathcona Dam DCP | SCA | 249 | 49.98 | 125.58 | Climate |
| Salmon R Div nr Campbell R DCP | SMN | 210 | 50.10 | 125.67 | Hydrometric |
| Wolf River Upper DCP | WOL | 1490 | 49.68 | 125.74 | Climate/Snow Pillow |
| Campbell River A | YBL | 106 | 49.95 | 125.27 | Climate |
| Forbidden Plateau | 3B01 | 1130 | 49.65 | 125.22 | Snow Course |
| Upper Thelwood Lake | 3B10 | 980 | 49.53 | 125.70 | Snow Course |
| Wolf River Middle | 3B18 | 1070 | 49.70 | 125.68 | Snow Course |
| Wolf River Lower | 3B19 | 640 | 49.73 | 125.70 | Snow Course |

[6] ***Data Collection Platform*** (DCP): Automated weather stations operated by BC Hydro.

### 3.2.2 Reservoir Inflow Data

Reservoir inflows are not directly measured by BC Hydro, but are instead calculated from measured changes in reservoir storage and discharge, specifically power and non-power releases, using the principle of conservation of mass as applied to flow volumes:

- The change in reservoir storage from the beginning to the end of the computational time step (typically, hour) is derived from measured reservoir elevation(s) and reservoir-specific stage-storage relationships. The reservoirs' stage-storage relationships and licensed operating ranges are shown in Figures 5-6. Between their minimum and maximum licensed elevations Strathcona (Upper Campbell and Buttle Lake Reservoirs), Ladore (Lower Campbell Lake Reservoir) and John Hart (John Hart Lake Reservoir) have licensed storage capacities[7] of approximately 10187 cms-days[8], 3583 cms-days and 236 cms-days (880 $Mm^3$, 310 $Mm^3$ and 20 $Mm^3$) , respectively.

- Power releases (i.e., reservoir discharge through turbines or, also called, turbine discharge) at the Strathcona, Ladore and John Hart power houses, are computed based on measurements of generation (i.e., megawatt output) and hydraulic head[9].

- Non-power releases (e.g., reservoir discharge through spill gates, weirs or valves) are computed from reservoir (or, forebay) elevation and rating curves for each structure. These rating curves are numeric representations of the relationship between discharge, gate opening, and reservoir elevation for a given release device. For illustration, rating curves for fully opened spill facilities at Strathcona, Ladore and John Hart Dams are shown in Figures 7-9.

BC Hydro computes inflow using a computer program called FLOCAL. Typically, the FLOCAL program calculates inflows as unregulated flows from the local drainage area only. However, for operational purposes, in some cases, controlled discharge from upstream reservoirs or diversions is included in the data. This is the case for FLOCAL's Ladore inflow data, which includes flows from the Salmon and Quinsam Diversions, and Strathcona inflow data which included flows from the Heber Diversion before it was closed in 2007. For the purpose of the Water Use Plan, flows from the Salmon, Quinsam and Heber Diversions were estimated and subtracted from the total inflow records to produce natural, local inflow

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[7] Storage capacities for all three basins are from water licenses issued on November 21st, 2012 under the BC Water Act.

[8] ***cms-days***: volume of water in units of flow rate ($m^3/s$) over a specified period (day).

[9] ***Hydraulic head*** is a measure of the vertical distance between the reservoir (or, forebay) elevation and the water level immediately below the turbine outlet adjusted for friction losses.

records[10]. Strathcona inflow data also includes flows from the Crest Diversion, but since it is permanently fully diverted, it effectively functions and is treated as an addition to the natural, local drainage area and inflow.

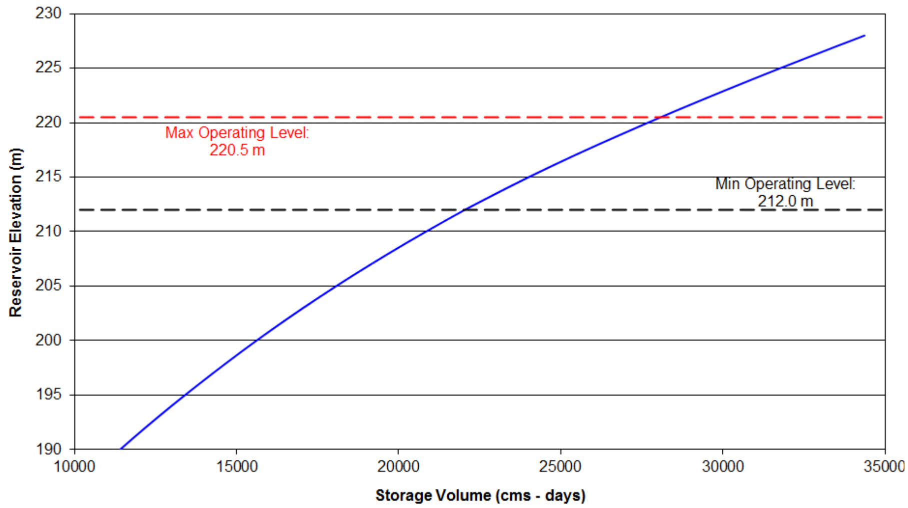


**Figure 5** Stage-storage relationship for Upper Campbell and Buttle Lake Reservoirs.

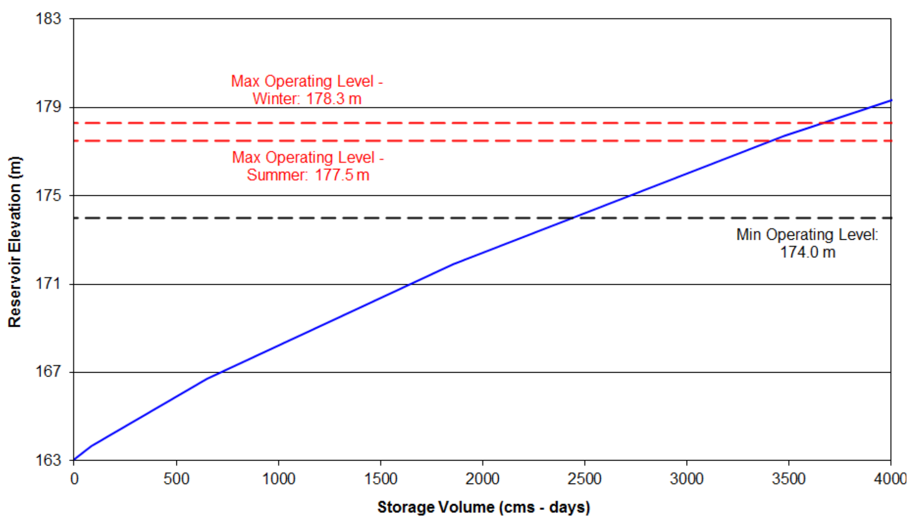


**Figure 6** Stage-storage relationship for Lower Campbell Lake Reservoir.

[10] Refer to interoffice memos to Eric Weiss, all included in file PSE 151.0 (Quinsam Diversion: dated 29 May 2001, Salmon Diversion: dated 30 May 2001, Heber/Crest Diversion: dated 6 June 2001, Upper Campbell Natural Inflows: dated 27 August 2001, Lower Campbell and John Hart Natural Inflows: dated 22 July 2002).

