Wahleach Project Water Use Plan

Herrling Island Chum Spawning Success Monitor

WAHMON#3

Herrling Island Chum Spawning Success Monitor

Study Period: 01 September 2006 – 30 April 2007

LGL Limited

December 5, 2007

Herrling Island Sidechannel Chum Salmon Spawning Success Monitoring, 2006 Annual Report

Prepared for

BC Hydro
Burnaby, BC V3N 4X8

5 December 2007

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Herrling Island Sidechannel Chum Salmon Spawning Success Monitoring, 2006 Annual Report

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EXECUTIVE SUMMARY

This report summarizes results from the second year (2006) of a proposed five-year program to monitor chum salmon (*Oncorhynchus keta*) spawning success in the Herrling Island sidechannel on the lower Fraser River, located approximately 25 km west of Hope, British Columbia. The primary objective of the study was to assess the effectiveness of operational measures at BC Hydro's Wahleach Generating Station (WAH GS) at minimizing chum salmon spawning in marginal areas and subsequent fry stranding. A secondary objective was to assess the risk of stranding of adult spawners associated with the recommended operations. Water Licence requirements stipulate that under normal operating conditions the WAH GS will curtail generation to zero for a 2-h period every 24 hours between 15 September and 30 November, while at all other times the WAH GS can generate at maximum capacity.

Due to a high inflow period from 3-11 November 2006, daily shutdowns at the WAH GS did not occur and discharge remained relatively constant at 13 m^3/s to reduce the potential threat of a free crest spill at Wahleach Dam with related downstream fisheries and property impacts adjacent to Jones Creek. In contrast, the WAH GS was shutdown for most of October when Fraser River stage height reached historic lows. These anomalous events occurred when chum salmon were present in the sidechannel and may have confounded results from the redd and fry stranding portion of the 2006 study.

Spawning behaviour observations and redd depths were recorded at three index sites in the Herrling Island sidechannel between 30 October and 20 November 2006. In addition, two hydrometric stations were installed near the index sites to record water level and water temperature at 15-min intervals from 12 September 2006 through 3 May 2007. Peak daily counts of live chum salmon were 304 fish at site 1 (18 November), 24 fish at site 2 (30 October), and 14 fish at site 3 (30 October). During WAH GS shutdown events from 12-17 November 2006, the wetted width in a 100-m section of site 1 decreased by 1.6 to 1.9 m (15-19%), and water depth decreased by 0.05 to 0.08 m (26-38%) on average. During the shutdown on 17 November, two chum salmon were observed stranded in a dewatered area at the lower end of site 1 along the left bank of the sidechannel. On 11, 18, and 20 November, chum salmon at site 1 appeared stressed as water levels dropped during WAH GS shutdowns.

Forty-nine redds were identified in 2006: 42 redds in site 1, 7 redds in site 2, and none in site 3. Of the 42 redds at site 1, 23 redds were complete, 11 redds were still active when field work concluded, and 8 redds were partial and assumed incomplete. Eighteen (88%) of the complete redds and nine (82%) of the active redds dewatered at least once between the fall of 2006 and 3 May 2007. As in 2005, excavating and reconfiguring the spawning channels (or "fingers") at the head of the tailrace pool is a mitigative measure that may reduce any potential impacts of WAH GS operations on the spawning success of chum salmon.

INTRODUCTION

The Wahleach hydroelectric facility is part of the BC Hydro Coastal Region and is located approximately 25 km west of Hope and 100 km east of Vancouver (Figure 1). The facility came into service in 1952 and includes the Boulder Creek Diversion Dam, Jones Lake (Wahleach) Reservoir, Wahleach Dam, and Wahleach Generating Station (WAH GS). Water from Jones Lake Reservoir enters an intake structure on the west side of the reservoir and is carried through a 4.2-km tunnel and a 500-m penstock to the WAH GS on the south bank of the Fraser River. Additional water is supplied to the reservoir by the diversion of Boulder Creek into Jones Lake Reservoir. The Boulder Creek Diversion Dam is located approximately 400 m east of Wahleach Dam. The WAH GS is a high-head station with a maximum sustained generating capacity of 63 MW. Discharge from the WAH GS enters the Herrling Island sidechannel of the Fraser River. Historically, the Wahleach hydroelectric facility has provided an average of 245 GWh per year and contributed approximately 0.67% of BC Hydro's hydroelectric generation (BCHydro 2004).

The Herrling Island sidechannel is 8 km long and located on the south bank of the Fraser River approximately 25 km downstream of Hope, BC (Figure 1). The WAH GS tailrace is located 2.3 km downstream from the inlet of the Fraser River. The sidechannel is fed by water from the Fraser River during freshet (May to August), tributary streams during periods of high rainfall, groundwater, and discharge from the WAH GS (Parsonage and Leake 1999). Historical hydrometric data shows that the mean daily discharge for the Fraser River near Hope peaks in mid-June at approximately 8,000 m^3/s, but is typically less than 2,500 m^3/s from mid-to-late October (Figure 2, Figure 3). The WAH GS typically operates to meet local peak electricity load. This results in daily fluctuations in flows in the Herrling Island sidechannel between August and May, a period when the Fraser River does not typically affect sidechannel flows except through groundwater contributions (BCHydro 2005).

Fish species known or believed to spawn in the Herrling Island sidechannel include: chum salmon (*Oncorhynchus keta*), pink salmon (*O. gorbuscha*), coho salmon (*O. kisutch*), cutthroat trout (*O. clarki*) and white sturgeon (*Acipenser transmontanus*) (Parsonage and Leake 1999). Based on observations by MacNair (2005b) in Lower Jones Creek, which drains into the Fraser River immediately upstream of the Herrling Island sidechannel, chum salmon spawn in the area from mid-October to mid-December with peak spawning occurring from 15-30 October (Figure 4). Smith (2006) observed chum salmon actively spawning in the Herrling Island sidechannel from late October through mid-November 2005. Eggs incubate from late October through early May and fry out-migrate from mid-March to early May. Upon emergence, chum salmon fry migrate directly to the estuary. Annual chum salmon escapements in the Herrling Island sidechannel are estimated to be between 2,000 and 10,000 adults (Hancock and Marshall 1985). Pink salmon were observed to spawn in Lower Jones Creek from early October to early November with fry outmigrating from early April to mid-May (Figure 4) (MacNair 2005b).

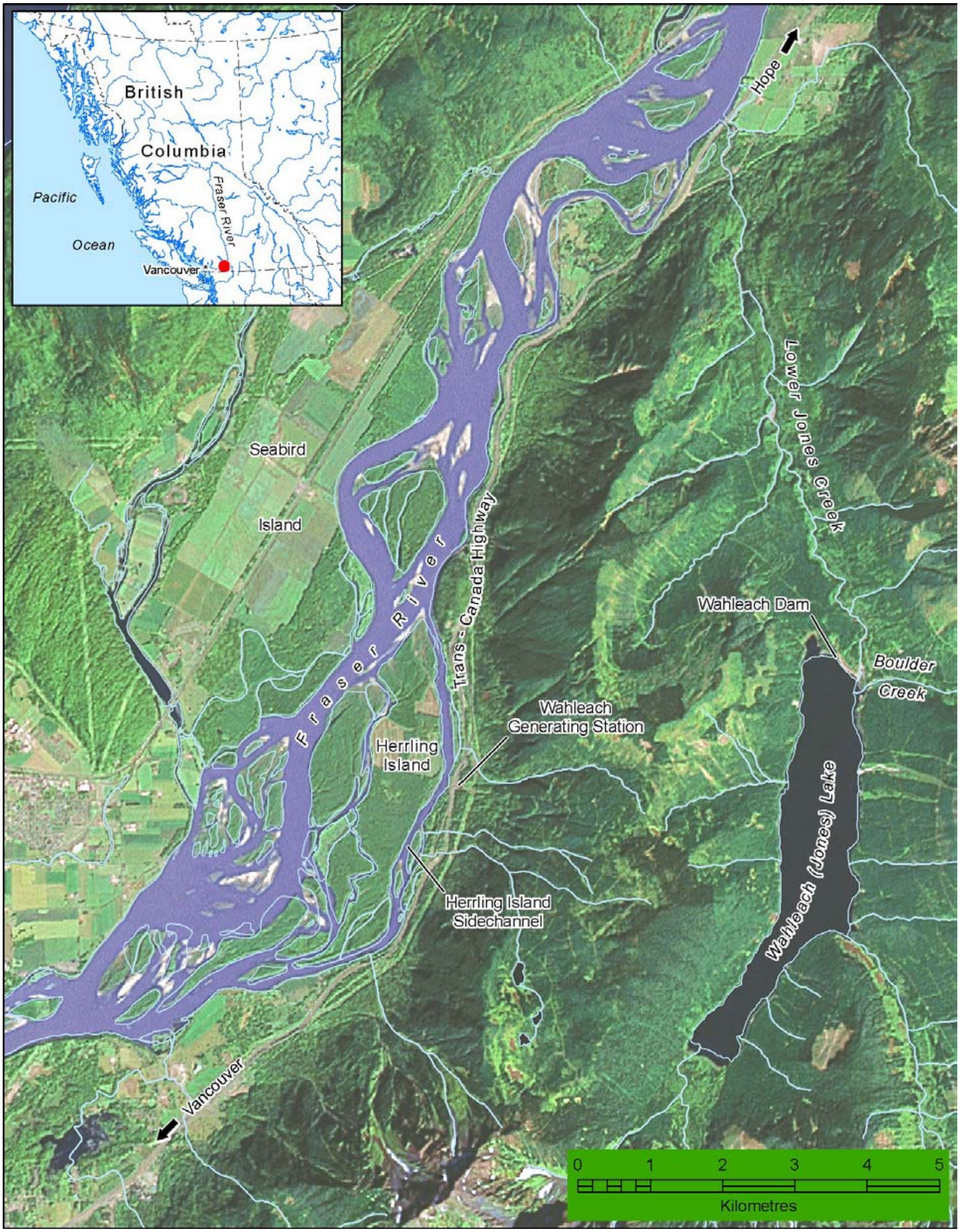


Figure 1. The Wahleach hydroelectric facility which includes the Boulder Creek Diversion Dam, Jones Lake (Wahleach) Reservoir, Wahleach Dam, and Wahleach Generating Station (WAH GS).

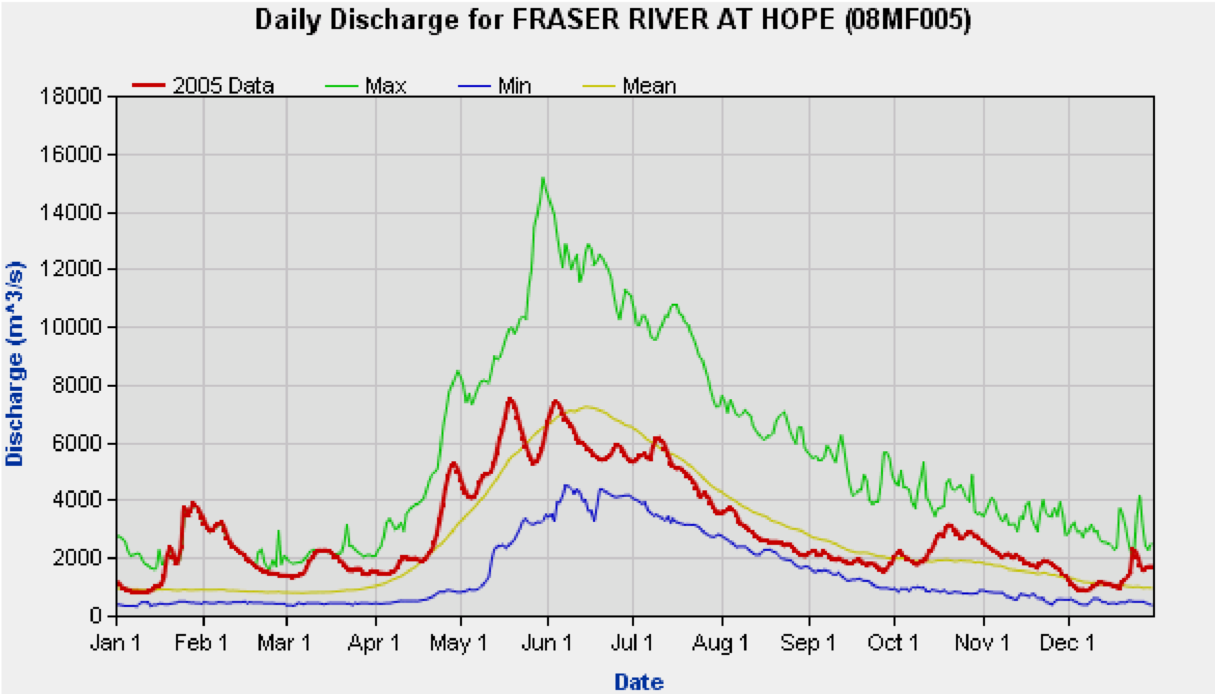


Figure 2. Historical daily discharge of the Fraser River near Hope, BC, 1965-2005 (EC 2007).

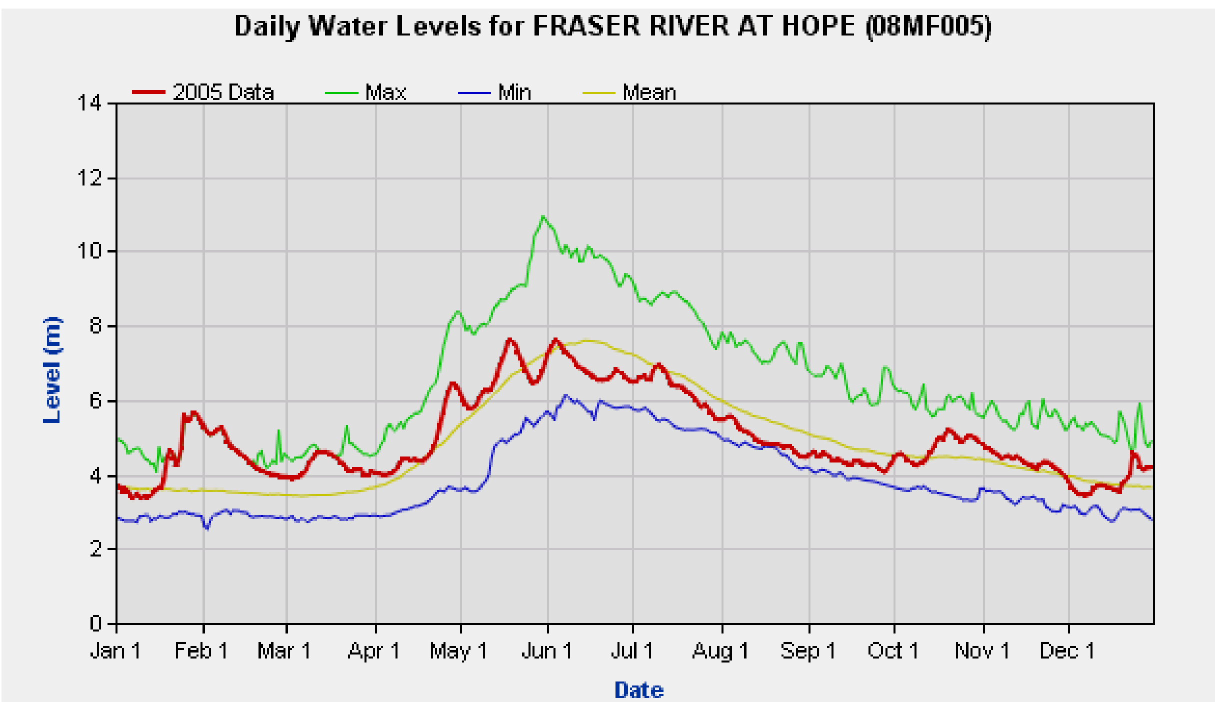
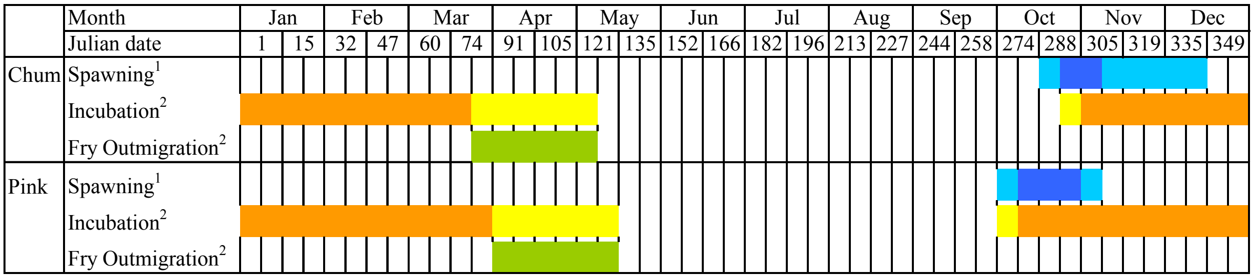


Figure 3. Historical daily water level of the Fraser River near Hope, BC, 1969-2005 (EC 2007).



