Walter Hardman (WHN) Water Use Plan

Monitoring and Physical Works Program Synthesis Report

- **WHNWORKS-1 Walter Hardman Diversion Dam Minimum Flow Release Facility**
- **WHNWORKS-2 Cranberry Creek Annual Gravel Placement Program**
- **WHNMON-1 Lower Cranberry Creek Kokanee Spawning and Incubation Habitat Monitoring**
- **WHNMON-2 Lower Cranberry Creek Rainbow Trout Rearing Habitat Monitoring**
- **WHNMON-3 Walter Hardman Headpond Drawdown Impacts (Fish) Monitoring**
- **WHNMON-4 Lower Cranberry Creek Temperature Effects Monitoring**
- **WHNMON-5 Lower Cranberry Creek Rainbow Trout Abundance/Biology Monitoring**
- **WHNMON-6 Walter Hardman Generating Station Tailrace Habitat Monitoring**

Draft Report

Authors: BC Hydro

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Executive Summary

The Walter Hardman (WHN) Water Use Plan (WUP) was initiated in 2003 and finalized in 2004. On March 22, 2006, the Comptroller of Water Rights (CWR) issued an Order (the "WUP Order") under the *Water Act*[1] in response to the Walter Hardman WUP that included implementing six monitoring projects and two physical works projects.

The purpose of the WUP Order Review is to determine whether the ordered facility operational constraints and the physical works in lieu of operation changes are achieving the specific environmental and social objectives identified in the WUP.

This document was prepared as part of the WUP Order Review process. It summarizes the outcomes from the monitoring studies and physical works projects and outlines whether the management questions and objectives have been addressed (Table E-1).

The draft Monitoring and Physical Works Program Synthesis Report (MPSR) is shared with government agencies, First Nations, and key stakeholders for review and comment. The review will enable BC Hydro to recommend to the Comptroller of Water Rights how the WUP Order and its conditions may be concluded, clarified, modified, or confirmed for future operations.

The primary outcome of the Walter Hardman facility Water Use Plan was a physical works to deliver a continuous 0.1 m^3/s minimum flow into Lower Cranberry Creek for the benefit of fish and fish habitat. It was uncertain if this operational change would achieve the intended benefits in Lower Cranberry Creek or result in any adverse effects for fish and fish habitat at the headpond. Five monitoring studies were initiated to assess the uncertainties and data gaps surrounding potential benefits or impacts of the WUP flow regime on fish habitat, particularly for Rainbow Trout and kokanee. One monitoring study was initiated to evaluate data gaps related to the potential for powerhouse outages to affect kokanee at the tailrace.

A second physical works project to continue the annual gravel placement at the diversion area was completed as ordered. There were no uncertainties or monitoring studies associated with this project and it continues to be implemented under regular facility operations. This activity is necessary to maintain proper function of the diversion area including the ability to direct flows into Lower Cranberry Creek.

The key water use decisions affected are the magnitude and timing of a minimum flow to Lower Cranberry Creek, headpond operating levels, and the timing of powerhouse operations.

Below is a summary of key findings of these studies and implications for operation of the Walter Hardman project.

[1] The *Water Act* was replaced by the *Water Sustainability Act* in February 2016; however, Orders and Water Licenses continue to be valid and are governed by the new *Water Sustainability Act*.

Effect of minimum flows

Lower Cranberry Creek – Rainbow Trout and kokanee

The biological significance of the minimum flow implementation on Rainbow Trout rearing habitat appears low to moderate based on concurrent studies (WHNMON-2 & WHNMON-5) which report good rearing habitat and no change in the health of the Rainbow Trout population over five years of monitoring. Monitoring before and after implementation of the minimum flow demonstrated the population is composed of healthy individuals with good density and growth and represented by multiple age classes. While Rainbow Trout can benefit from improved habitat (e.g. pools, glides) with the Ordered 0.1 m^3/s minimum flow, there is an optimum discharge beyond which increased velocities render habitats less suitable. There was generally no significant improvement in habitat suitability for a minimum flow of 0.5 m^3/s over 0.1 m^3/s.