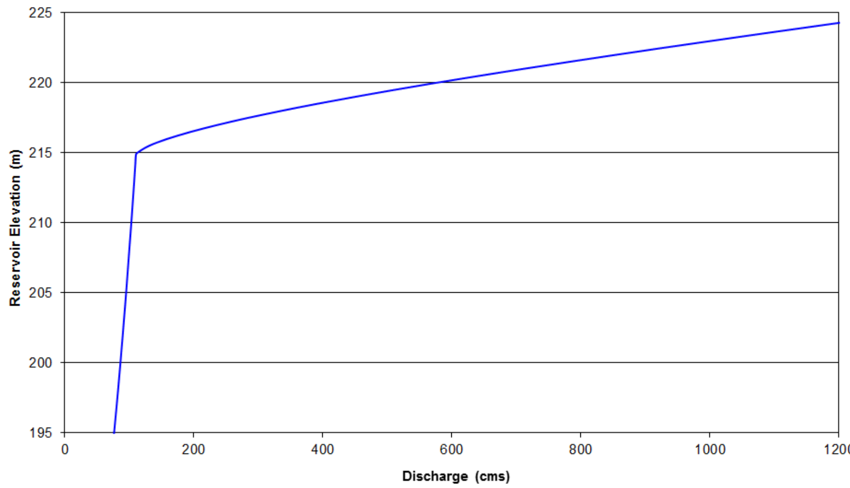


**Figure 7** Stage-discharge relationship for Strathcona Dam with all discharge facilities open.

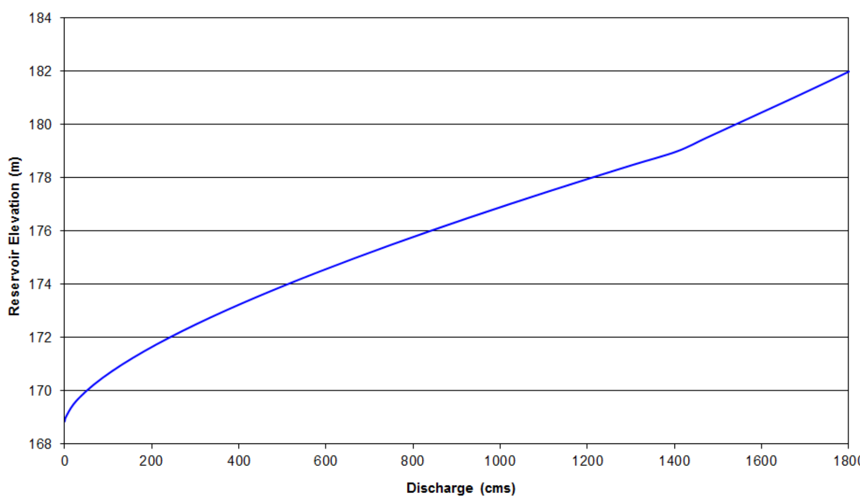


**Figure 8** Stage-discharge relationship for Ladore Dam with all discharge facilities open.

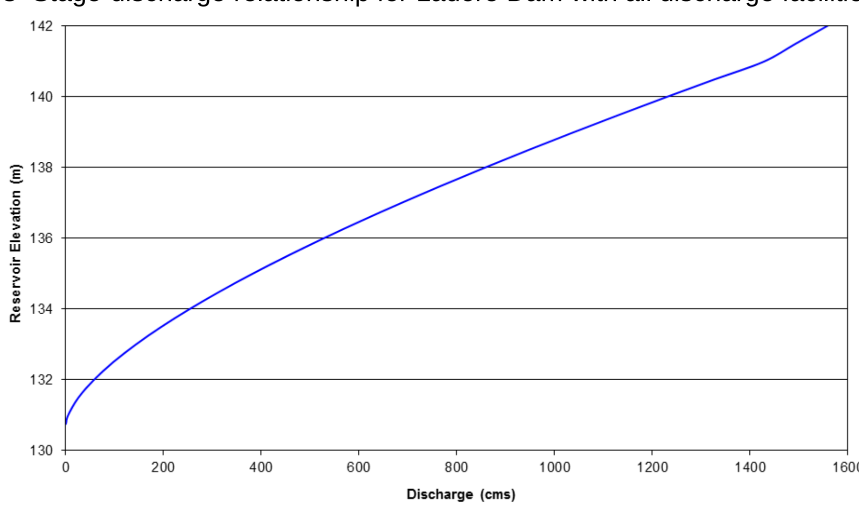


**Figure 9** Stage-discharge relationship for John Hart Dam with all discharge facilities open.

Unregulated, local inflows are very close to, but not identical to natural, local flows (i.e., streamflows that would have occurred if the reservoirs had not been built). The differences are caused by losses from the system through reservoir evaporation and seepage through dams and into the groundwater that exceed natural evapotranspiration and natural influent river conditions. These differences are not taken into account in BC Hydro calculations. For that reason, calculated inflow is also referred to as ‘inflow available for outflow’.

Inflow data of hourly and daily resolution can exhibit a large degree of random error or noise. Random errors become more obvious at times of low inflow, which is when the signal-to-noise ratio is low. Random errors are predominantly caused by the difficulty of determining the precise and representative reservoir volume:

- Measurements of reservoir elevations are affected by temporary wind set up on reservoirs (so-called ‘seiches’) and by the limited resolution of the instruments measuring reservoir elevations. The latter effect is particularly pronounced in large reservoirs, where a small change in stage is associated with a large change in volume. As a result, small errors in stage measurements can cause significant errors in the storage volume and, thus, reservoir inflows. Furthermore, temperatures below freezing can negatively affect the operation of gauges.

- An inaccurate stage-storage curve can contribute to errors. In some cases, the curve is the composite of a number of curve segments. These curve segments may not fit together smoothly and therefore may not yield good continuous estimates of reservoir storage.

Other error sources are faulty measurements of releases due to inaccurate measurements and (or) rating curves. Additionally, human errors in entering and transcribing data can occur.

BC Hydro regularly performs quality control of historical daily inflows for the Strathcona basin. This process involves the comparison of inflow data with data from nearby Water Survey of Canada streamflow gauges in hydrologically similar watersheds to check for outliers, plausibility and consistency. Data are corrected for errors, while conserving the overall (i.e., annual) inflow volume to the maximum extent possible.

# 4 Geology

The Campbell River region belongs to the insular belt[11]. This belt includes Vancouver Island, Haida Gwaii and the Alaska Panhandle and consists of a chain of volcanic islands fused onto the west coast of North America.

The Campbell River system is largely underlain by the volcanic pillow basalts and breccias of the Late Triassic Karmutsen Formation, which forms about half the mountains in the region, including the highest ones. These rocks are interspersed by other volcanic rock and small areas of granodioritic intrusive rock. There are very small patches of calcareous sedimentary rock in the center of the Strathcona basin and unsorted glacial till and outwash sand in the southern Ladore basin (Massey et al. 2005 and BC Geological Survey 1995). In the Strathcona basin, the steep topography results in a moderately dense channel network. The drainage pattern in this region has elements of the trellis[12] and dendritic[13] patterns. In the gentler topography of the Ladore and John Hart basins, the drainage network is less dense, very irregular and includes a large number of lakes.

# 5 Climatology

The Campbell River basin is in the transition zone between the wet west coast and drier east coast climates of Vancouver Island. The west facing mountain slopes of the island are usually cloud covered and wet during the winter due to prolonged and heavy rains formed by the orographic lifting of warm, moist air from Pacific cyclones flowing inland. The east faces of these mountains experience the spillover effect of the moisture laden winds which lift precipitation over the mountain barrier. The climate tends to be somewhat drier on the east coast of the island because the descending air disperses cloud and lessens the cyclonic rainfall.

[11] The division of BC into geological ***belts*** is based on the distinctive nature of bedrock. From west to east BC consists of the Insular, Coastal, Intermontane, Omineca and Foreland belts.