[1] Based on observed adult escapement in Lower Jones Creek (MacNair 2005a).
[2] Based on observed fry outmigration from Lower Jones Creek (MacNair 2004).

Figure 4. Periodicity chart for chum and pink salmon in Lower Jones Creek (adapted from Figs. 2 & 3 in the Wahleach Water Use Plan Monitoring Terms of Reference).

Past studies (BCHydro 1998; McLean 1998; Parsonage and Leake 1999) have shown that fluctuations in water levels in the Herrling Island sidechannel due to operational conditions at the WAH GS may contribute to:

(1) Extensive dewatering of shallow riffles and gravel bars in the sidechannel;
(2) Partial or full dewatering of chum salmon redds;
(3) Stranding of spawning adult chum salmon; and
(4) Stranding of outmigrating juvenile chum salmon in isolated pools or dewatered areas (Appendix A).

In response to these issues, the Wahleach Water Use Plan consultative process was initiated in September 2000 "to develop recommendations defining a preferred operating alternative using a multi-stakeholder consultative process" (Anonymous 2003). A Consultative Committee report and draft Water Use Plan (WUP) were submitted to the Comptroller of Water Rights in December 2003, and the Wahleach WUP was accepted and implemented in January 2005 (BCHydro 2004). One of the recommended operational changes for the WAH GS was meant to limit spawning use in marginal areas (i.e., those areas that are at risk to be subsequently dewatered during operations or maintenance) and therefore reduce stranding during fry out-migration. Specifically, this recommendation stipulated that from 15 September to 30 November, BC Hydro would curtail generation at the WAH GS to zero for a two-hour period every twenty-four hours. At all other times, BC Hydro could generate at maximum capacity and there was no constraint on the rate of change of flow from the powerhouse.

The potential effectiveness of these operational changes was uncertain because the behavioural response of spawners to flow reductions was poorly understood. As a result, the Consultative Committee recommended that all operational changes be monitored for their effectiveness (BCHydro 2005). It was hypothesized that the amount of salmon habitat would decrease in the Herrling Island sidechannel as a result of decreased flows through the WAH GS; however, spawning success (as measured by egg-to-fry survival) was expected to increase as a result of the operational changes. Management questions pertaining to the potential affects on salmon and their habitat in the Herrling Island sidechannel that needed to be addressed included:

(1) Will the recommended operational measures keep spawning away from marginal areas?
(2) Will the operational measures in the fall result in stranding of adult spawners?
(3) Will the operational measures in the fall result in minimal fry stranding in the spring?

Based on these management questions, it was proposed that the following hypotheses be tested in relation to the effectiveness of the recommended operational measures:

(1) H_1: Suspending Wahleach generation for 2 h daily during the chum salmon spawning period does not deter spawning in marginal areas;
(2) H_2: Suspending Wahleach generation for 2 h daily during the chum salmon spawning period does result in stranding of spawning adults; and
(3) H_3: Suspending Wahleach generation for 2 h daily during the chum salmon spawning period does not eliminate fry or redd stranding caused by operations.

The primary objective of this study was to assess the effectiveness of the WAH GS operational measures at minimizing chum salmon spawning in marginal areas and subsequent fry stranding in the Herrling Island sidechannel. A secondary objective was to assess the risk of stranding of adult spawners associated with the recommended operations. To meet these objectives, three study components were utilized for this monitoring program. The *behavioural response of chum salmon was monitored* before, during, and after daily outage events at three index sites within the Herrling Island sidechannel. An *adult stranding risk assessment* was conducted by monitoring the area of habitat dewatered or cut off from mainstem flow due to WAH GS operations, the number of spawners stranded in affected habitat, and the rate of stage change at each index site as related with stranding risk. And lastly, a *redd and fry stranding assessment* was conducted using water level data collected at three hydrometric stations and chum salmon redd depths measured at the index sites.

In the first year of this study (2005), chum salmon were observed spawning at two main locations within the Herrling Island sidechannel between 24 October and 16 November (Smith 2006). During periods immediately following WAH GS shutdowns, eight chum salmon were found stranded in dewatered areas within the sidechannel and 21 chum salmon were found stranded in isolated pools. Forty-six percent (n = 35) of redds were estimated to have dewatered at least once, and dewatering events were more frequent during egg incubation than during fry emergence.

This report summarizes results from the second year (2006) of a proposed five-year monitoring program.

METHODS

LGL Limited (Sidney, BC) partnered with the Cheam First Nation (Rosedale, BC) to conduct the 2006 field work. The study team was responsible for completing four primary tasks:

(1) Monitoring the behavioural response of chum salmon before, during and after WAH GS outage events at each of the three index sites identified in 2005;
(2) Recording the total area of spawning habitat either dewatered or cut off from the mainstem flow due to WAH GS operations;
(3) Recording the number of stranded spawners in the affected habitat; and
(4) Monitoring the wetting of chum salmon redds using recorded water level data and tracking known redd elevations.

Index Sites for Monitoring Chum Salmon

In 2006, three index sites (sites 1, 2, and 3) were used to monitor chum salmon spawning activity (Figure 5, Figure 6). These index sites were the same as the ones used during the 2005 study. The index sites were initially selected based on information collected during previous field studies (BCHydro 1998; McLean 1998; Parsonage and Leake 1999). Each index site was approximately 200-m long and spanned the entire width of the sidechannel.

Temporary staff gauges were installed at two locations within index site 1 and monitored several times during the field component of the study. These gauges were located 60 m (rebar 1) and 150 m (rebar 2) from the top of the left-bank finger and consisted of pieces of rebar (1 m long x 1.3 cm dia.) that were pounded into the substrate using a sledgehammer. The gauges were removed from the site at the end of November.

Hydrometric Data

Fraser River at Hope

Hourly Fraser River stage height and discharge data collected at a gauging station (08MF005) near Hope, BC, from September 2006 through May 2007 was provided by Environment Canada (Lauren Wick, Environment Canada, personal communication).

Herrling Island Sidechannel

As part of a separate contract with BC Hydro, Via-Sat Data Systems, Inc. (North Vancouver, BC) installed and operated two hydrometric stations (stations 1 and 2) in the Herrling Island sidechannel from mid-September 2006 through early May 2007. Each hydrometric station consisted of a Model PT2X pressure transducer (0-5 psi) from Instrumentation Northwest Inc. (Kirkland, WA). The pressure transducers logged water level and water temperature at 15-min intervals. Water levels at each station were referenced to local datum (pressure transducer) as 0.000 m. Locations were selected in consideration of vandalism avoidance, effectiveness through ranges of expected water levels, and stability.

Station 1: The uppermost hydrometric station (station 1) was located on the left bank approximately 2.2 m downstream from the inlet of the sidechannel and 50 m upstream from WAH GS tailrace (Figure 5, Figure 6, Appendix B). The data logger/pressure transducer was housed inside an aluminum pipe which was rock-bolted to a large boulder. The cable-end, desiccant, and external battery were housed in an aluminum box and placed approximately 8 m up the left bank. The shelter was attached to a large boulder. All benchmarks for this station where established on 12 September 2006.

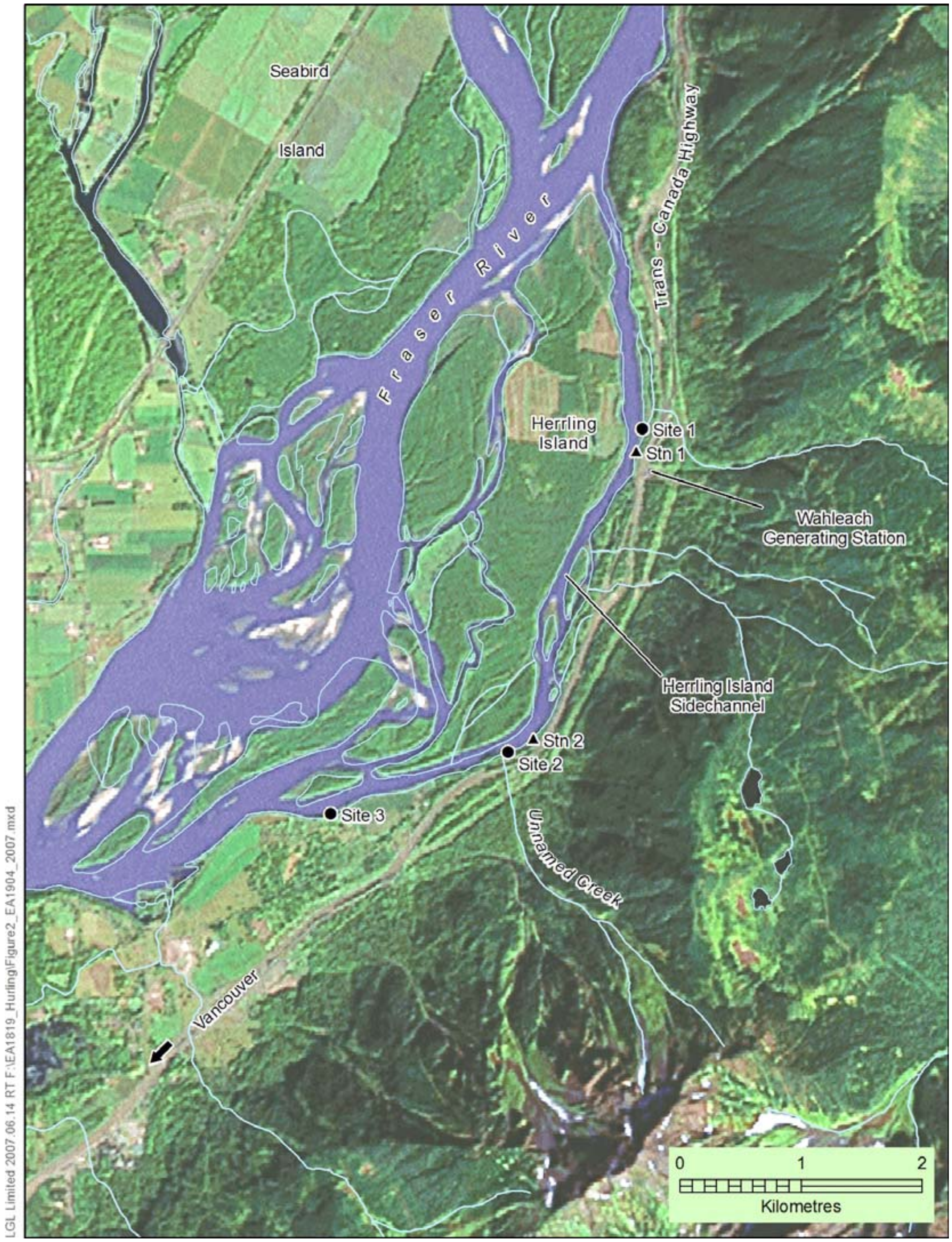


Figure 5. Location of the WAH GS, three index sites (sites 1, 2, and 3) used to monitor chum salmon spawning, and two hydrometric stations (stations 1 and 2) used to record water levels and water temperature in the Herrling Island sidechannel, 2006.

Figure 6. Aerial photograph of the Herrling Island sidechannel showing the location of the Wahleach Generating Station (WAH GS), two hydrometric stations (stations 1 & 2), and three index sites (site 1, 2, and 3) used to monitor chum salmon spawning activity, 2006. This photograph was taken on 28 March 1998 when the WAH GS was at 0 MW (0 m^3/s).

Station 2: The lowermost hydrometric station (station 2) was located on the left bank approximately 2.2 km downstream from the WAH GS tailrace and 150 m upstream from the mouth of Unnamed Creek (Figure 5, Figure 6, Appendix B). The data logger/pressure transducer was housed inside an aluminum pipe which was rock-bolted to an existing piece of angle iron in the channel. The angle iron was on the downstream side of a large snag attached to the left bank. The cable-end, desiccant, and external battery were housed in an aluminum box and placed approximately 5 m up the left bank. The shelter was attached to a piece of angle iron that was driven into the ground. All benchmarks for this station were established on 12 September 2006.

Discharge at the Wahleach Generating Station

Hourly discharge data collected at the Wahleach Generating Station from September 2006 through May 2007 was provided by BC Hydro (Dave Hunter, BC Hydro, personal communication).

Adult Spawning Behaviour Observations

The initial goal of this assessment was to observe spawning behaviour over a minimum of 10 consecutive days and over a continuous 10-h period each day (~1700-0300 hours) during the 2-week peak spawning period at each of the three index sites. Typically, peak load discharge from the WAH GS drops off around 2200 hours nightly, which should have coincided with the planned 2-h WAH GS shutdown. Given this scenario, daily observations would describe the effects of a shutdown from 2200 to 0000 hours. This plan allowed 3 h for water levels in the sidechannel to recede and stabilize, and an additional 2 h for monitoring while the WAH GS discharges were restored.

However, during the 2006 field study, WAH GS shutdowns typically occurred during the day (~1200-1400 hours), and thus the sampling schedule was adjusted accordingly. The crew tried to visit all three index sites prior to a shutdown (~0900-1200 hours), remain at site 1 during the shutdown, and then visit sites 2 and 3 before WAH GS discharges were restored (~1400-1500 hours).

Adult chum salmon were enumerated at each site before and after WAH GS shutdowns and their specific activity (migrating, holding, spawning) and location (thalweg, left/right bank) were documented. Each redd received a unique identification code (date-site-#, GPS location) and was marked with a flag-taped rock. All redds were measured for depth before and after the WAH GS shutdown and described based on their status (false, partial, full) and composition (sand, gravel, cobble). Redd depths were measured from the substrate surface at the lowest point in the redd pit to the water surface. Additionally, the river depth of the undisturbed substrate adjacent to redds was measured. The crew also tried to estimate the amount of dewatered area and area cut-off from mainstem flow during shutdowns.