Kokanee typically access the first 1 km of Lower Cranberry Creek to spawn. Kokanee spawner abundance, size, and fecundity are influenced predominantly by conditions in Arrow Lakes Reservoir. Spawners using Lower Cranberry Creek benefit from the Ordered 0.1 m^3/s minimum flow that improves habitat availability over a no minimum flow scenario; however, the naturally variable discharge limits the availability of suitably sized substrate for kokanee spawning and can produce unsuitably high-water velocities.

Water temperatures in Lower Cranberry Creek were not altered by implementation of the minimum flow. There was no biologically significant effect of flows on water temperatures for Rainbow Trout rearing or kokanee incubation.

Consensus of the monitoring studies evaluating minimum flow to Lower Cranberry Creek is that 0.1 m^3/s provides benefits for Rainbow Trout rearing and kokanee spawning and incubation by increasing available habitat. Habitat suitability for both Rainbow Trout and kokanee is optimised at low to moderate flows in Cranberry Creek and the benefit of the minimum flow is most noticeable over the historic conditions of no minimum flow. Cranberry Creek discharge can be highly variable within and between years and a 0.1 m^3/s minimum flow is often surpassed by natural discharge. A higher minimum flow of 0.5 m^3/s would have an adverse effect on kokanee by reducing riffle and glide habitats used for spawning and would not substantially increase habitat for both Rainbow Trout fry and juveniles.

Headpond Elevation – Rainbow Trout

Headpond elevation targets appear sufficient to minimize fish stranding during drawdown events. The Rainbow Trout population in the headpond is resilient as fish are routinely documented in salvage operations, the population likely sustained by continuing recruitment from Cranberry Creek. Fish salvage work completed during two headpond drawdown events after completion of the Water Use Plan monitoring studies also recorded only Rainbow Trout. In October 2013 (Summit 2013) only fry was captured during a minor drawdown, but in September 2018, when the headpond was completely emptied for intake maintenance, fry, juveniles, and adults were salvaged, indicating the headpond supports all life stages.

Point sampled dissolved oxygen levels in winter 2010 were below threshold for Rainbow Trout; however, the biological significance of low dissolved oxygen levels in winter is likely low as the headpond Rainbow Trout population is persistent, as noted above. Circulation and mixing of dissolved oxygen in winter is likely limited by thick ice cover and could potentially be affected by reduced inflow during the winter low flow period.

Effects of Powerhouse Operations

Tailrace - kokanee

There is no effect of WHN powerhouse operations to potential kokanee spawning in the tailrace. The tailrace and back channel are typically inundated by Arrow Lakes Reservoir during kokanee spawning season. In years when ALR is <430 m and the reservoir is not backwatering the channel, there is little to no suitable spawning habitat available.

Table E1. Summary of objectives, source requirements and completion timeline for the Walter Hardman WUP physical works projects.

Project	Objectives	Source Requirements	Completion
WHNWORKS-1 Walter Hardman Diversion Dam Minimum Flow Release Facility	Within 12 months, prepare and submit for approval, plans for the installation of a release facility that will release a minimum flow into Cranberry Creek downstream from diversion dam which is suitable to make the controlled release of water as specified in Schedule B(1) (e.g., 0.1 cubic metres per second (m^3/s) or natural inflow if less than 0.1 m^3/s.	Schedule A of *Water Act* Order Section 88 dated March 22, 2006, Clause 1 and Schedule B, Clause 1.	Terms of Reference submitted on March 22, 2007 CWR issued Leave to Commence on June 8, 2007.
	On written approval by the CWR, and upon receiving leave to commence construction, install the release facilities at Walter Hardman to provide continuous discharges of minimum flow of 0.1 m^3/s into Cranberry Creek below the diversion dam.	Schedule A of *Water Act* Order Section 88 dated March 22, 2006, Clause 2 CWR issued Leave to Commence on June 8, 2007.	First construction: 30 April 2008 Modification 1: October 2008 Modification 2: Excavation and installation of graduated rock fill around drywells 8-15th December 2008. Modification 3: Excavation and installation of coarse material around drywells and change in Headworks Operating Gate (HWOG) mechanism in November 2009 achieved 0.1 m^3/s minimum flow.
WHNWORKS-2 Walter Hardman Annual Gravel Placement	An annual placement program which transfers up to 5000 cubic metres of gravel deposited into the diversion dam pond into Cranberry Creek downstream of the diversion dam	Schedule B, Clause (5) of *Water Act* Order Section 88, dated March 22, 2006 Terms of Reference approved on June 8, 2007 for six years (2007 to 2012)	Annual gravel placement completed from 2007-2012 as part of WUP project, since 2012 annual works have continued under regular BC Hydro operations.