[12] ***Trellis drainage patterns*** look similar to their namesake, the common garden trellis. Trellis drainage develops in folded topography. Short tributary streams enter the main channel at sharp, nearly right angles as they run down sides of parallel ridges called anticlines (Ritter 2006).

[13] ***Dendritic drainage patterns*** look like the branching pattern of tree roots. They develop in regions underlain by homogeneous material. That is, the subsurface geology has a similar resistance to weathering so there is no apparent control over the direction the tributaries take. Tributaries join larger streams at acute angle (Ritter 2006).

The critical months for heavy precipitation in the Campbell River basin are October through March. In this period, a semi-stationary low-pressure center, the Aleutian Low, sets up in the Gulf of Alaska and brings a regular procession of frontal storms off the Pacific Ocean from the southwest towards the BC coast. These storms are associated with strong, moist winds that bring very heavy precipitation for durations of a few hours to four days. Very often a series of cyclonic storms are carried in the flow of air separated by hours or days. (St. Clair 2009).

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

The dominant weather pattern during the summer stems from a strong area of high pressure, the Pacific High, which keeps the area warm and relatively dry. This pattern is periodically broken by surges of moisture from the Pacific.

Figure 10 shows mean annual precipitation throughout the Campbell River region as derived from ClimateBC's PRISM-based data (Wang et al. 2006 and Daly et al. 2002). There is a gradient from higher precipitation in the southwest to lower precipitation in the northeast due to the rain shadow of the Vancouver Island Ranges. There is also a strong correlation between elevation and precipitation with the highest values in the peaks of the Elk River Mountains on the southern and western boundaries of the Strathcona basin and the lowest values in the lowlands near Strathcona Dam and in the Ladore and John Hart basins. Annual precipitation ranges from a maximum of almost 4400 mm to just under 1300 mm. Mean annual basin precipitation is 2596 mm, 1438 mm and 1602 mm in the Strathcona, Ladore and John Hart basins, respectively.

Figure 11 shows average monthly precipitation at Strathcona Dam (elevation 249 m). Average monthly precipitation ranges from less than 50 mm in July and August to a maximum of close to 250 mm in November. Most of the precipitation falls throughout the winter months when the climate is dominated by Pacific storms. In a given year, monthly totals can exceed 300 mm from October through January.

Figure 12 shows the average snow water equivalent (SWE) at the regionally representative Forbidden Plateau snow course (1B01, elevation 1130 m). Maximum snow accumulation is equally likely to occur on the April 1 or May 1 measurement dates. Peak accumulation averages about 1600 mm, but can range from less than 500 mm in a dry year to over 3500 mm in a wet year.

Figure 13 shows the average monthly minimum, mean and maximum temperatures at Strathcona Dam. Average monthly temperatures range from a minimum of about 2°C in December and January to a maximum of 17°C in July and August. Temperatures are moderated throughout the year by the influence of the Pacific Ocean minimizing the occurrence of extreme temperatures in both winter and summer.

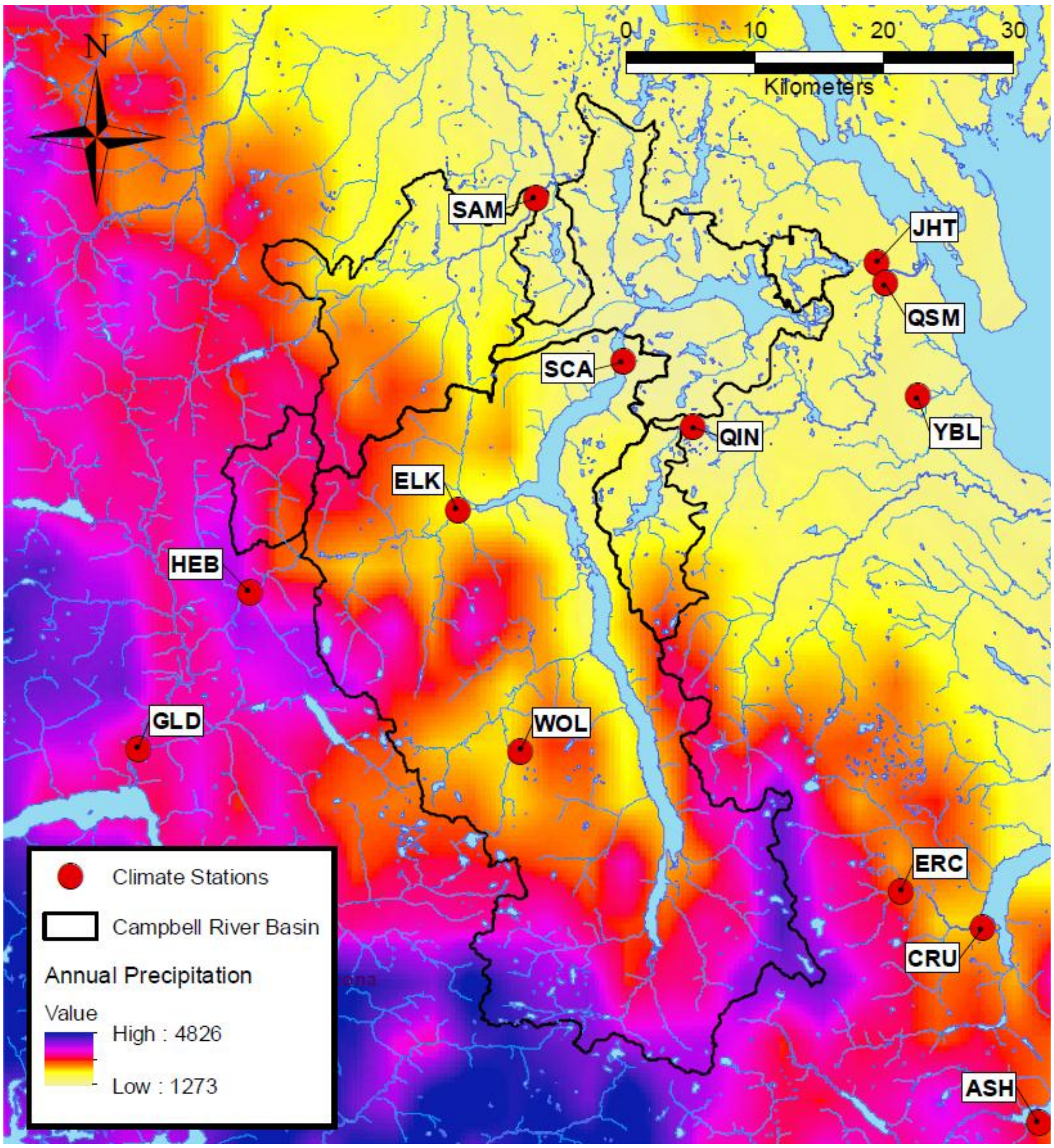


**Figure 10** Mean annual precipitation as derived from ClimateBC PRISM data.

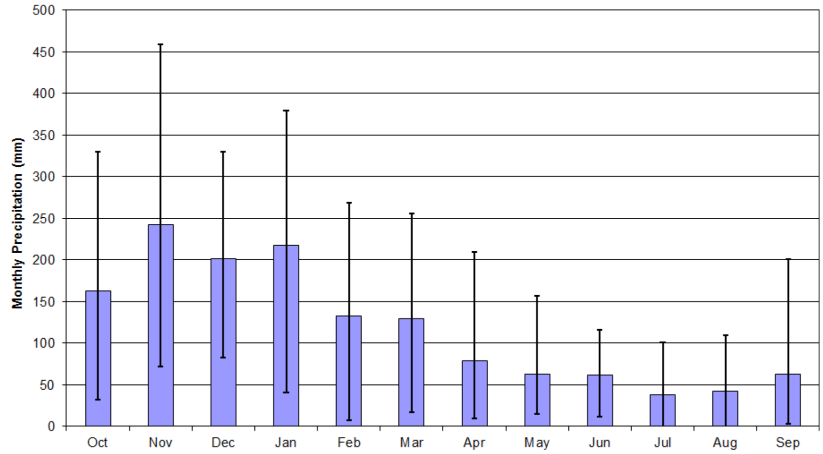


**Figure 11** Minimum, mean and maximum monthly precipitation at the Strathcona Dam weather station (SCA; 249 m, 1981-2012).