Results from this assessment were intended to test the hypothesis (H_1) that *suspending Wahleach generation for 2-hours daily does not deter spawning in marginal areas*. Tests of significance were to be performed for each site to determine whether there was a statistically significant difference between the number of redds (or active spawners) per unit area in spawning areas affected and not affected during the shutdown.

Adult Stranding Risk Assessment

During low-water conditions following WAH GS shutdowns, the crew documented the number of adult chum salmon found in isolated pools or dewatered areas at each index site. The condition (live, pre/post-spawn moribund, pre/post-spawn mortality) and location (GPS coordinates) of stranded chum salmon was recorded.

Results from this assessment were used to test the hypothesis (H_2) that *suspending Wahleach generation for 2-hours daily does not result in stranding of spawning adults*. Analysis of these data was qualitative based on the incidence of pre-spawn or recently spawned adults that were stranded due to WAH GS operations. Since moribund adults are susceptible to stranding they were not considered representative of the target population of this study and thus were excluded from this assessment.

Redd and Fry Stranding Assessment

River bed and redd depths collected during the spawning behaviour monitoring assessment were tracked against water level recordings from the two hydrometric stations operated in the sidechannel. Results from this assessment were used to test the hypothesis (H_3) that *suspending Wahleach generation for 2-hours daily does not eliminate fry or redd stranding caused by operations*. For each redd identified at the index sites, the following analyses were performed:

(1) Redds were classified as complete, active, or partial. A redd was complete if fish were observed spawning and/or there was evidence over consecutive site visits that the redd pit had been infilled. Active redds were ones where spawning was still occurring or fish were still present on a redd but the pit had not yet been filled by the end of the sampling period. A redd was classified as partial if the pit was not infilled and consecutive site visits indicated no further spawning activity.

(2) Redd depth, and the depth of the "undisturbed" river bed adjacent to a redd, were measured before and during WAH GS shutdowns each day (Figure 7);

(3) A redd was considered dewatered when the undisturbed bed depth was zero. Stage height of the sidechannel where individual redds dewatered was estimated using one of two methods:
   a. Regression analyses of paired bed depth and water level measurements collected before and during WAH GS shutdowns; or
   b. If a redd was observed dewatered during field observations, stage height at the hydrometric station at the corresponding time was used.

(4) The <u>frequency</u> of dewatering events was calculated as the number of times during the study period (i.e., Oct/Nov 2006 through 3 May 2007) when the stage height at a particular hydrometric station was at or below the depth where a redd was considered dewatered;

(5) The duration of dewatering events was calculated as the length of time (in hours) that each dewatering event lasted; and

(6) The extent of redd dewatering was determined based on timing – dewatering events were categorized as either egg stranding during incubation (October 2006 – 31 March 2007) or fry stranding over emergence (1 April – 3 May 2007). These periods were based on outmigration data for chum salmon fry collected at nearby Jones Creek in 2005 (MacNair 2005b).

It is important to note that chum salmon egg burial depths of 8-49 cm have been reported on other rivers (Devries 1997). Our definition of a redd dewatering when the undisturbed redd depth equals zero does not necessarily mean that eggs were physically exposed to air.

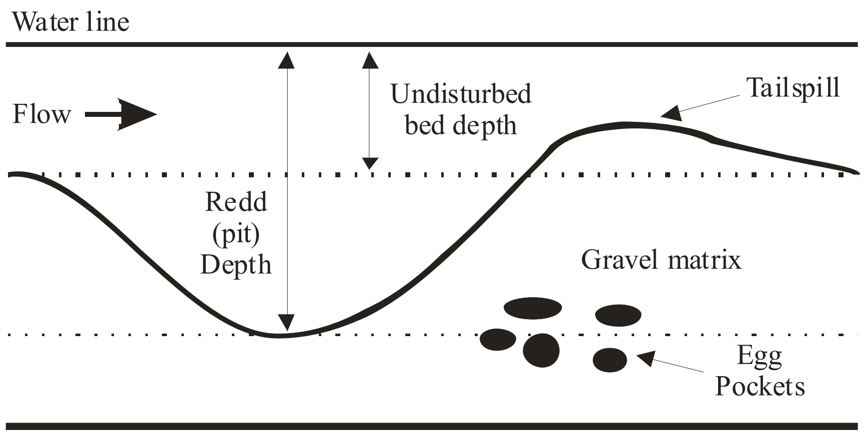


Figure 7. Schematic of a chum salmon redd depicting the location of egg pockets in the gravel matrix. Redd depth was measured from the water line to the river substrate at the deepest section of the redd pit. Undisturbed bed depth was measured from the water line to the river substrate at a location near the redd that has not been influenced by spawning activity.

RESULTS

Index Sites for Monitoring Chum Salmon

The first index site (site 1) was located at the head of the WAH GS tailrace pool approximately 2 km downstream from the inlet of the Herring Island sidechannel and 0.5 km upstream from the WAH GS tailrace (Figure 8; Photo 1, Photo 2, Photo 3). Scott Paper Limited constructed three chum salmon spawning channels (or "fingers") when they removed gravel from the sidechannel for road construction on Herrling Island (Parsonage and Leake 1999). Site 1 extended from the top of the fingers downstream to the mouth of a small tributary that drained into the sidechannel on the east (left) bank. Access to the site was via the Herrling Island off-ramp (Exit 146) off Highway 1 approximately 1.5 km east of the WAH GS. This was also a popular area for recreational motorcyclists and four-wheelers.

Figure 8. The uppermost index site (site 1) used to monitor chum salmon spawning in the Herrling Island sidechannel, 2006 (photo: 28 March 1998, 0 MW, 0 m^3/s).

The second index site (site 2) was located approximately 2 km downstream of the WAH GS tailrace and 200 to 400 m upstream of the mouth of an unnamed creek (herein called Unnamed Creek) that drains into the sidechannel from the left bank (Figure 9 , Photo 4). Site 2 was accessed from an unmarked exit off Highway 1 at the "Popkum Road 2500 m" road sign approximately 2.5 km south on Highway 1 from site 1.

Figure 9. The middle index site (site 2) used to monitor chum salmon spawning in the Herrling Island sidechannel, 2006 (photo: 28 March 1998, 0 MW, 0 m^3/s).

The third index site (site 3) was located approximately 4 km downstream of the WAH GS tailrace and 500 m upstream from the outlet of the Herrling Island sidechannel (Figure 10, Photo 5). Access to site 3 was via Julseth Road which was located 2 km northeast on Yale Road East from the Popkum Road off-ramp (Exit 138) off Highway 1. A hydrometric station was not installed at the third index site (site 3) in 2006 because no chum salmon were observed spawning there in 2005.

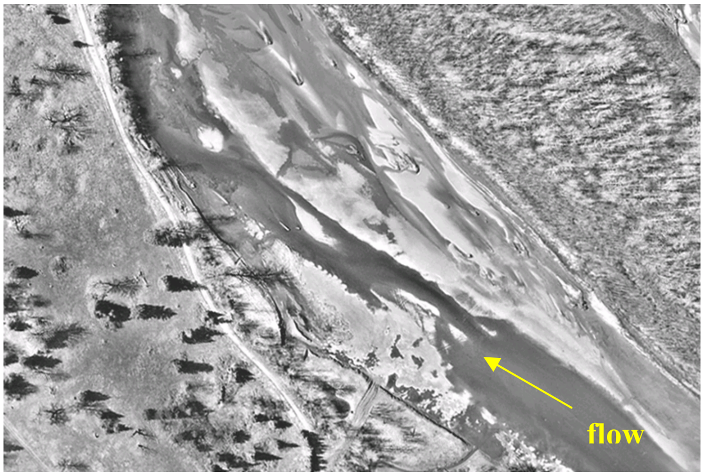


Figure 10. The lowermost index site (site 3) used to monitor chum salmon spawning in the Herrling Island sidechannel, 2006 (photo: 28 March 1998, 0 MW, 0 m^3/s).

Hydrometric Data

Fraser River at Hope

From 1 October 2006 to 23 May 2007, discharge of the Fraser River at Hope ranged from 469 to 6,974 m^3/s and stage height ranged from 2.73 to 7.38 m (Figure 11). During the period when 2006 field work was conducted (30 October to 20 November), Fraser River discharge ranged from 836 to 3,141 m^3/s and stage height ranged from 3.40 to 5.21 m. Stage height was below historic lows for most of October 2006 and near historic lows from mid-January to early March 2007 (Figure 12). Apart from two short periods (6-8 November and 16 November), Fraser River discharge was less than the historic average for November. Stage height and discharge data were not available from 1300 hours on 6 April to 1300 hours on 13 April or from 1300-1400 hours on 18 April.

Herrling Island Sidechannel

Hydrometric stations 1 and 2 collected stage height and temperature data in the Herrling Island sidechannel between 12 September 2006 and 3 May 2007 (Figure 13, Figure 14, Figure 15). Over this period, stage height ranged from 0.19 to 1.84 m at station 1 and 0.06 to 2.48 m at station 2. Due to the pressure transducers clogging with silt, stage height was not recorded from 1 December (0100 hours) to 3 January (1000 hours) at Station 1 or from 26 November (1315 hours) to 3 January (1100 hours) at Station 2 (Appendix B). Water temperatures ranged from 1.6 to 17.8 ^{o}C at station 1 and from 0.8 to 17.8 ^{o}C at station 2. Water temperature was not recorded from 1 January (0000 hours) to 3 January (1000 hours) at station 1 or from 1 January (0000 hours) to 3 January (1100 hours) at station 2.

Stage heights measured at temporary staff gauges (rebar 1 and 2) in index site 1 were plotted against corresponding stage heights recorded at hydrometric station 1 (Appendix C). These data show that for a given change in stage height at station 1, water levels in the upper section of the left-bank finger of site 1 (rebar 1) change less than water levels in the middle section of the left-bank finger (rebar 2).

Wetted width and water depth were recorded before and during WAH GS shutdowns at 10-m increments over a 100-m section in the upper left-bank finger of index site 1 (Appendix D). Based on data collected on 12 November and 17 November, wetted width in the 100-m section decreased by 1.6 to 1.9 m (15-19%), and water depth decreased by 0.05 to 0.08 m (26-38%) on average during a WAH GS shutdown.

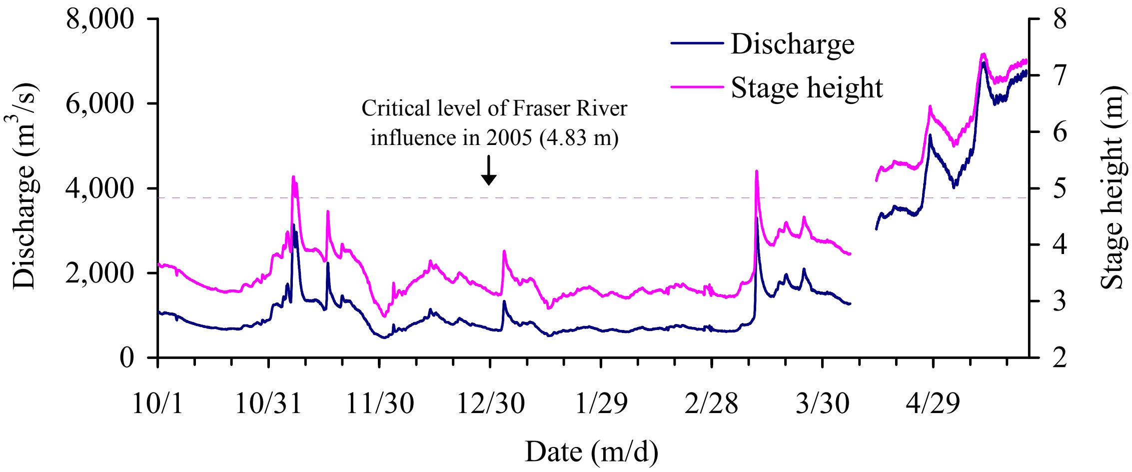


Figure 11. Stage height and discharge of the Fraser River at Hope, BC, from 1 October 2006 to 23 May 2007. The dashed line indicates the critical level (4.83 m) above which Fraser River discharge influenced water levels in the Herrling Island sidechannel in 2005 (add 27.926 m to the water levels shown here to convert to Geodetic Survey of Canada datum).

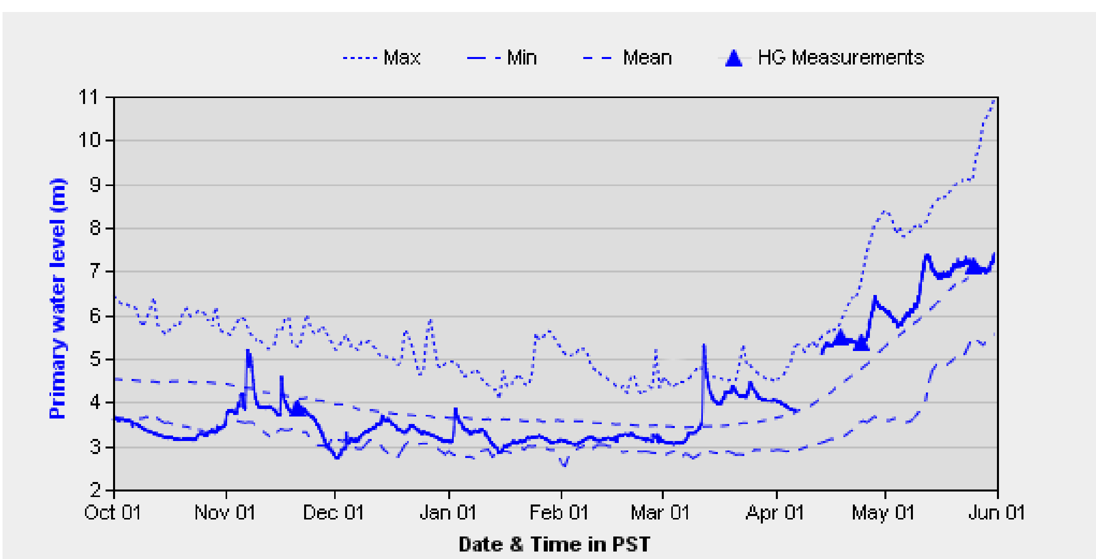


Figure 12. Stage height of the Fraser River at Hope, BC, from 1 October 2006 to 31 May 2007 relative to historical data (EC 2007).

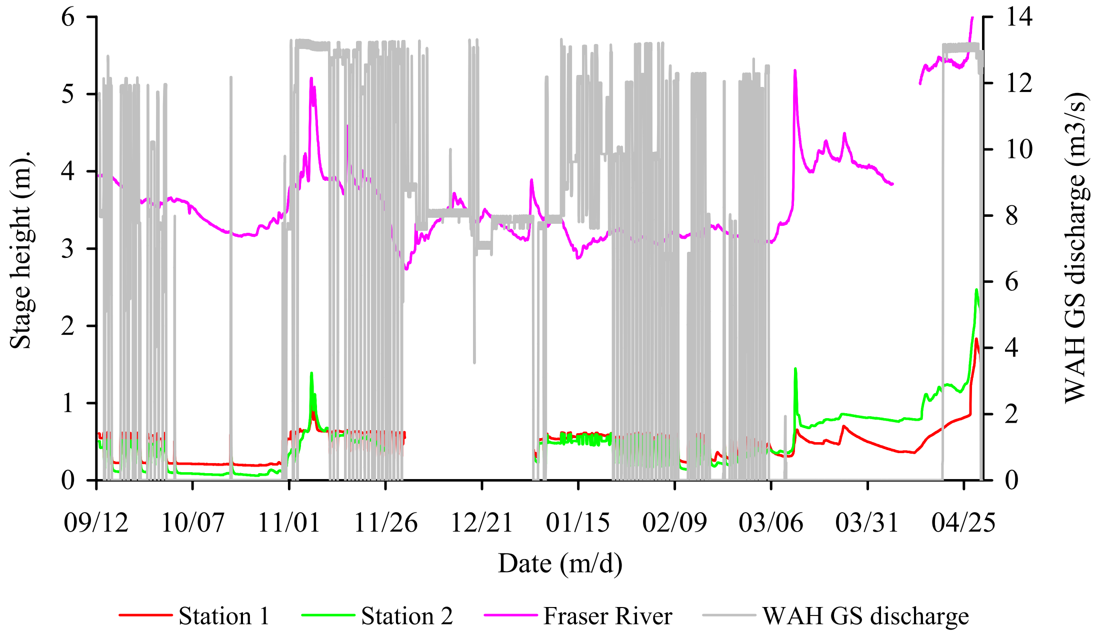


Figure 13. Hourly stage height of the Fraser River at Hope, stage height of the Herrling Island sidechannel at two hydrometric stations, and discharge at the WAH GS, 12 September 2006 to 30 April 2007.

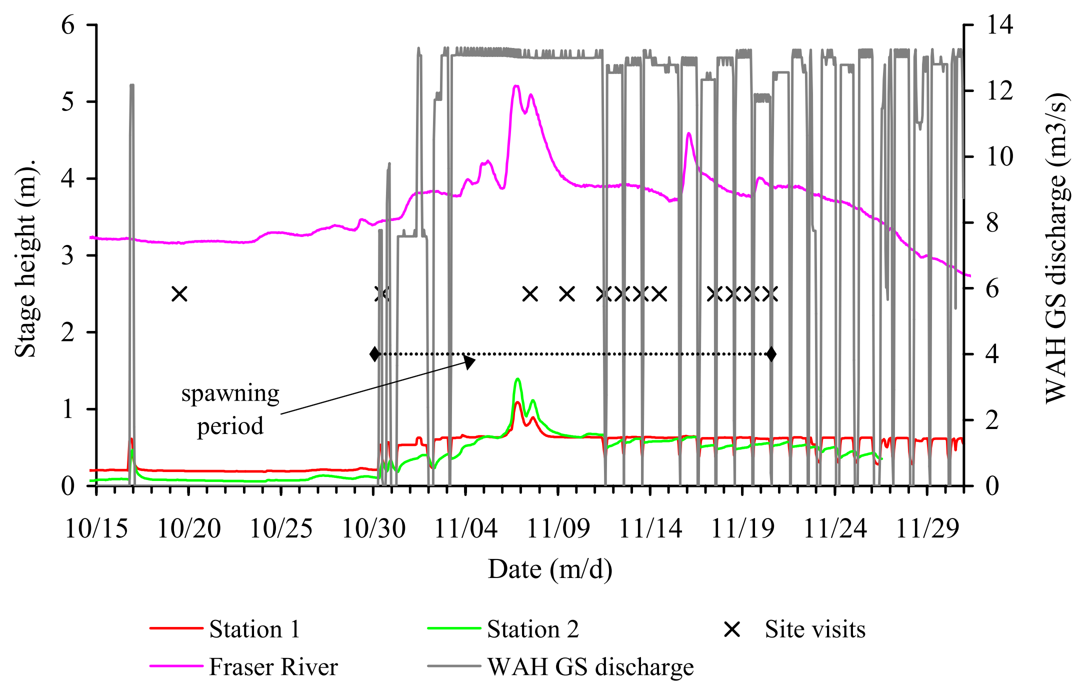


Figure 14. Hourly stage height of the Fraser River at Hope, stage height of the Herrling Island sidechannel at two hydrometric stations, and discharge at the WAH GS, 15 October to 1 December 2006. Days when site visits were conducted (X) and the major chum salmon spawning period (dashed line) were included for reference.

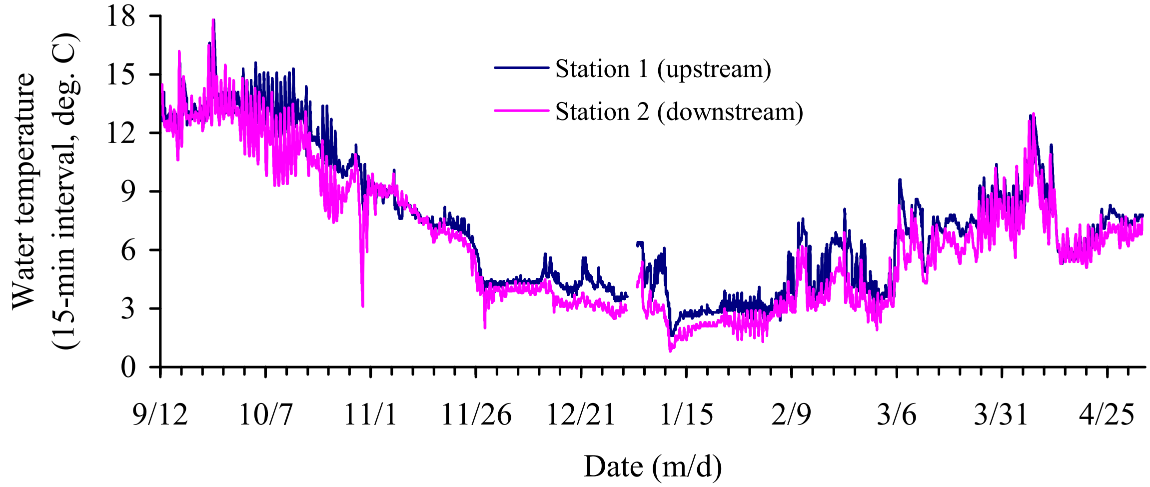


Figure 15. Water temperature of the Fraser River measured at two hydrometric stations located in the Herrling Island sidechannel from mid-September 2006 through April 2007.

Discharge at the Wahleach Generating Station

Apart from two brief periods of generation (2 h on 2 October and 5 h on 16-17 October), the WAH GS was shutdown from 0400 hours on 30 September to 0700 hours on 30 October (Figure 13, Figure 14). In an effort to draw fish into the Herrling Island sidechannel, BC Hydro discharged 8 m^3/s (40 MW) from 0700-1100 hours on 30 October. Over the 8-d period from 3-11 November, discharge at the WAH GS remained relatively constant at 13 m^3/s. Contrary to Water Licence requirements under normal operating conditions, the 15 September to 30 November daily 2-h shutdown of the WAH GS did not occur during this high inflow period. A note was sent to the Water Comptroller's office advising of the operation change. The decision to discontinue the WAH GS 2-h shutdowns was to reduce the potential threat of a free crest spill at Wahleach Dam with related downstream fisheries and property impacts adjacent to Jones Creek. In addition the potential inability to restart the WAH GS after a daily shutdown could have serious consequences with the inability to pass Wahleach Reservoir inflows. During sampling periods from 11-13 November and 17-20 November, WAH GS shutdowns occurred daily from approximately 1300-1500 hours. No WAH GS shutdown occurred on 14 November.

Fraser River Influence on the Herrling Island Sidechannel

The critical point where Fraser River stage height influenced water levels in the Herrling Island sidechannel was estimated in 2006. To do this, Herrling Island stage height was compared with Fraser River stage height and WAH GS discharge over several time periods. For example, from 1200 hours on 11 March 2007 to 0400 hours on 12 March 2007, a period when there was no WAH GS discharge, Fraser River stage height increased by 1.763 m (3.545-5.308 m; Figure 16). However, stage height in the Herrling Island sidechannel did not show a substantial increase during this period until the Fraser River stage height exceeded 4.970 m (0000 hours on 12 March). From 0200-1700 hours on 6 November 2006, a period when WAH GS discharge was held constant at 13.0 m^3/s, Fraser River stage height increased by 1.329 m (3.878-5.207 m;

Figure 17). Stage height in the Herrling Island sidechannel increased substantially at 1200 hours when the Fraser River stage height reached 4.952 m. Based on these examples, the Fraser River influences sidechannel levels when the stage height reaches about 4.96 m. Based on a critical level of 4.96 m, the Fraser River influenced water levels in the Herrling Island sidechannel during the chum salmon spawning period from 1300 hours on 6 November to 0000 hours on 7 November, and from 1000-1700 hours on 7 November. No field work was conducted during these periods.

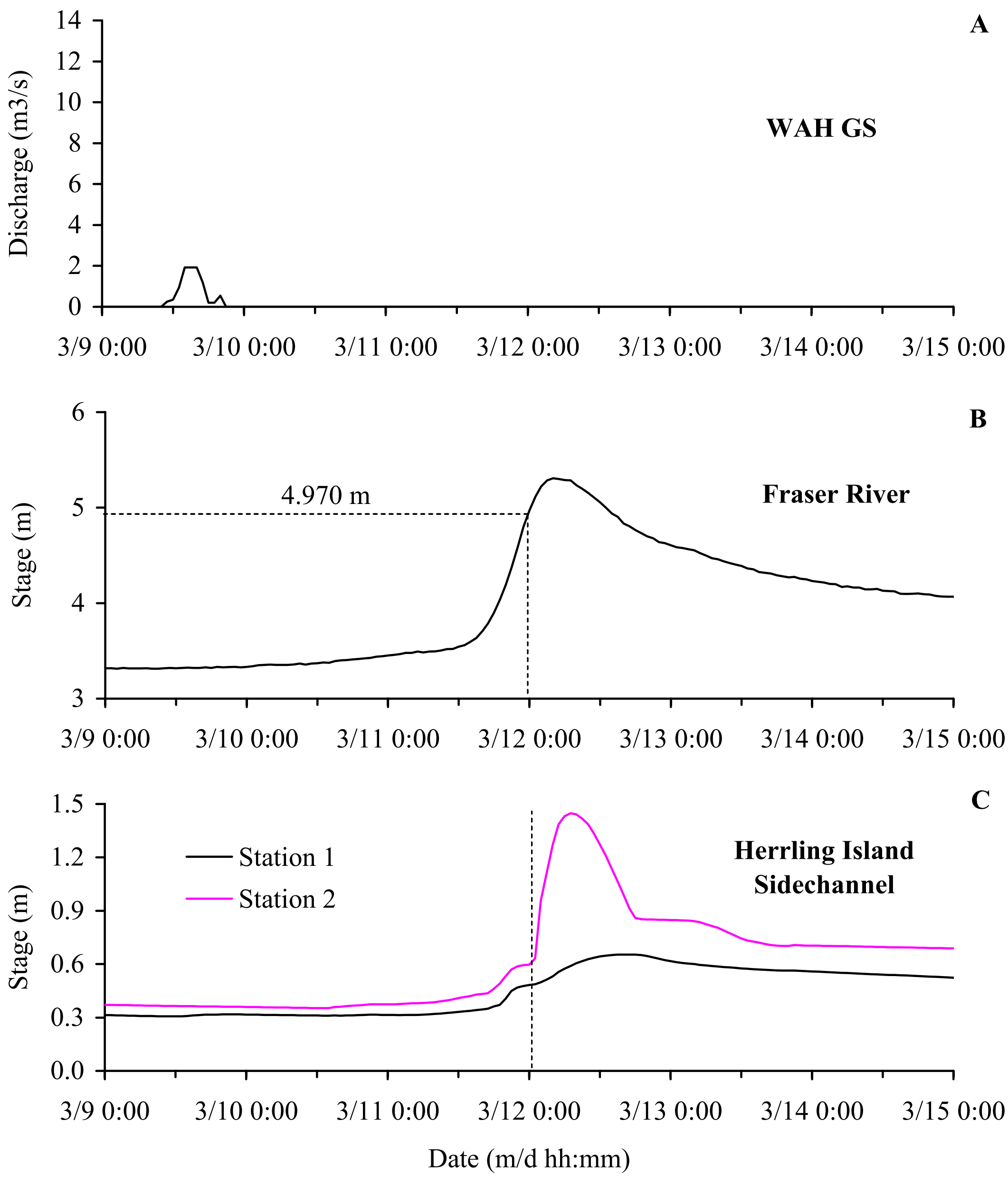


Figure 16. WAH GS discharge (Panel A), Fraser River stage height at Hope (Panel B), and Herrling Island sidechannel stage height measured at hydrometric stations 1 and 2 (Panel C), 9-15 March 2007.

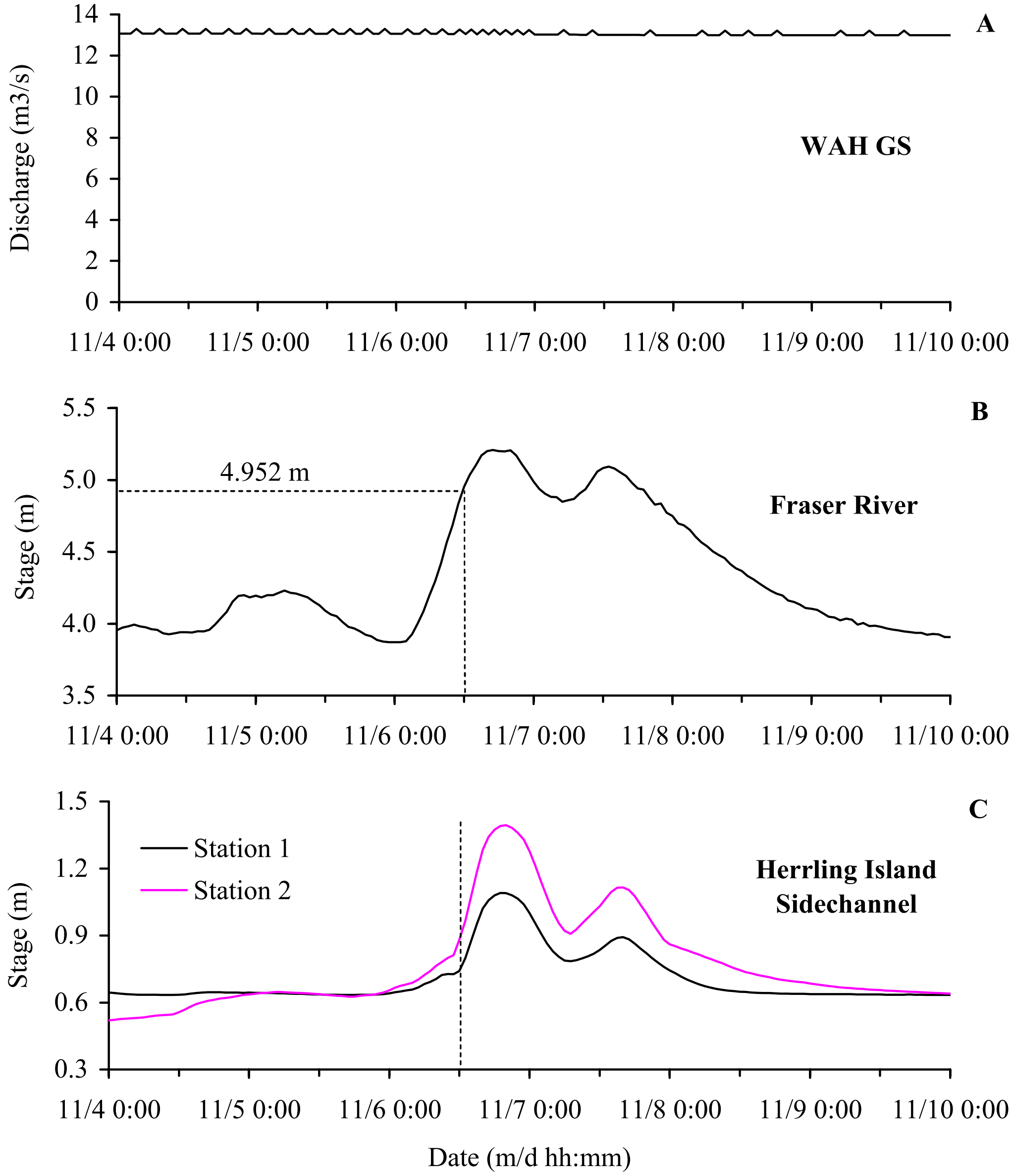


Figure 17. WAH GS discharge (Panel A), Fraser River stage height at Hope (Panel B), and Herrling Island sidechannel stage height measured at hydrometric stations 1 and 2 (Panel C), 4-10 November 2006.