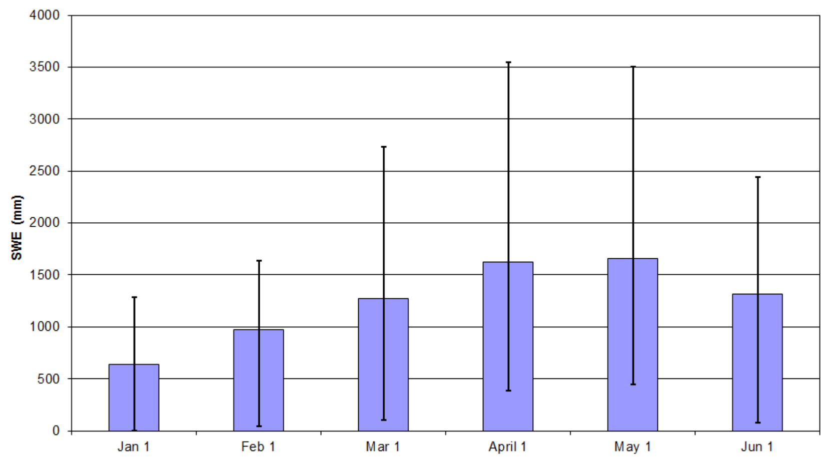


**Figure 12** Minimum, mean and maximum snow water equivalent at the Forbidden Plateau snow course (1B01; 1130 m, 1956-2012).

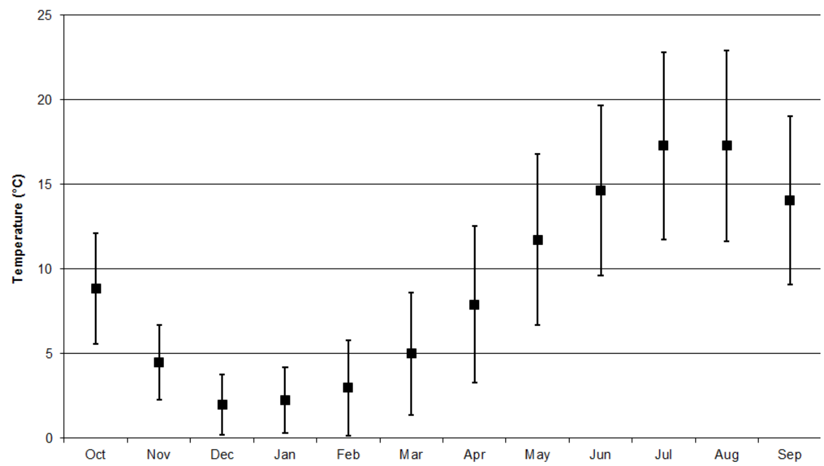


**Figure 13** Minimum, mean and maximum monthly temperatures at the Strathcona Dam weather station (SCA; 249 m, 1981-2012).

# 6 Flora

Vegetation is the product of interactions between geology, topography, climate, glaciation, flora colonization and the competition among species for space (Cannings and Cannings 1996). The Campbell River system is dominated by the dense mountain forests typical of coastal British Columbia.

The valleys and lower mountain slopes of the Strathcona basin, and most of the Ladore and John Hart basins are largely covered by forests of Douglas fir, western red cedar, grand fir, amabilis fir and western hemlock. At higher elevations, sub-alpine forests are made up of sub-alpine fir, mountain hemlock and creeping juniper. Although the region is mostly covered by coniferous forest, meadows of wildflowers can be found in various areas from sea level to above 1800 meters of elevation (BC Ministry of Environment 2012).

Since so many factors influence a region's dominant vegetation cover, it is commonly used as a surrogate for categorizing the physical environment as a whole. The ecoprovinces system uses climatology and physiography to categorize ecosystems in BC. Based on this classification, most of the Campbell River system belongs to the Eastern Vancouver Island Ecoregion of the Georgian Depression Ecoprovince, which encompasses the portion of Vancouver Island on the leeward side of the Vancouver Island Ranges (Demarchi 2011). Only the Heber Diversion basin and a small portion in the mountains on the western fringes of the Strathcona basin are instead part of the Western Vancouver Island Ecoregion in the Coast and Mountains Ecoprovince.

The system of biogeoclimatic zones is an alternative ecosystem classification system. It is based on climatic factors and defined by the dominant tree species. According to this system, the three basins are mainly encompassed by the Coastal Western Hemlock zone with the Mountain Hemlock and Alpine Tundra zones at higher elevations (Cannings and Cannings 1996).

# 7 Water Resources

## 7.1 Hydrologic Regime

Historical inflows to the Strathcona basin (Upper Campbell and Buttle Lake Reservoirs) are shown in Figure 14. Strathcona inflows exhibit a double annual peak, one in fall driven by rainfall runoff and a second one in spring driven by snowmelt. The watershed is therefore classified as a pluvio-nival hybrid regime[14]. Low flows occur in the summer months of August and September after the majority of the snowpack has melted. The snowmelt freshet starts in late April and, on average, reaches its peak in June. Annual maximum peak flows occur from October to March from rainfall-runoff, usually superimposed with a snowmelt component.

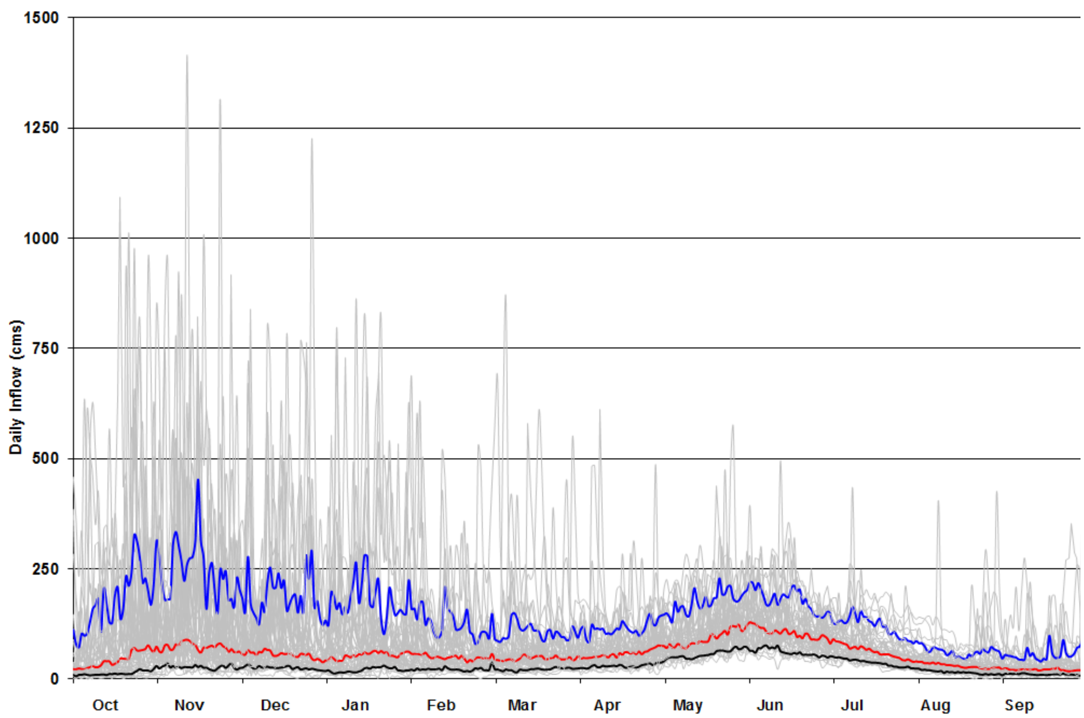


**Figure 14** Historical daily local, unregulated inflows to Upper Campbell and Buttle Lake Reservoirs (1964-2012 water years). The 10th, 50th and 90th percentile non-exceedance inflows are shown in bold black, red, and blue lines, respectively.

[14] A ***hydrologic regime*** categorizes a river or stream by its dominant flow-producing processes. In BC the following regimes can be observed: pluvial (rainfall-dominated), pluvio-nival hybrid (a combination of rainfall- and snowmelt-dominated), nival (snowmelt-dominated) and nivo-glacial (a combination of snowmelt- and glaciermelt-dominated).

Historical inflows to Ladore (Lower Campbell Lake Reservoir) are shown in Figure 15. Ladore also exhibits the double annual peak typical of a pluvio-nival hybrid regime, but with a shallower snowmelt peak than Strathcona due to the lower elevation of the watershed. The peak of the freshet also typically occurs earlier, in May on average. Peak annual flows at Ladore also result from intense rainfall often augmented by snowmelt in the winter months from October through March, and low flows also occur in the summer months of August and September.

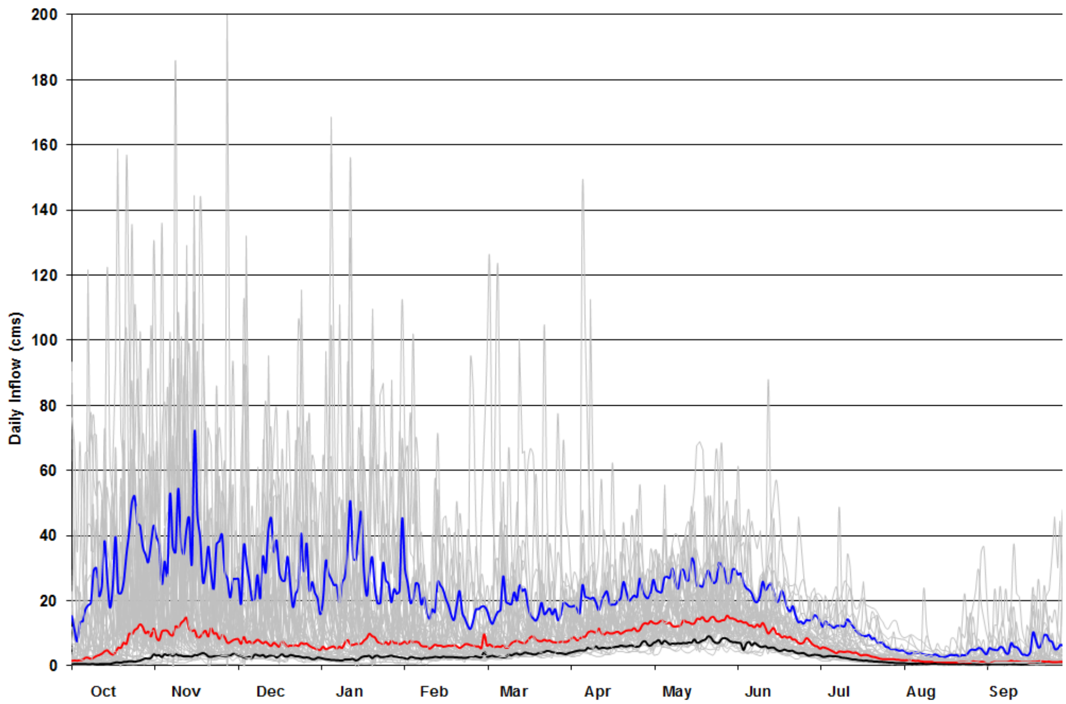


**Figure 15** Historical daily local, unregulated inflows to Lower Campbell Lake Reservoir (1964-2012 water years). The 10th, 50th and 90th percentile non-exceedance inflows are shown in bold black, red, and blue lines, respectively.

## 7.2 Hydrologic Characteristics

Mean annual inflow into the Strathcona and Ladore basins is 77 $m^3/s$ and 10 $m^3/s$, respectively, thereby reflecting the size, and hydroclimatic, physiographic and geologic characteristics of the basins. Inflows to the John Hart basin are negligible due to its small drainage area.

When normalized by drainage area, mean annual runoff in the Strathcona and Ladore basins is 2048 mm and 1316 mm, respectively. Those numbers reflect the hydroclimatic, physiographic and geologic characteristics of the basins only. The Strathcona basin produces the higher runoff per unit area due to its location in the relatively wetter and higher elevation western portion of the Campbell River region.

Figure 16 illustrates the monthly distribution of inflows and the variability of daily inflows within each month of the year for Strathcona and Ladore. Tables 4 and 5 show the data in greater detail. Due to its much larger drainage area and greater annual precipitation, the Strathcona basin receives much higher monthly inflow than Ladore throughout the year. Due to the dual rainfall and snowmelt peaks, average monthly inflows are relatively constant throughout the year except in the drier summer months of August and September. Maximum flows generally occur during intense rainfall-runoff events, which also usually include some snowmelt component, in the winter months from October to March.

Figure 17 shows a flow duration curve[15] of daily inflows for Strathcona and Ladore. Figure 18 shows the duration curves for annual flows.

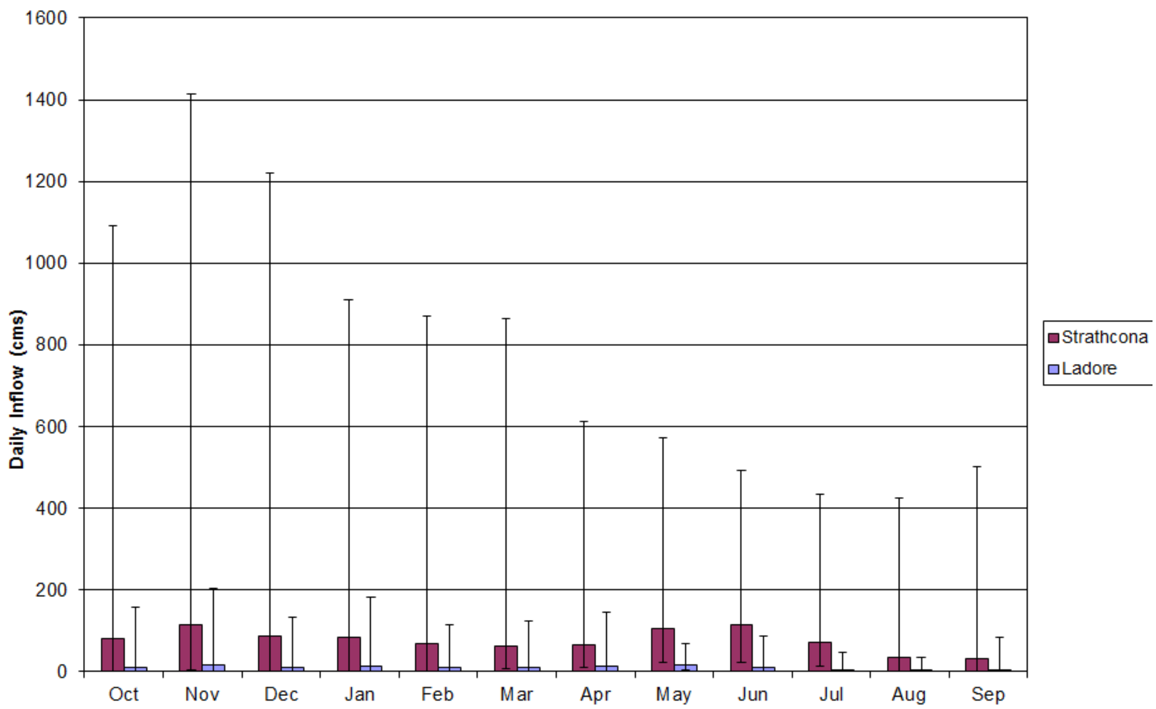


**Figure 16** Minimum, mean and maximum daily local, unregulated inflows to Campbell River reservoirs for each month of the year (1963-2012).