It is important to note that there were periods when Fraser River stage height was less than 4.96 m yet still appeared to have a minor influence on sidechannel stage height (e.g., 0000-1200 hours on 6 November in Figure 17). This may have been caused by direct inflow at the top end of the sidechannel or by subsurface flows. Photos 6 and 7 show where the Fraser River flows into the Herrling Island sidechannel. Also, for a given change in Fraser River stage height, water levels at station 2 typically changed more dramatically than water levels at station 1 due to a more confined channel configuration. For example, from 0000-0700 hours on 12 March when Fraser River stage height increased by 0.316 m, water levels at station 1 increased by 0.108 m while water levels at station 2 increased by 0.857 m (Figure 16).

Adult Spawning Behaviour Observations

No chum salmon were observed during visits to the Herrling Island sidechannel on 6 October (site 3) and 19 October 2006 (sites 1 and 2). Water levels during these visits were extremely low and likely precluded fish from accessing spawning habitat in the upper reaches of the sidechannel. Subsequent field work was conducted between 30 October and 20 November 2006 (see Appendix E for a detailed summary of site visits).

<u>Site 1</u>

On 30 October, water levels at site 1 were still extremely low and no chum salmon were present. Chum salmon were observed at site 1 on 7 November and 9 November; however, high turbidity caused by heavy rains made it difficult to get an accurate count of fish. By 11 November, water levels had decreased substantially in the sidechannel. From 11-20 November, chum salmon counts ranged from 136 to 304 fish prior to WAH GS shutdowns, and from 204 to 302 fish during WAH GS shutdowns. The peak count of 304 fish occurred on 16 November. Counts made during WAH GS shutdowns were generally higher than counts made prior to shutdowns, which was attributed to being better able to see fish in the sidechannel at lower water levels.

The majority of chum salmon observed during this period were actively spawning in the left-bank "finger," followed by the middle and right-bank fingers. Surface flows were limited in the upper section of the left-bank finger. Due to the relatively steep banks along the middle section of the left-bank finger, spawning activity was typically confined to deeper areas. Water levels in the lower left-bank finger were typically lower than elsewhere in site 1.

On 17 November, a large number of eggs were observed spread over the top of a redd (ID#17-01-38) located in the upper section of the left-bank finger. River bed depth was approximately 3 cm and it appeared that the spawning fish had abandoned the redd during the WAH GS shutdown that afternoon. The redd was observed completed at 0930 hours on 18 November. It appeared that the chum salmon had returned to the redd to bury the eggs that were exposed the day before.

<u>Site 2</u>

On 30 October, up to 30 live, pre-spawn chum salmon and 6 carcasses were observed at index site 2 (Appendix E). These fish were actively digging redds in relatively deep, low-risk areas along the left bank of the sidechannel in a 200-m long section upstream from the mouth of Unnamed Creek (Photo 8). Fifteen live chum salmon were observed on 9 November, and 30 fish were observed on 13 November, although high turbidity on both days precluded accurate counts.

<u>Site 3</u>

On 30 October, up to 14 live chum salmon (holding) and 50 carcasses were observed at site 3 (Photo 9). No spawning activity was observed between the lower boundaries of sites 2 and 3.

Adult Stranding Risk Assessment

During the WAH GS shutdown on 18 November (1317 hours), two live chum salmon were observed lying on their sides in shallow water at the lower end of the left-bank finger at site 1 (Figure 18). At 1330 hours, the crew observed that these fish had died. During the same WAH GS shutdown, 3 three-spine stickleback (*Gasterosteus aculeatus*) were found dead in the left-bank finger of site 1. No adult chum salmon were found stranded at sites 2 or 3 in 2006.

Redd and Fry Stranding Assessment

A total of 49 chum salmon redds were identified during the 2006 study: 42 redds at site 1, 7 redds at site 2, and no redds at site 3 (Table 1, Table 2; Appendix F).

Table 1. Number of new chum salmon redds identified at index sites 1 and 2 in the Herrling Island sidechannel, 2006.

	Number of new redds		
Date	Site 1	Site 2	Total
11-Nov	6	-	6
12-Nov	7	-	7
13-Nov	8	0	8
14-Nov	5	-	5
17-Nov	7	-	7
18-Nov	2	-	2
19-Nov	3	-	3
20-Nov	6	-	6
30-Nov	-	5	5

Table 2. Location and condition of chum salmon redds observed in the Herrling Island sidechannel, 2006.

Index	Redd location		Redd Condition			
Site	Finger	Reach	Complete	Active	Partial	Total
1	Left-bank	Upper	3	0	1	4
		Middle	6	0	2	8
		Lower	8	1	4	13
	Middle	Upper	5	7	0	12
	Middle & Right-bank	Lower	1	3	1	5
2			0	0	7	7
3			0	0	0	0
Total			23	11	15	49

Site 1

Of the 42 redds identified at site 1, 23 were complete, 11 were active, and 8 were partial (Figure 18). Twenty-five redds were observed in the left-bank finger, 4 in the upper section, 8 in the middle section, and 13 in the lower section near the mouth of the small tributary that drains into the lower end of site 1. Twelve redds were observed in the upper section of the middle finger, and 6 redds were observed in the lower sections of the middle and right-bank fingers.

Eighteen (88%) of the 23 complete redds dewatered over the study period. Of these, 14 redds were observed dewatered during field observations in November 2006 and 4 redds were estimated to have dewatered at least once based on the relationship between measured redd depths and hydrometric station data (Figure 19). There were 904 dewatering events amongst the 18 complete redds that dewatered: 892 (99%) events occurred during egg incubation and 12 events occurred during fry emergence. These redds dewatered 9 to 58 times (avg. = 49.6) during egg incubation and 0 to 1 times (avg. = 0.7) during fry emergence (Figure 19). The duration of dewatering events for the 18 complete redds that dewatered at least once ranged from 0.25 h to 801 h during egg incubation and 0 h to 344 h during fry emergence (Figure 20). The cumulative length of time that individual redds were dewatered ranged from 309 h to 932 h (avg. = 675 h) during egg incubation and from 0 h to 344 h (avg. = 171 h) during fry emergence. Of the five complete redds that did not dewater, two were located in the upper left-finger and three were located in the middle left-finger of site 1.

Nine (82%) of the 11 active redds at site 1 dewatered over the study period. Of these, 4 redds were observed dewatered during field observations in November 2006 and 7 redds were estimated to have dewatered at least once (Figure 21). There were 352 dewatering events amongst the 9 active redds that dewatered: 345 (98%) events occurred during egg incubation and 7 events occurred during fry emergence. These redds dewatered 13 to 50 times (avg. = 38) during egg incubation and 0 to 2 times (avg. = 0.8) during fry emergence (Figure 21). The duration of dewatering events for the 9 active redds that dewatered ranged from 0.25 h to 141 h during egg incubation and 0 h to 180 h during fry emergence (Figure 22). The cumulative length of time that any one of these redds was dewatered ranged from 119 h to 628 h (avg. = 425 h) during egg incubation and from 0 h to 180 h (avg. = 77 h) during fry emergence. Seven active redds were located in the upper section of the middle finger, 2 active redds were located in the lower sections of the middle and right-bank fingers, and 1 active redd was located in the lower section of the left-bank finger. Both active redds that did not dewater were located in the upper section of the middle finger.

Eight redds identified by the crew did not appear to progress beyond the pit stage and thus were classified as partial redds. Of these, 3 redds were superimposed by other redds, 1 redd was located in shallow water in the upper section of the left-bank finger and was apparently abandoned during the 11 November WAH GS shutdown, and 4 redds simply did not appear to be completed. Four partial redds were observed dewatered at least once during field observations in November 2006 and 3 partial redds were located in shallow water (i.e., ≤ 6 cm bed depth during WAH GS shutdowns).

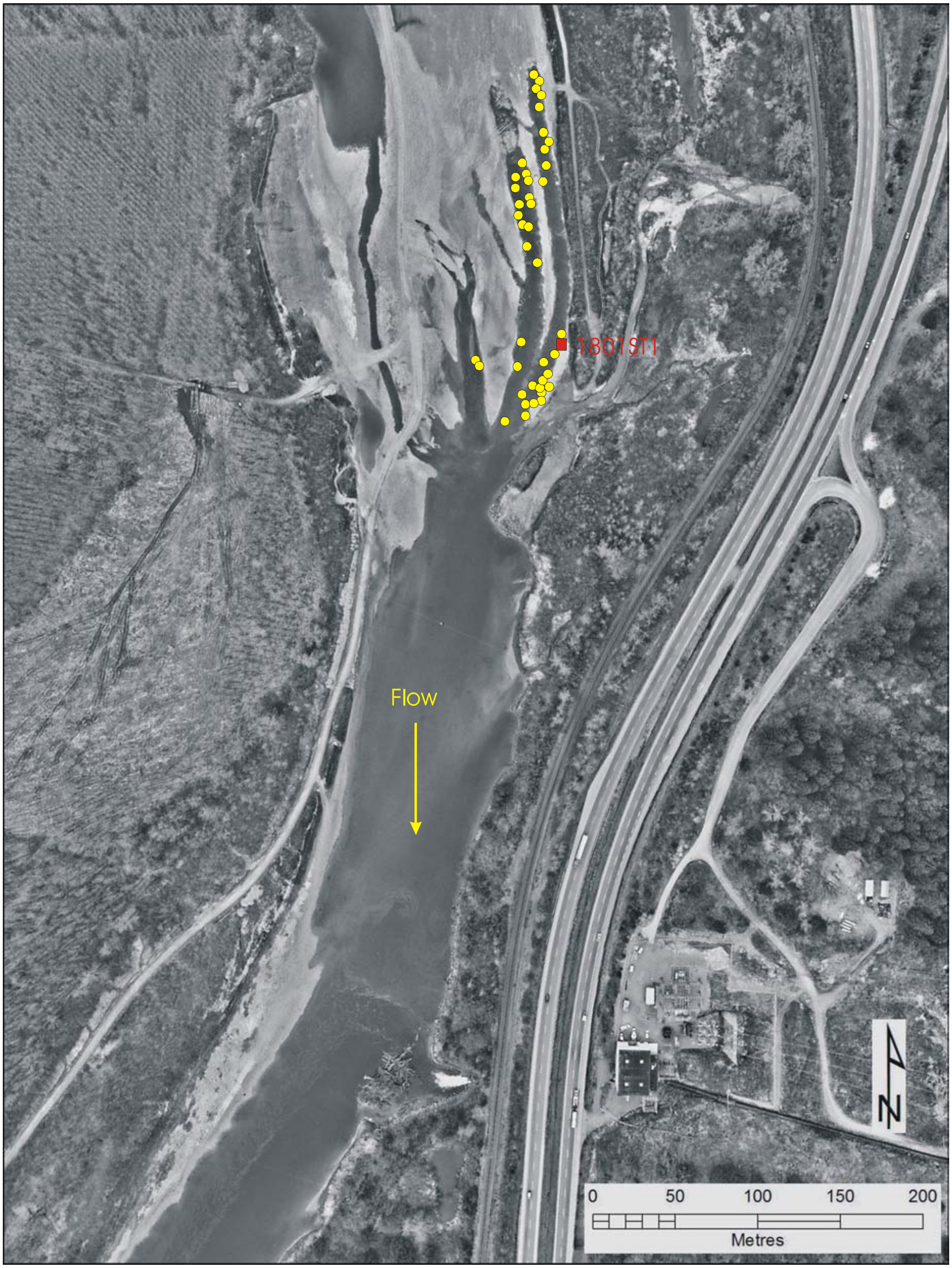


Figure 18. Location of chum salmon redds (yellow circles) and an adult stranding event (red square) that were observed at site 1 in the Herrling Island sidechannel, 2006.

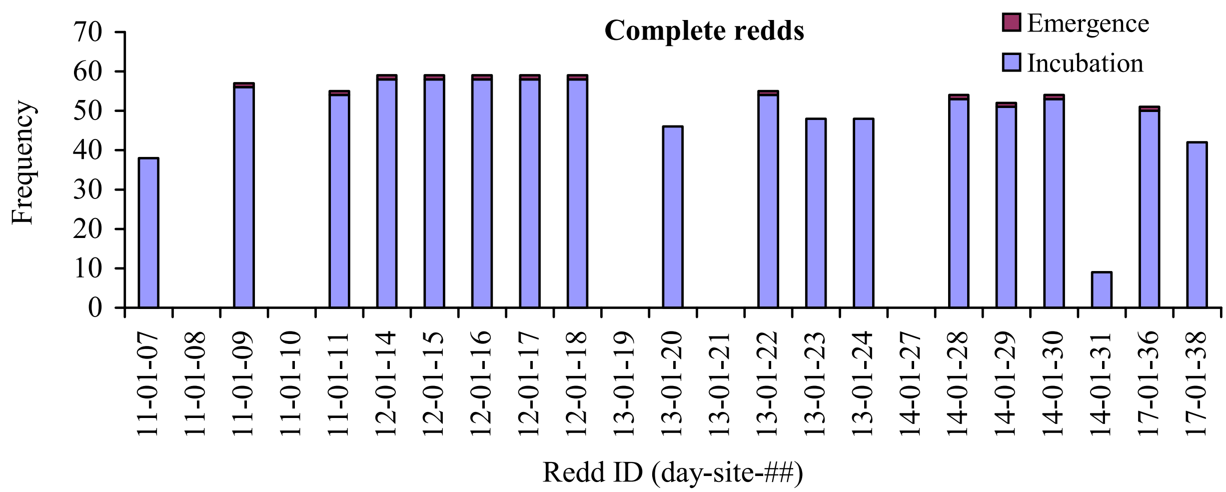


Figure 19. Frequency of dewatering events for 23 chum salmon redds that were classified as complete and monitored at site 1 from incubation through emergence in the Herrling Island sidechannel, 2006.