[15] ***Flow duration curves*** show the fraction of time that flows of a certain magnitude are exceeded.

**Table 4** Monthly distribution of daily local, unregulated Strathcona inflows in $m^3/s$ (1963-2012).

| Month | Min | 5% | 30% | 50% | Mean | 70% | 95% | Max |
|---|---|---|---|---|---|---|---|---|
| October | <1 | 8 | 23 | 42 | 80 | 76 | 287 | 1093 |
| November | 5 | 20 | 50 | 74 | 116 | 112 | 353 | 1414 |
| December | 2 | 19 | 38 | 55 | 89 | 88 | 261 | 1221 |
| January | 2 | 14 | 36 | 56 | 86 | 83 | 276 | 911 |
| February | 1 | 17 | 36 | 50 | 68 | 68 | 175 | 870 |
| March | 9 | 19 | 35 | 46 | 63 | 65 | 146 | 866 |
| April | 10 | 25 | 43 | 56 | 67 | 75 | 145 | 612 |
| May | 24 | 45 | 72 | 91 | 106 | 122 | 211 | 572 |
| June | 23 | 52 | 82 | 104 | 114 | 130 | 212 | 493 |
| July | 15 | 28 | 46 | 62 | 72 | 83 | 148 | 435 |
| August | <1 | 11 | 22 | 30 | 36 | 39 | 79 | 424 |
| September | <1 | 9 | 16 | 21 | 32 | 30 | 91 | 501 |
| **Annual** | <1 | 14 | 36 | 56 | 77 | 84 | 205 | 1414 |

**Table 5** Monthly distribution of daily local, unregulated Ladore inflows in $m^3/s$ (1963-2012).

| Month | Min | 5% | 30% | 50% | Mean | 70% | 95% | Max |
|---|---|---|---|---|---|---|---|---|
| October | <1 | <1 | 2 | 5 | 12 | 12 | 49 | 159 |
| November | <1 | 2 | 6 | 10 | 17 | 16 | 55 | 204 |
| December | <1 | 2 | 4 | 7 | 12 | 12 | 42 | 132 |
| January | <1 | 2 | 4 | 7 | 13 | 12 | 45 | 183 |
| February | <1 | 2 | 4 | 7 | 10 | 10 | 27 | 114 |
| March | 2 | 3 | 5 | 7 | 10 | 10 | 26 | 125 |
| April | 3 | 5 | 8 | 10 | 12 | 14 | 26 | 146 |
| May | 3 | 6 | 11 | 14 | 16 | 18 | 33 | 69 |
| June | 2 | 4 | 7 | 10 | 12 | 14 | 25 | 87 |
| July | <1 | 1 | 2 | 4 | 5 | 5 | 14 | 49 |
| August | <1 | <1 | <1 | 1 | 2 | 2 | 5 | 37 |
| September | <1 | <1 | <1 | 1 | 3 | 2 | 11 | 84 |
| **Annual** | <1 | <1 | 4 | 7 | 10 | 11 | 31 | 204 |