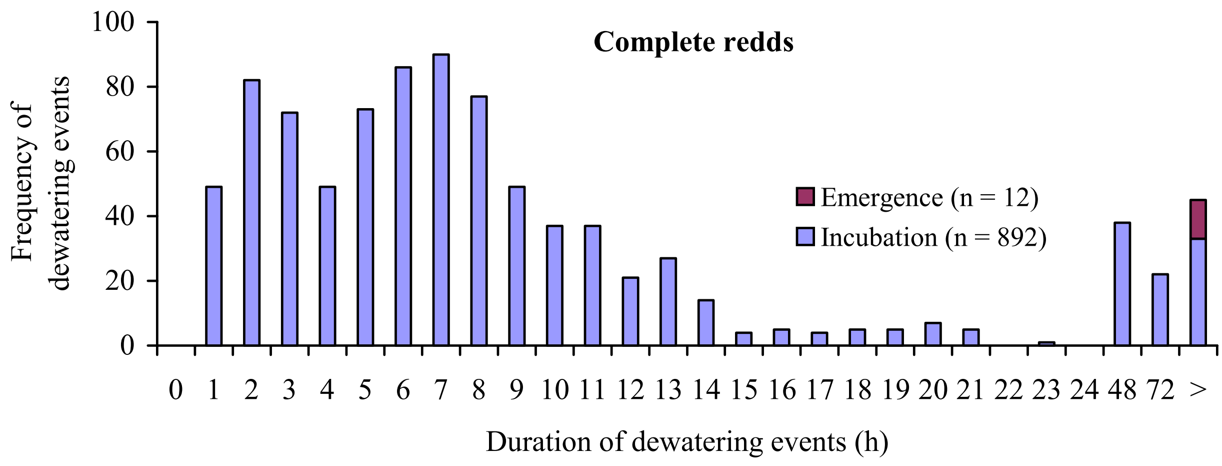


Figure 20. Duration of dewatering events for 23 chum salmon redds that were classified as complete and monitored at site 1 from incubation through emergence in the Herrling Island sidechannel, 2006.

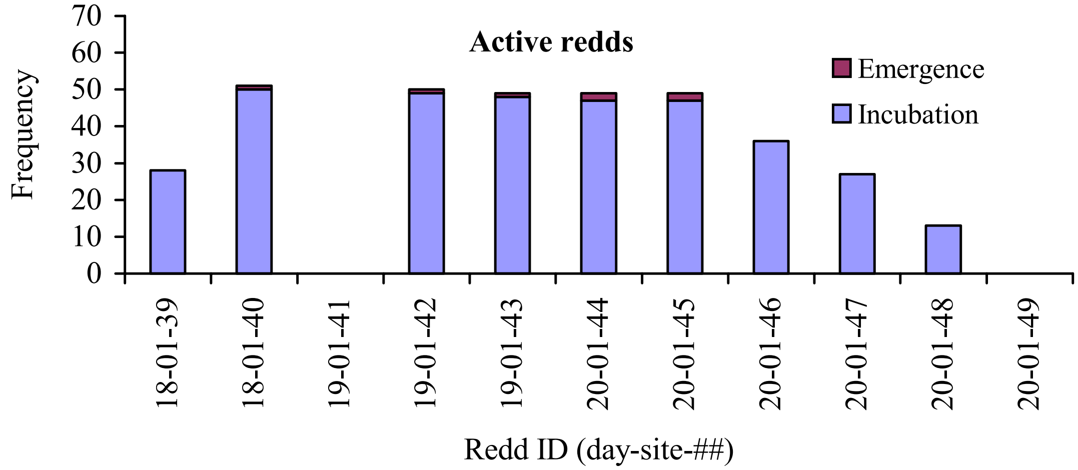


Figure 21. Frequency of dewatering events for 11 chum salmon redds that were classified as active and monitored at site 1 from incubation through emergence in the Herrling Island sidechannel, 2006.

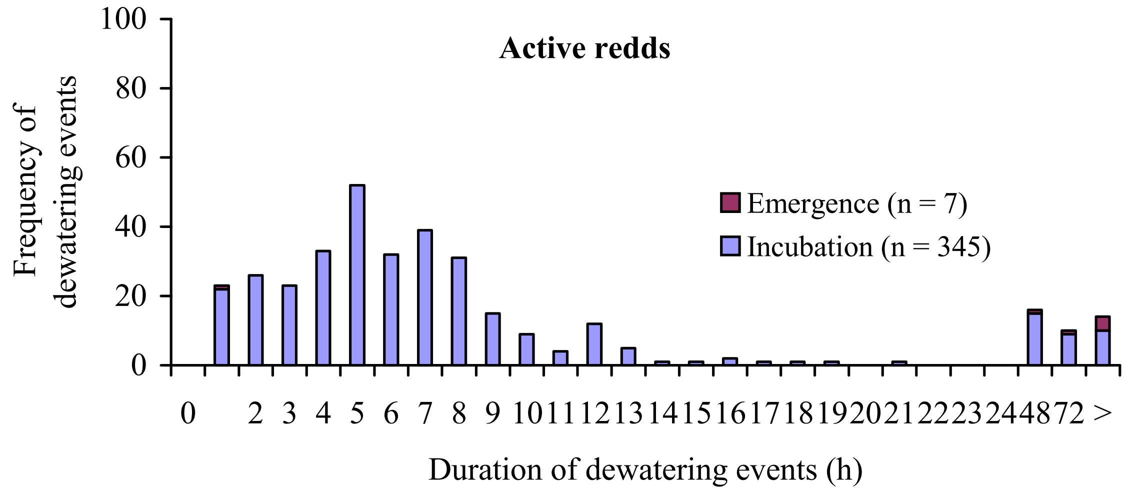


Figure 22. Duration of dewatering events for 11 chum salmon redds that were classified as active and monitored at site 1 from incubation through emergence in the Herrling Island sidechannel, 2006.

<u>Site 2</u>

Seven redds were measured for depth at site 2 (Figure 23). These redds were classified as partial, although due to poor visibility it was difficult to assess their true condition. None of the redds were observed dewatered during field observations. Visits to site 2 were sporadic and thus the relationship between water depths measured at the redds and hydrometric station 2 were weak. However, based on the range of pit (0.13-0.94 m) and bed (0.03-0.89 m) depths encountered it is unlikely that the redds at site 2 dewatered during egg incubation or fry emergence.

Figure 23. Location of chum salmon redds (yellow circles) observed at site 2 in the Herrling Island sidechannel, 2006.

Site 3

No chum salmon redds were observed at site 3 in 2006.

DISCUSSION

Adult Spawning Behaviour Observations

Record low Fraser River discharge and limited discharge from the WAH GS led to extremely low water levels in the Herrling Island sidechannel for most of October 2006. These conditions may have limited or restricted fish access to the sidechannel as well as changed the timing of spawning at the index sites relative to 2005. The first chum salmon were observed in the sidechannel on 30 October 2006, which was 13 d later than their arrival date in 2005. Although it is possible that the 50 chum salmon carcasses observed at site 3 on 30 October were fish that had spawned at site 2, it seems more likely that these were pre-spawn mortalities that were unable to access upstream spawning areas (i.e., site 1) during low water levels. In 2005, chum salmon were first observed at site 1 on 17 October; their numbers peaked on 27 October and had declined substantially by 15 November. In contrast, no chum salmon were observed at site 1 until 7 November 2006, and their numbers remained relatively high through 20 November. The pulse of fish at site 2 in mid-November was relatively small in 2006 (30 fish) compared to the numbers seen in 2005 (300 fish). It is also worth noting that water temperatures at station 1 averaged 12.0 ^{o}C (7.8 - 15.6 ^{o}C) in October 2006 which was higher than the average water temperature of 10.7 ^{o}C (8.3 - 13.8 ^{o}C) in October 2005.

Changes in spawning behaviour (e.g., distribution in channel, fish size relative to spawning location, territoriality) during periods of high and low flows were not easily quantified. Nonetheless, the crew reported that fish in site 1 appeared "stressed" due to decreases in water levels during the WAH GS shutdowns on 11, 18, and 20 November. For example, when water levels dropped during a WAH GS shutdown, fish in low-water sections of the left-bank and middle fingers of site 1 had to quickly swim downstream to deeper water to escape being stranded. This behavioural response requires fish to utilize resources that would otherwise be allocated to spawning activity. In contrast, there were instances where fish tended to remain on or near their redds during WAH GS shutdowns when they clearly had access to deeper water. This territorial behaviour would undoubtedly increase stress levels and exposure to predation.

From early November to the end of December 2006, the WAH GS discharged sediment-laden water into the Herrling Island sidechannel (Photo 10). These releases were the result of a slide in the Wahleach Reservoir watershed. The sediment releases may have contributed to poor visibility at site 2 on 9 November and 13 November, but they did not noticeably increase turbidity levels at site 1 during the sample period or confound results of the study.

Adult Stranding Risk Assessment

In general, although water levels at site 1 were relatively low during WAH GS shutdowns in November 2006, most chum salmon were able to escape into deeper water at the lower end of the site and thus avoid being stranded. Only two chum salmon (and 3 three-spine stickleback) were observed stranded in the lower section of the left-bank finger in site 1 during WAH GS shutdowns. Although spawning densities in the upper sections of site 1 were also high, these areas were more buffered from the effects of attenuating water stage during WAH GS shutdowns. No adult chum salmon were found stranded at sites 2 or 3 in 2006. To reduce the probability of adult stranding, it is recommended that reductions in WAH GS discharge be attenuated over a prolonged period so that fish have more time to move to deeper water in the sidechannel.

Redd and Fry Stranding Assessment

Suspending WAH GS discharge for 2 h daily during chum salmon spawning did not appear to eliminate redd or fry stranding in the Herrling Island sidechannel during this study. Overall, 27 out of 34 or 79% of the complete and active redds in site 1 dewatered at least once. This was substantially higher than the 40% of redds that were observed dewatered at site 1 in 2005. Continuous WAH GS discharge from 3-11 November 2006 may have increased the proportion of chum salmon spawning in at-risk areas in site 1 relative to 2005. A portion of the redds identified and measured for depth may have been formed prior to the commencement of WAH GS shutdown events. If so, the frequency and duration of dewatering events as related to WAH GS operational measures may be biased high. However, the proportion (16/21 = 76%) of active and partial redds measured from 11-14 November that dewatered at least once was not significantly different than the proportion (11/13 = 85%) measured from 17-20 November that dewatered at least once ($\chi^2 = 0.35$, $P = 0.55$, df = 1). None of the redds at site 2 were believed to have dewatered; however, insufficient data was collected at these redds to conduct a thorough redd and fry stranding assessment. Similar to 2005, redd dewatering was more frequent during egg incubation than during fry emergence.

Potential impacts of flow fluctuations on the developmental phases of salmon will vary with the timing, magnitude, and duration of the fluctuations as well as with characteristics of the affected site. Water-level reductions over a salmonid redd may cause a cessation of inter-gravel flow and drainage of water from gravel, changes in water temperature, desiccation, reduced dissolved oxygen concentrations, settling of gravel, and increased concentration of biotic wastes (Neitzel and Becker 1985). Studies have shown that incubating salmon eggs are considerably more tolerant of dewatering than alevins that have not yet emerged from the substrate (Becker et al. 1982; Becker et al. 1983; Neitzel and Becker 1985). McMichael et al. (2005) reported that Chinook salmon (*O. tshawytscha*) redds could be expected to tolerate dewatering periods as long as 8 h, whereas fry survival would be expected to be significantly impacted if redds were dewatered for even 1 h. Given the frequency, duration, and extent of dewatering events observed in the Herrling Island sidechannel from November 2006 to May 2007, it is reasonable to assume that the events had a negative effect on the survival of chum salmon eggs and emerging fry. For example, if the tolerance limits for Chinook salmon reported by McMichael et al. (2005) held true for chum salmon, then 78% of complete redds and 82% of active redds in site 1 were significantly impacted by dewatering events in 2006.

One potential source of uncertainty in the redd and fry stranding assessment related to the method used to calculate the depth where a redd dewatered. In 2005, redd depths were measured from the deepest area of the pit to the surface of the river. For the majority of redds, the first depth measurement was also the deepest. Subsequent depth measurements tended to be shallower which may have been due to redd superimposition, infilling of partial redds, substrate scour/aggradation, measurement error, WAH GS discharge, or the degree of Fraser River influence. DeVries (1997) explained that if the pit depth were measured pre-spawning, it should be equal to the depth of the deepest egg pocket. If it is measured post-spawning, the depth may underestimate egg depths because females only dig deep enough to cover the last eggs deposited. Therefore, it is possible that the redd depths used in the 2005 dewatering analysis were biased low, and the depths where redds were considered dewatered biased high. In 2006, both the redd depth and the depth of the undisturbed river bed adjacent to the redd were measured; but only the latter was used to calculate the depth at which the redd dewatered. DeVries (1997) suggested that the depth of the undisturbed river bed may be a more consistent measure. Since the bed depth was typically shallower than the redd depth, the depth of dewatering was also shallower, which likely contributed to the higher proportion of redds observed dewatered in 2006 relative to 2005.

Due to the large data gap in hydrometric station data, the frequency and duration of dewatering events from the end of November 2006 to early January 2007 could not be estimated. Given the low Fraser River discharges and moderate WAH GS discharges, it was likely that many of the redds measured in 2006 dewatered during this period. The proportion of redds that dewatered, as well as the frequency and duration of dewatering events presented in this report, may be biased low as a result.

Dewatering events were categorized as either egg stranding during incubation (October 2006 – 31 March 2007) or fry stranding over emergence (1 April – 3 May 2007). These periods were based on outmigration data for chum salmon fry collected at nearby Jones Creek in 2005 (MacNair 2005b). McNair (2005b) reported that chum salmon fry were captured from 26 March to 18 May, with 10% of fish captured by 6 April, 50% by 25 April, and 90% by 10 May. If the timing of fry outmigration in the Herrling Island sidechannel is assumed to be the same, then a small number of fry may have been outmigrating after the hydrometric stations were shutdown on 3 May.

As in 2005, it was difficult for the crew to access and measure chum salmon redds located in deeper water areas in 2006, particularly when turbidity was high. These deep-water redds tend to be in areas that are less likely to dewater. It is therefore possible that the redds measured in 2006 were not necessarily representative of all the redds in the index site. If so, then the redd and bed depths measured may biased "shallow," and the frequency and duration of dewatering events may be biased high.

The two hydrometric stations were placed in locations suitable for measuring river depth and temperature from September 2006 through May 2007; however, neither was situated within an index site. As a result, water depths and temperatures recorded at the stations were not necessarily representative of the conditions within the index sites. For example, a 1.0 cm decrease in water level at hydrometric station 1 translated into a 0.45 cm decrease in water level in the upper section of site 1 (rebar 1) and a 0.85 cm drop in water level in the middle section of site 1 (rebar 2). Due to this discrepancy it was necessary to use regression analysis to determine the relationship between changes in sidechannel depths and subsequent changes in redd depths in different sections of site 1. It is recommended that temporary staff gauges continue to be used and monitored during subsequent studies.

In 2006, Fraser River surface flows influenced water levels in the Herrling Island sidechannel until the elevation at Hope dropped below 4.96 m. This threshold level was similar to the 4.83 m level reported by Smith (2006) following the 2005 field study and to the 4.9 m level reported by Parsonage and Leake (1999).

Mitigative Measures (in lieu of WAH GS operations)

Parsonage and Leake (1999) and Smith (2006) recommended a mitigative measure to reduce the potential impacts of WAH GS operations on the spawning success of chum salmon in the Herrling Island sidechannel. This recommendation involves excavating and reconfiguring the three spawning “fingers” at index site 1. There is evidence that infilling of the right-bank finger has made this habitat unsuitable for spawning. McLean (1998) observed chum salmon spawning in the right-bank finger; however in 2005 and 2006, chum salmon were only observed spawning in the left-bank and middle fingers (except for 1 redd that was observed in an area between fingers 2 and 3 in 2006). If the depth of the fingers was increased, then the quantity of spawning habitat would increase and the probability of adult stranding and redd dewatering would decrease. If the slope of the banks was steepened, adult chum salmon may be restricted to areas that are at a lower risk of dewatering. And lastly, additional spawning habitat could be created by extending the fingers at site 1 farther upstream. Low water levels encountered during the 2006 field study highlighted the need to follow-up on this recommendation. As of July 2007, Scott Paper Ltd. was planning to excavate and reconfigure the fingers at site 1 in the August-September 2007 time period (D. Hunter, personal communication).