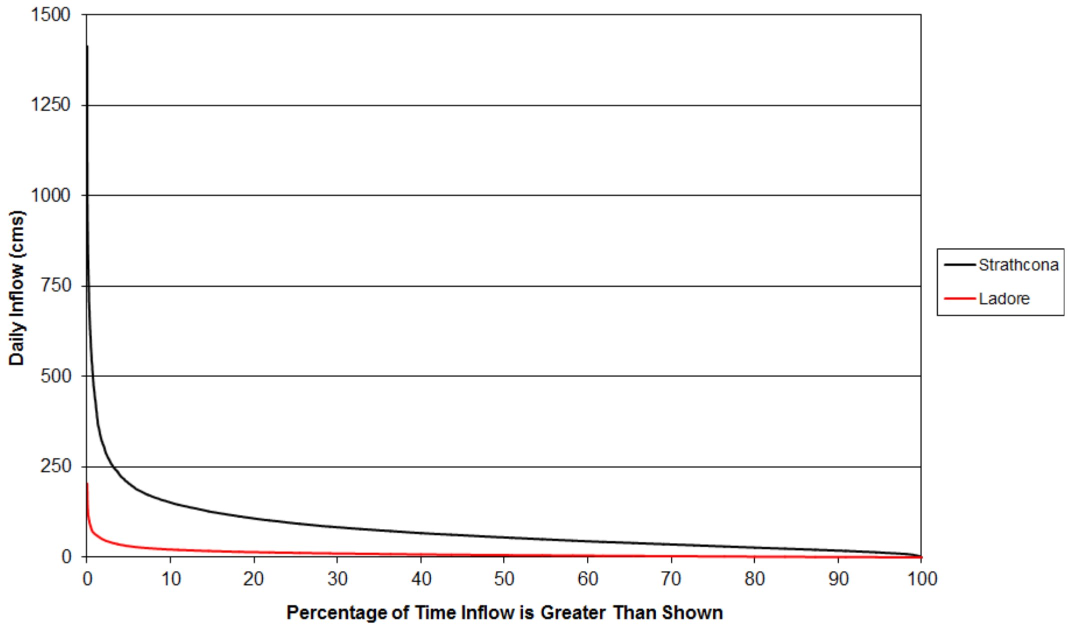


**Figure 17** Duration curves of daily local, unregulated inflows to the Campbell River reservoirs (1963-2012).

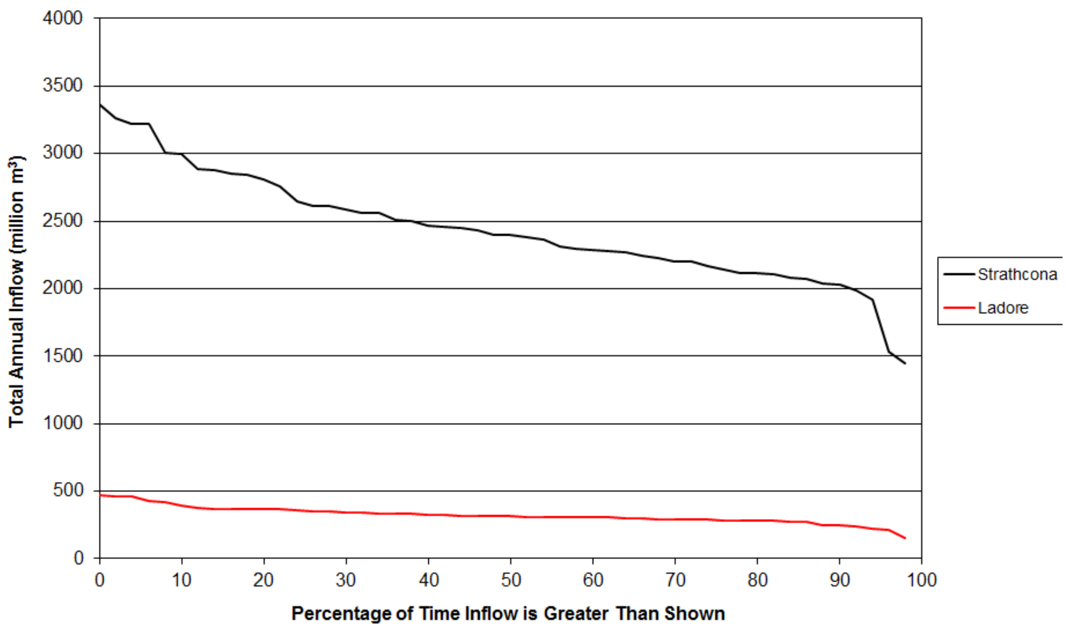


**Figure 18** Duration curve of annual local, unregulated inflows to the Campbell River reservoirs (1963-2012).

## 7.3 Inflow Design Floods

The Probable Maximum Flood (PMF) for Strathcona Dam has a peak 6-hour inflow of 5453 $m^3/s$ and a maximum reservoir elevation of 226.69 m (Stewart – OMSSCA 2005).

The PMF for Ladore Dam has a peak 6-hour inflow of 3194 $m^3/s$ and a maximum reservoir elevation of 181.91 m (Stewart – OMSLDR 2005).

The PMF for John Hart Dam has a peak 6-hour inflow of 2434 $m^3/s$ and a maximum reservoir level of 142.37 m (Stewart – OMSJHT 2005).

The Inflow Design Flood (IDF) for all three dams was under review as of the writing of the most recent OMS manuals. Mitigative measures were underway to increase the flood routing capability of the entire Campbell River system. These measures would allow floods of 72% of the PMF to be routed through the system.

## 7.4 Hydrologic Impacts of Land Cover and Climate Change

The Pacific Climate Impacts Consortium (PCIC) recently completed a study aimed at quantifying the hydrologic impacts of climate change on British Columbia, specifically on three BC Hydro watersheds, including the Campbell River system. The following summary draws from that PCIC report (Schnorbus et al. 2011).

On the BC South Coast, annual average temperatures are expected to warm by 1.8-2.2°C by 2050 depending on the emission scenario, with that warming distributed relatively evenly throughout the year. Precipitation could possibly increase by a marginal amount (an average of 0-6% is modelled by PCIC) with winters likely to be wetter and summers likely to be drier.

There isn't expected to be a significant change in annual streamflow volume due to climate change in the Strathcona watershed (an increase of 0-4% is modelled by PCIC), but the distribution of runoff throughout the year is expected to undergo major modification. By 2050, the Strathcona watershed is projected to change from a hybrid regime to a pluvial (rainfall) dominated regime. Due to less precipitation falling in the form of snow, flows from October to April will increase while the spring freshet will be substantially reduced. General Circulation Models are consistent in predicting the highest flow increases in January and the largest flow decreases in June.

## 7.5 Hydraulic Characteristics of BC Hydro Reservoirs

The licensed storage capacity[16] of BC Hydro's major storage reservoirs is plotted in Figure 19. Amongst those, the storage capacity of the Strathcona basin ranks in the middle. In Figures 20 and 21, mean annual local, unregulated inflow is compared with the licensed storage capacity for BC Hydro's major storage reservoirs. Upper Campbell and Buttle Lake Reservoirs can store just under 40% of the Strathcona basin's local, annual inflow within their licensed storage limits. Ladore and John Hart have storage capacities that greatly exceed their local inflows.

[16] **Licensed storage** is the amount of storage capacity in a reservoir between the minimum and maximum water license elevations. Normal operating elevations will often differ from these values and can vary throughout the year resulting in different associated storage values.

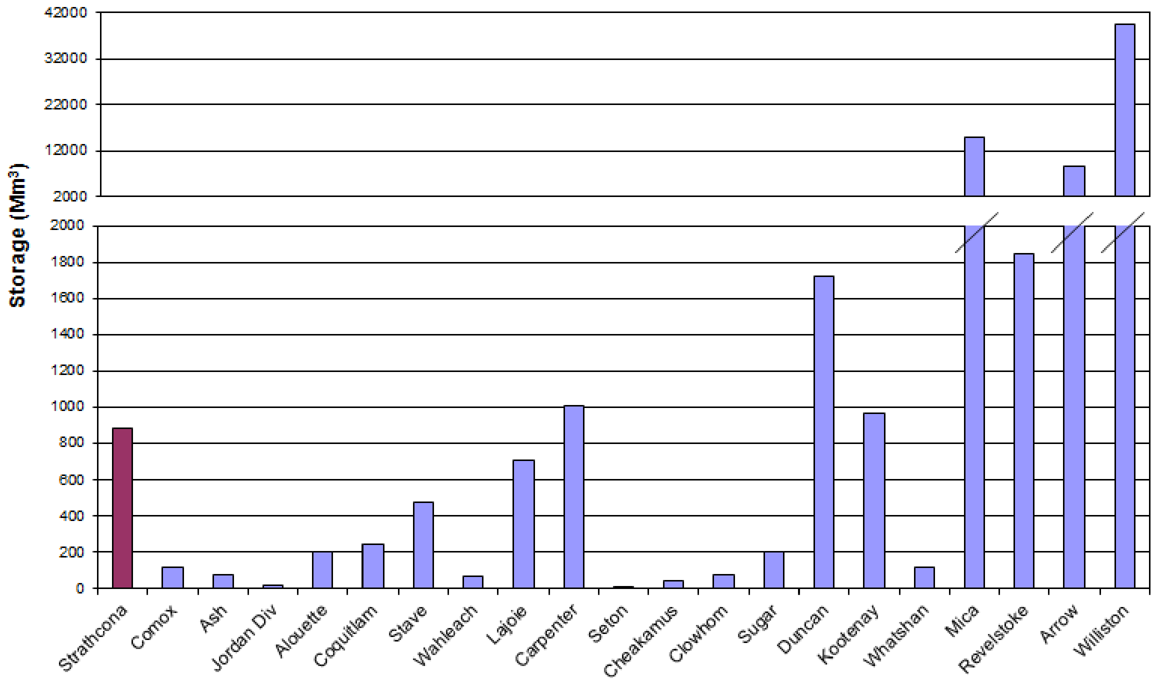


**Figure 19** Comparison of reservoir storage throughout BC Hydro's system. Storage is based on licensed water storage volume.