Recreational users may have a negative impact on chum salmon spawning success in the Herrling Island sidechannel. As in 2005, off-road vehicles were observed driving through areas known to contain chum salmon redds in 2006. To reduce the potential impacts of human activities, it is recommended that vehicle use be confined to areas where there is no chum salmon spawning habitat. Efforts to raise public awareness amongst recreational users of the sidechannel should also be undertaken (e.g., put up signs designating spawning habitat, contact off-road vehicle groups).

Data Collection Methods

The following list contains items that may improve data collection in future years:

- To determine the relative success of redds in areas at risk of dewatering to those not at risk of dewatering, a hydraulic sampler should be used to estimate the density of eggs in both habitat types. We propose that sampling be initiated in January 2008 at known chum and pink salmon spawning areas in the sidechannel.

- WAH GS shutdowns should continue to occur during daylight hours when fieldwork is being conducted. In the original study plan, WAH GS shutdowns were planned from 2200-0000 hours daily such that the majority of field observations would have been at night. However, conducting this field work during the night would be extremely difficult and not nearly as effective as the day-time surveys conducted in 2005 and 2006.

- A portion of chum salmon carcasses found in the sidechannel should be inspected to confirm whether they are pre- or post-spawn mortalities.

- Two temporary staff gauges (rebar 1 and 2) in site 1 should be installed and monitored in subsequent years, and a third gauge should be installed near the lower end of site 1.

- Site visits during one or two low-water periods between December and May would provide additional information on water conditions (e.g., water depth, water velocity, amount of dewatered habitat, location of dewatered redds) and help "ground-truth" results from the redd and fry stranding assessments.

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APPENDICES

Appendix A. Past studies of chum salmon and spawning habitat in the Herrling Island sidechannel (adapted from Parsonage and Leake [1999]).

Date	Proponent	Topic	Results
1998		Flow vs. wetted area of sidechannel	Decreasing WAH GS flows from 60 to 40 MW decreased wetted area by 15%; decreasing flows from 60 to 0 MW decreased wetted area by 25%.
Apr 1998		Fry stranding	WAH GS was shut down. Habitat dewatered at head of tailrace pool, in the fingers and at Sites 3 & 4. Fry stranded in isolated pools at Sites 1-3 (not Site 4); 300 fry salvaged over 2 days.
Oct 1998	BC Hydro, DFO (BC Hydro 1998)	Flow vs. chum spawning	Flow decreased from 40 to 0 MW. Four sites were surveyed, 2 adult chum found stranded, redd dewatering at two of the sites, fish access was maintained throughout the shutdown.
Oct 1998	BC Hydro (McLean 1998)	Flow vs. chum spawning	WAH GS shut down for 18 h. Three sites surveyed, no apparent effect on spawning activity; several dewatered redds but no eggs found in them; no evidence of stranding.
Apr 1999	Ben Alken	Habitat survey	10 habitat units, 3 habitat types, coarse gravel-sand.

Appendix B. Description of hydrometric stations installed and operated in the Herrling Island sidechannel from September 2006 through May 2007.

VIA-SAT DATA SYSTEMS INC.
124 Garden Avenue, North Vancouver, B.C. V7P 3H2
Tel: 604-980-6062 - Fax: 604-980-9262
www.via-sat.com

Dave Hunter
Natural Resource Specialist
Coastal Generation
BC Hydro

7 May 2007

Herrling Island Hydrometric Stations

This letter outlines the attached 2006 and 2007 data for the two hydrometric stations at Herrling Island (Herrling #1 Upstream and Herrling #2 Midstream). They were originally installed on September 28, 2005 and removed on April 27, 2006. The stations were then re-installed on 12 September 2006, and surveyed into the existing datum. Station #1 was removed again on 3 May 2007. We were unable to remove station #2 due to high water levels. The data summaries for stations #1 and #2 have been updated to include the data from 22 November 2006 to 3 May 2007.

The data from these stations are in Excel spreadsheets. These spreadsheets contain multiple sheets. The hourly and daily data sets and plots are compiled from the original 15-minute data set. Daily minimum, average and maximum daily water temperatures have also been included.

Herrling Island #1 Upstream

Since being reinstalled on 12 September 2006 until removal on 3 May 2007, there had been 3 service trips to this site.

Between 12 September 2006 to 22 November 2006, the pressure transducer was logging correctly and no problems were encountered.

Between 22 November 2006 and 1 December 2006 the pressure transducer was reading correctly. After 1 December 2006, the transducer was clogged with silt and was not able to accurately record the water levels. Data from 1 December 2006 to 3 January 2007 was removed and the pressure transducer was cleaned of the silt.

From 3 January 2007 to 3 May 2007, when the pressure transducer was removed, data was logging correctly and no problems were encountered.

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Herrling Island #2 Midstream

Since being reinstalled on 12 September 2006 until 3 May 2007, there had been 3 service trips to this site.

Between 12 September 2006 to 22 November 2006, the pressure transducer was logging correctly and no problems were encountered.

Between 22 November 2006 and 26 November 2006 the pressure transducer was reading correctly. After 26 November 2006, the transducer was clogged with silt and was not able to accurately record the water levels. Data from 26 November 2006 to 3 January 2007 was removed and the pressure transducer was cleaned of the silt.

From 3 January 2007 to 3 May 2007, data was logging correctly. Upon arrival on 3 May 2007, the water level was too high for the removal of the pressure transducer. The end connector and desiccant were sealed into a container using silicone and electrical tape for protection against flooding that may occur.

If you have any questions, feel free to contact me at 604-980-6062 or pcr@via-sat.com.

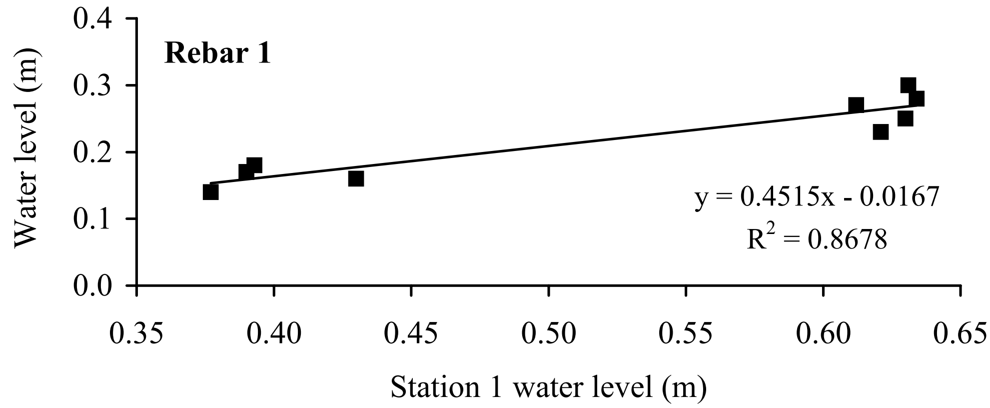
Sincerely,

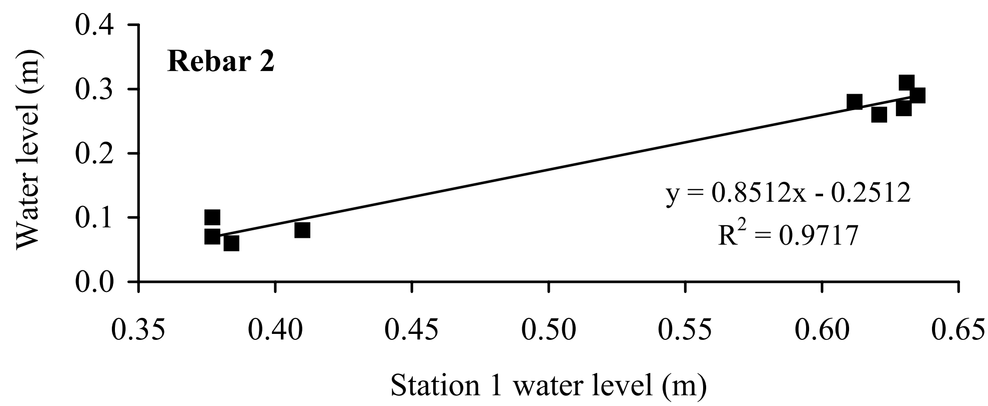
Paul Rocchetti, A.Sc.T
Manager, Via-Sat Data Systems

Attachments: Herrling 1_2006.xls, Herrling 1_2007.xls
Herrling 2_2006.xls, Herrling 2_2007.xls

Appendix C. Water levels (m) recorded at two, temporary staff gauges installed at index site 1. Water levels at these gauges were then compared to corresponding water levels recorded at hydrometric station 1.

	Rebar 1 (60 m from top of site 1)				Rebar 2 (150 m from top of site 1)			
	Before shutdown		During shutdown		Before shutdown		During shutdown	
Date	Time	Depth (m)	Time	Depth (m)	Time	Depth (m)	Time	Depth (m)
14-Nov	9:26	0.30			9:42	0.31		
17-Nov	9:32	0.23	13:22	0.14	9:45	0.26	13:22	0.10
18-Nov	9:30	0.25	13:00	0.16	10:01	0.27	13:11	0.08
19-Nov	11:00	0.28	13:14	0.17	11:10	0.29	13:20	0.06
20-Nov	9:30	0.27	13:19	0.18	9:56	0.28	13:28	0.07





Appendix D. Wetted width and water depth recorded before and during WAH GS shutdowns at 10-m increments in a 100-m section of the upper left-bank finger of index site 1, 2006.

		Prior to shutdown		During shutdown			
Date	Distance (m)	Wetted width (m)	Depth (m)	Wetted width (m)	Depth (m)	Change in wetted width (m)	Change in depth (m)
12-Nov	0	4.4	0.07	3.5	0.03	-1.0	-0.04
	10	7.3	0.15	5.4	0.10	-1.9	-0.05
	20	9.4	0.13	8.3	0.11	-1.1	-0.02
	30	9.3	0.30	7.0	0.20	-2.2	-0.10
	40	11.9	0.18	9.9	0.15	-2.0	-0.03
	50	13.0	0.24	12.4	0.16	-0.6	-0.08
	60	13.1	0.22	12.4	0.19	-0.6	-0.03
	70	12.6	0.21	11.3	0.15	-1.4	-0.06
	80	11.9	0.26	10.3	0.25	-1.6	-0.01
	90	11.4	0.24	10.5	0.23	-0.9	-0.01
	100	10.6	0.29	6.3	0.11	-4.2	-0.18
	Average	10.4	0.21	8.8	0.15	-1.6	-0.05
	% change					-15.3%	-26.3%
17-Nov	0	3.8	0.09	0.9	0.05	-2.9	-0.04
	10	6.5	0.17	4.8	0.06	-1.7	-0.11
	20	9.1	0.16	8.3	0.12	-0.8	-0.04
	30	7.7	0.22	6.7	0.17	-1.1	-0.05
	40	9.3	0.22	3.6	0.11	-5.7	-0.11
	50	11.5	0.21	10.3	0.14	-1.2	-0.07
	60	12.9	0.25	12.4	0.16	-0.5	-0.09
	70	12.6	0.17	10.0	0.12	-2.6	-0.05
	80	11.9	0.28	10.7	0.20	-1.2	-0.08
	90	11.5	0.28	10.4	0.17	-1.1	-0.11
	100	8.9	0.20	7.3	0.10	-1.7	-0.10
	Average	9.6	0.2	7.8	0.13	-1.9	-0.08
	Change (%)					-19.3%	-37.8%

Appendix E. Summary of site visits and daily chum salmon observations in the Herrling Island sidechannel, 2006.

		Before Shutdown					After Shutdown					
Date	Site	Start	Stop	# Chum	Activity	Comments	Start	Stop	# Chum	# Stranded	Comments	General Observations
6-Oct	3			0								D. Hunter & M. Fredette site visit - no fish, extremely low flow may be limiting access to channel.
19-Oct	1,2											M. Fredette site visit - no fish, low water
30-Oct	1	8:30	9:30	0		No fish, very low water, > 3ft visibility.						Very little water in fingers; access & suitability for spawning limited.
30-Oct	2	10:00	10:30	24	pairing, digging	Fish in rough shape; activity only in deeper, low-risk areas; 6 carcasses.	13:06	14:15	30		Slower velocities; water dropped 9 cm from 10:10-13:40; 1-10 ft of margins dewatered depending on bank slope.	Little fish activity; possibly end of "early" run; no noticeable behavior changes after shutdown.
30-Oct	3	11:30	12:00	55	postspawn?, holding	50 morts, 5 live, no signs of spawning activity (now or in past).	14:15	15:15	64		50 morts; 4 live in upper area; 10 live at gravel-pit road.	These fish were probably drop-backs from site 2 or did not successfully spawn due to water levels.
7-Nov	1,2											M. Fredette site visit - very high, murky water, fish present, poor vis.
09-Nov	1			100		Poor visibility; count inaccurate.						
09-Nov	2			15	prespawn	Poor visibility; count inaccurate.						
09-Nov	3			5	holding	No signs of spawning activity.						Fish may be dying prespawn.
11-Nov	1	9:00	11:15	239	digging/spawning	Fish in all 3 fingers and creek; 40 postspawn carcasses.	13:00	14:00	276		Low water; fish appear stressed, remain near redds despite deeper water being available.	Off-road vehicles present
12-Nov	1	9:00	11:55	136	digging/spawning		13:00	14:30	204			Heavy rain most of day. Photos taken before/after SD.
13-Nov	1	9:00	11:00	241	spawning	Fish holding in creek; carcasses present	12:30	14:00	276			Heavy rain in PM.
13-Nov	2	11:10	11:30	30	digging/spawning	Turbid water, can not locate redds						
14-Nov	1	8:00	10:30	224	spawning	20 carcasses	-	-	-			No GS shutdown in PM due to rain.
17-Nov	1	9:00	11:00	236	spawning		13:00	14:35	302			

Appendix E (continued). Summary of site visits and daily chum salmon observations in the Herrling Island sidechannel, 2006.

		Before Shutdown					After Shutdown					
Date	Site	Start	Stop	# Chum	Activity	Comments	Start	Stop	# Chum	# Stranded	Comments	General Observations
18-Nov	1	9:00	11:30	304	spawning	Less active spawning; seems like more fish holding in creek	13:00	14:00	300	2	Active spawning, 2 prespawn males observed stressed, lying on side at 1317 h, later found both dead on redd	ATV's driving through 3rd finger, redds probably disturbed; found 3 dead stickleback (1 at top of 1st finger, 2 at bottom)
19-Nov	1	9:00	11:30	254	spawning	Fish in all 3 fingers	13:00	14:00	287			Heavy rain in AM; fish hard to see; anglers trying to catch chum by hand.
20-Nov	1	9:00	11:30	251	active digging	Fish more active after rain stopped	13:00	14:00	284		3 fish at bottom of 2nd finger appear stressed after shutdown (2M/1F); fish healthy new spawners	Raining in AM; 2 cutthroat at bottom of fingers

Appendix F. Location of chum salmon redds, stranding event, and temporary staff gauges in the Herrling Island sidechannel, 2006.

ID (day-site-#)	Date-Time	UTM Coordinates
Redds		
110106	11/11/2006 9:55	10 U 596007 5455181
110107	11/11/2006 10:07	10 U 595989 5455157
110108	11/11/2006 10:12	10 U 596007 5455139
110109	11/11/2006 10:19	10 U 595981 5455138
110110	11/11/2006 10:25	10 U 595997 5455121
110111	11/11/2006 10:29	10 U 595997 5455116
120112	11/12/2006 10:37	10 U 596003 5455150
120113	11/12/2006 11:19	10 U 595995 5455003
120114	11/12/2006 11:22	10 U 595995 5455013
120115	11/12/2006 11:27	10 U 596004 5455036
120116	11/12/2006 11:28	10 U 595999 5455026
120117	11/12/2006 11:35	10 U 596005 5455039
120118	11/12/2006 11:39	10 U 596003 5455033
130119	11/13/2006 9:41	10 U 596030 5455177
130120	11/13/2006 10:15	10 U 596004 5455185
130121	11/13/2006 10:15	10 U 596001 5455180
130122	11/13/2006 10:28	10 U 595972 5455123
130123	11/13/2006 10:31	10 U 595981 5455108
130124	11/13/2006 10:35	10 U 595977 5455090
130225	11/13/2006 11:08	10 U 594856 5452365
130226	11/13/2006 11:09	10 U 594874 5452369
140127	11/14/2006 8:32	10 U 596006 5455124
140128	11/14/2006 8:42	10 U 596007 5455043
140129	11/14/2006 8:48	10 U 596008 5455002
140130	11/14/2006 8:54	10 U 596000 5455018
140131	11/14/2006 9:10	10 U 596007 5455079
170132	11/17/2006 9:37	10 U 595993 5455115
170133	11/17/2006 9:56	10 U 595998 5455009
170134	11/17/2006 10:12	10 U 595996 5455013
170135	11/17/2006 10:18	10 U 595997 5455021
170136	11/17/2006 10:41	10 U 595960 5454997
170137	11/17/2006 10:46	10 U 595969 5454994
170138	11/17/2006 14:28	10 U 596004 5455129
180139	11/18/2006 10:44	10 U 595990 5455118
180140	11/18/2006 10:49	10 U 595998 5455091

Appendix F (continued). Location of chum salmon redds, stranding event, and temporary staff gauges in the Herrling Island sidechannel, 2006.

ID (day-site-#)	Date-Time	UTM Coordinates
190141	11/19/2006 10:21	10 U 595984 5455112
190142	11/19/2006 10:26	10 U 595995 5455122
190143	11/19/2006 10:37	10 U 595988 5455004
200144	11/20/2006 9:44	10 U 595988 5455130
200145	11/20/2006 10:03	10 U 596003 5455008
200146	11/20/2006 10:25	10 U 595980 5454997
200147	11/20/2006 10:35	10 U 595963 5454997
200148	11/20/2006 10:41	10 U 595980 5455104
200149	11/20/2006 13:21	10 U 595974 5455141
300201	10/30/2006 10:14	10 U 594864 5452372
300202	10/30/2006 13:16	10 U 594790 5452338
300203	10/30/2006 13:22	10 U 594821 5452354
300204	10/30/2006 13:30	10 U 594824 5452361
300205	10/30/2006 13:46	10 U 594858 5452385
Site 1 temporary staff gauges (rebar)		
RB1	11/14/2006 9:26	10 U 596005 5455154
RB2	11/14/2006 9:42	10 U 596013 5455062
Adult chum salmon stranding event		
1801ST1	11/18/2006 13:16	10 U 596003 5455032

PHOTO PLATES

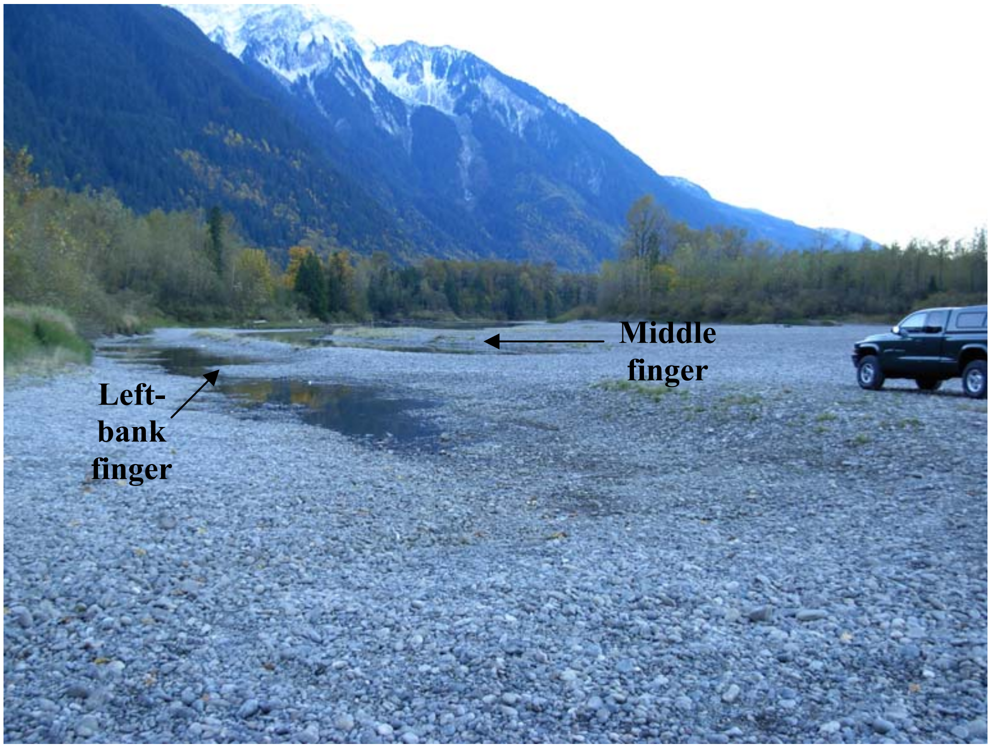


Photo 1. Index site 1 in the Herrling Island sidechannel, 30 October 2006 (0900 hours). This photo was taken from the left bank of the sidechannel looking downstream prior to a WAH GS shutdown. Note the difference in water levels relative to those observed in October 2005 (see Photo 2).

Photo 2. Index site 1 in the Herrling Island sidechannel, 24 October 2005. This photo was taken from the left bank of the sidechannel looking downstream.

Photo 3. Index site 1 in the Herrling Island sidechannel, 14 November 2006 (1000 hours). This photo was taken from the left bank looking downstream prior to a WAH GS shutdown.

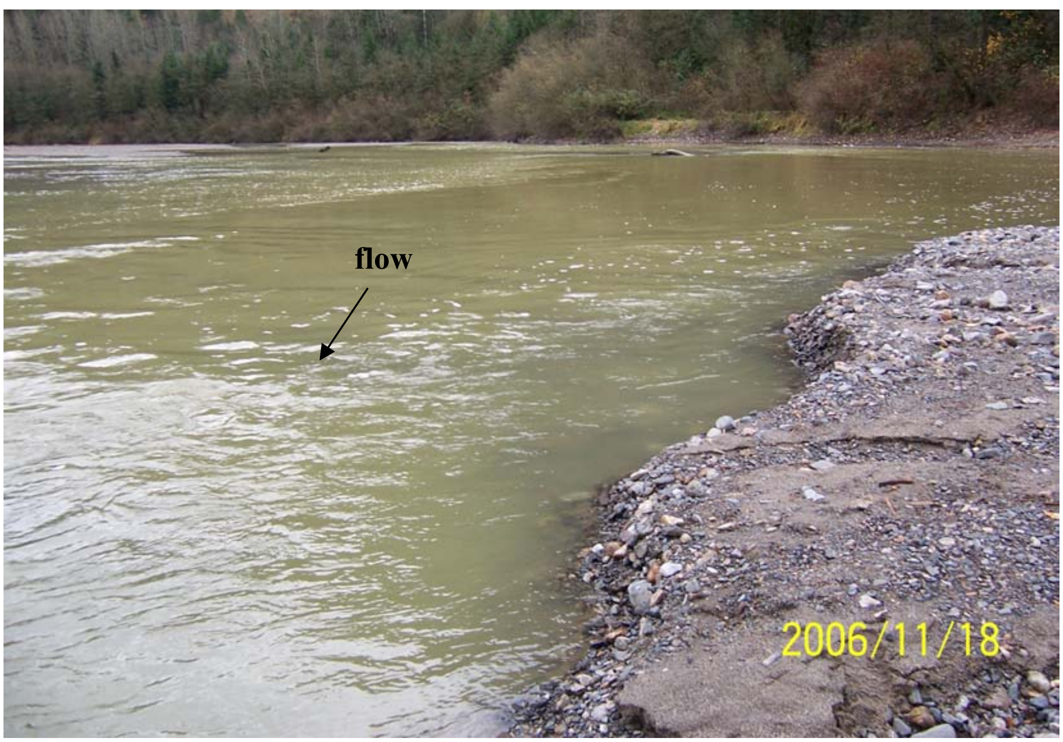


Photo 4. Index site 2 in the Herrling Island sidechannel, 18 November (1330 hours). This photo was taken from the left bank looking upstream during a WAH GS shutdown.

Photo 5. Index site 3 in the Herrling Island sidechannel, 30 October 2006 (1540 hours). This photo was taken from the left bank looking downstream during a WAH GS shutdown.

Photo 6. Confluence of the Fraser River and the upper end of the Herrling Island sidechannel (looking upstream), 30 October 2006. At this stage height, there is no surface flow from the Fraser River into the sidechannel.

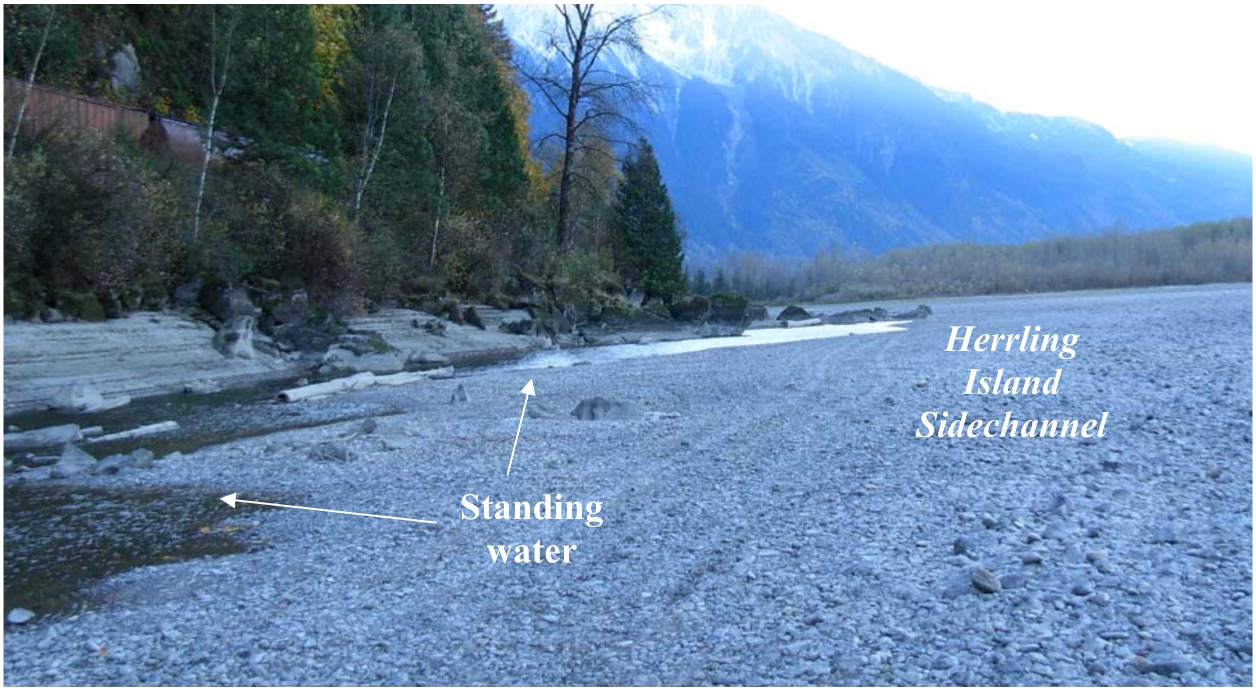


Photo 7. Confluence of the Fraser River and the upper end of the Herrling Island sidechannel (looking downstream), 30 October 2006.

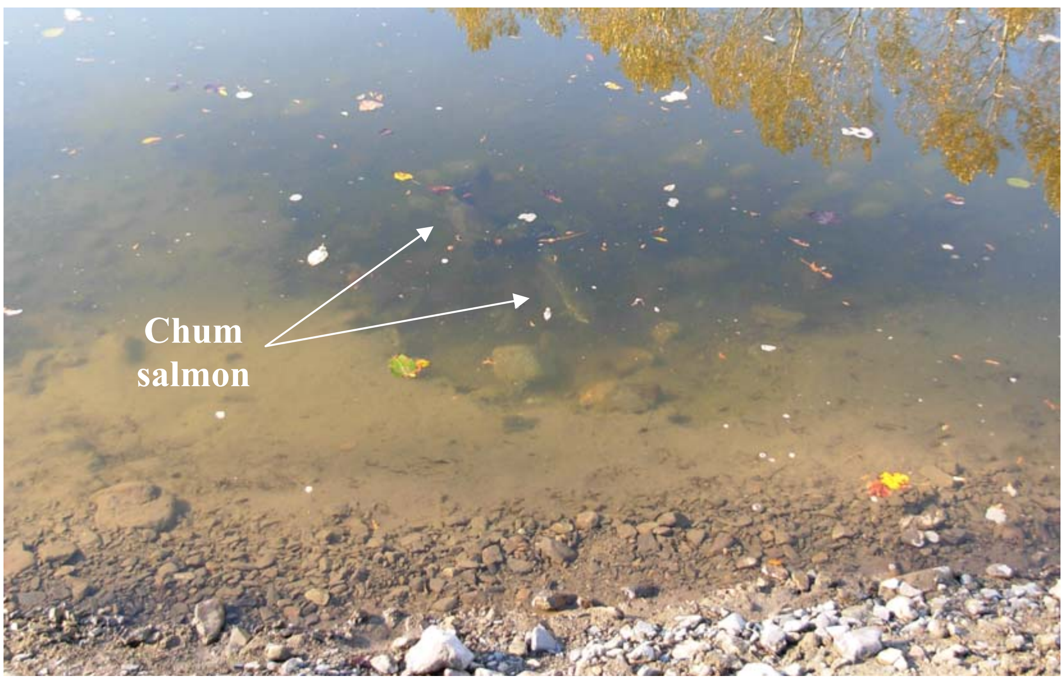


Photo 8. Chum salmon observed spawning at site 2 along the left bank of the Herrling Island sidechannel near the mouth of Unnamed Creek. This photo was taken on 30 October 2006 (1410 hours) during a WAH GS shutdown.

Photo 9. Adult male chum salmon in the Herrling Island sidechannel, 30 October 2006.

Photo 10. Aerial photograph showing sediment-laden water being released from the WAH GS on 11 November 2006 (photo courtesy of Vince Busto, DFO).