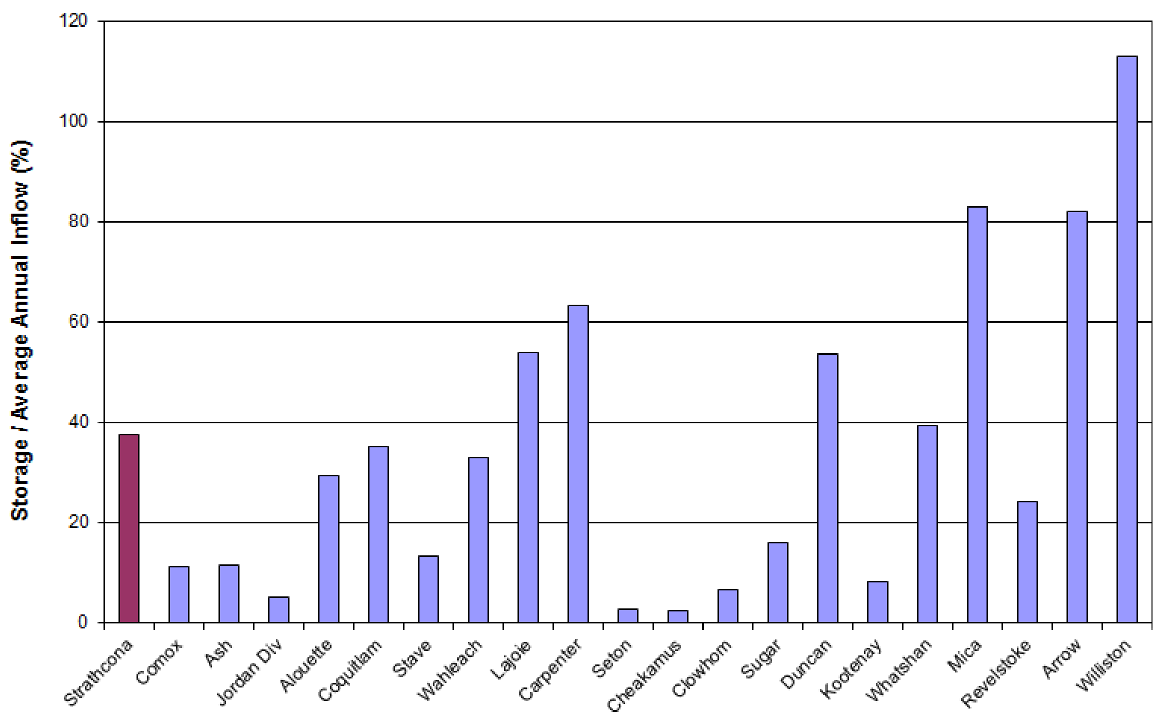


**Figure 20** Comparison of the capacity of BC Hydro reservoirs to store a year of local, unregulated inflow. Storage is based on licensed water storage volume.

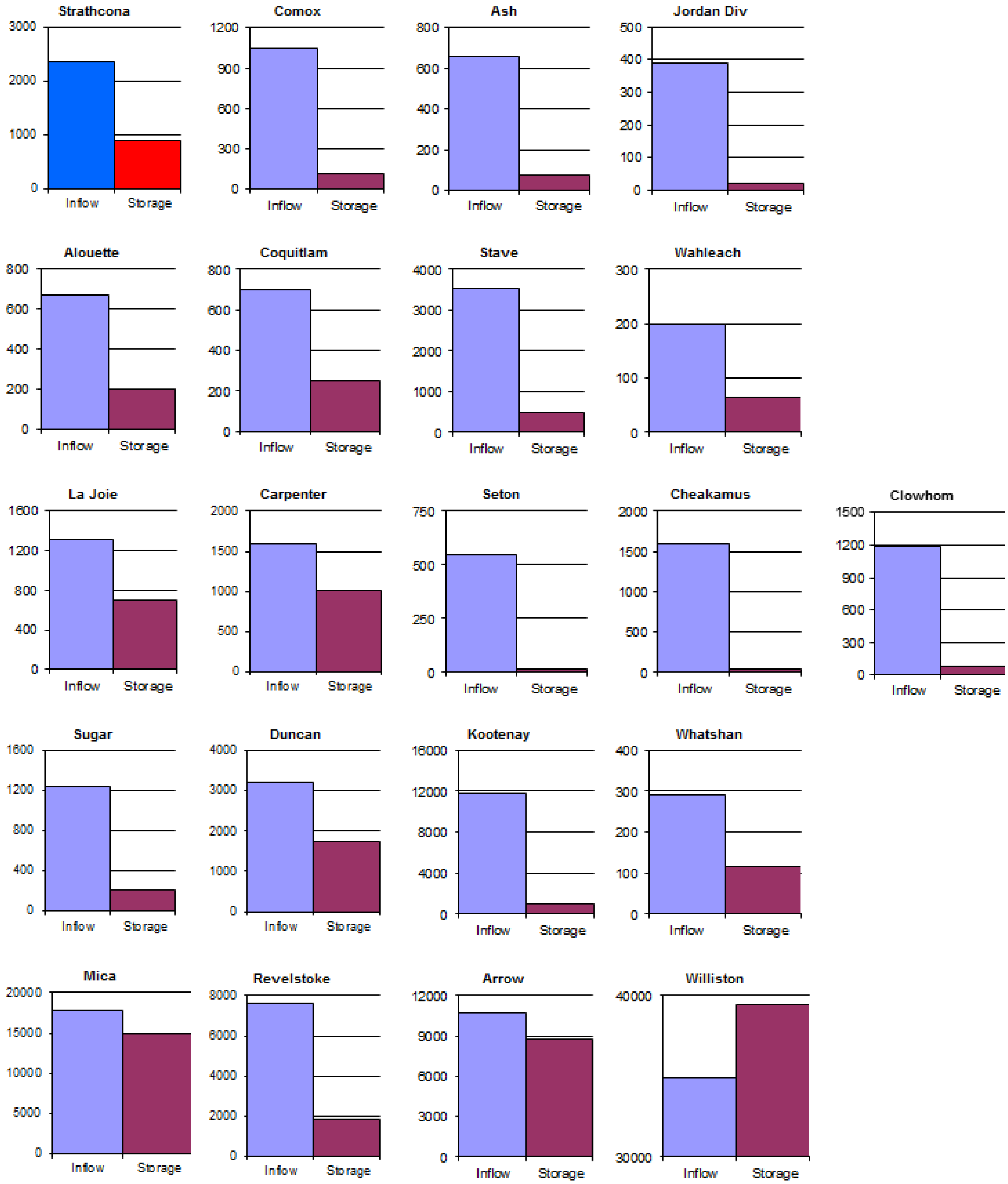


**Figure 21** Mean annual local, unregulated inflow volume (1971-2000) and licensed reservoir storage volume of major BC Hydro's reservoirs in millions of cubic meters.

# 8 Inflow Forecasting

BC Hydro Generation Resource Management's Runoff Forecasting group produces operational hydrologic short-range and long-range seasonal inflow forecasts for the Strathcona basin.

## 8.1 Short-range Inflow Forecasts

Forecasts of daily (midnight-to-midnight) inflows for up to seven days into the future are produced using the process-based, semi-distributed UBC Watershed Model. The model requires observed and forecast daily precipitation and daily minimum and maximum temperature data to simulate inflows. Forecast skill is derived primarily from skillful weather forecasts (e.g., forecasts from the Canadian Meteorological Center's Global Environmental Model), but also from knowing the hydrologic conditions in the basin at the time the forecast is issued. These hydrologic conditions include variables such as mountain snowpack, soil moisture and baseflow. The current short-range forecast system only issues deterministic forecasts, but is in the process of being expanded into a probabilistic forecast system. Forecasts are typically issued before 12 pm of each working day for the Strathcona basin.

## 8.2 Long-range Seasonal Inflow Forecasts

Water supply (also 'long-range' or 'seasonal') forecasts are made at the beginning of every month, from November to August, for the Strathcona basin. Forecasts issued in November, December, and August are labelled 'outlooks', whereas those issued in other months are labelled 'forecasts', with the latter term denoting a higher level of confidence in the forecasts. The overall emphasis is on predicting total inflow volumes over the upcoming February-September period.

Two techniques are used and yield probabilistic forecasts: one technique is based on statistical hydrologic models (specifically, principal components regression) and the other is based on the process-based UBC Watershed Model, run in an Ensemble Streamflow Prediction (ESP) framework. Water supply forecasts mainly reflect the hydrologic conditions in the basin as of the forecast date, including mountain snowpack, and proxies thereof, such as soil moisture and antecedent flows. In some cases, statistical forecasts also incorporate climate information from the El Niño-Southern Oscillation as a predictor.

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