Table E2. Summary of objectives, management questions, outcomes, and implications for the Walter Hardman WUP monitoring projects.

Project	Objectives	Management Questions	Response
WHNMON-1 Lower Cranberry Creek Kokanee Spawning and Incubation Habitat Monitoring	A one-year study to provide an estimate of changes to kokanee spawning habitat suitability (depth and velocity) in Lower Cranberry Creek to ascertain the effectiveness of a minimum flow.	1. Does the implementation of the 0.1 m^3/s minimum flow release improve the quality and quantity of spawning habitat (depth and velocity) for kokanee over that predicted for historical operating practice (no minimum flow)? 2. Would the implementation of a 0.5 m^3/s minimum flow release provide increased protection and/or enhancement of kokanee spawning habitat over that delivered by the 0.1 m^3/s minimum flow release?	1. The release of a 0.1 m^3/s minimum flow results in a small positive effect on pool habitat but a negative trend in riffle and glide habitats that improves spawning habitat for kokanee over the historical practice of no minimum flow. 2. The release of a 0.5 m^3/s minimum flow will not significantly increase protection or enhancement of suitable habitat for kokanee spawning over a 0.1 m^3/s minimum flow release.
WHNMON-2 Lower Cranberry Creek Rainbow Trout Rearing Habitat Monitoring	A one-year study to provide an estimate of changes to Rainbow Trout rearing habitat as a function of discharge in Lower Cranberry Creek to ascertain the effectiveness of a minimum flow.	1. Does the implementation of the 0.1 m^3/s minimum flow release improve the quality and quantity of effective rearing habitat for Rainbow Trout over that predicted for historical operation of no minimum flow release provision? 2. Would the Implementation of a 0.5 m^3/s minimum flow release provide increased protection and/or enhancement of Rainbow Trout rearing habitat over that delivered by the 0.1 m^3/s minimum flow release?	1. The release of a 0.1 m^3/s minimum flow results in a significant increase in suitable habitat area in key Rainbow Trout rearing locations, but only within a range of flows above baseline levels. An optimal discharge was determined for both fry and juveniles after which habitat suitability begins to decline because of increased water velocity. 2. The release of a 0.5 m^3/s minimum flow will not significantly increase protection or enhancement of suitable habitat for Rainbow Trout rearing over a 0.1 m^3/s minimum flow release.
WHNMON-3 Walter Hardman Headpond Drawdown Impacts (Fish) Monitoring	A one-year study to support future decisions regarding operation of Walter Hardman headpond.	What is the effect of drawdown on fish and fish habitat conditions in the headpond?	The study looked at effects of headpond drawdown on fish stranding and dissolved oxygen. The effect of drawdown on fish stranding risk was assessed as low based on the number of pools with stranded fish and those without (3 vs. 27). Winter levels of dissolved oxygen were low in the two headpond locations assessed in February 2010 (point samples)

Project	Objectives	Management Questions	Response
			when the headpond was already at its maximum level. It is not known whether these low levels were representative of the whole season or of the area in general.
WHNMON-4 Lower Cranberry Creek Temperature Effects Monitoring	A five-year study to evaluate the potential effects of minimum flow release on water temperature in Lower Cranberry Creek.	Does a minimum flow affect water temperatures for fish in Lower Cranberry Creek? Specifically, does implementation of a minimum flow release over the diversion dam mitigate warm temperatures during summer and fall and cold temperatures over winter to the benefit of fish in Lower Cranberry Creek?	There was no clear indication of changes in water temperatures in Lower Cranberry Creek following implementation of the minimum flow. There was no discernable relationship between discharge variations and water temperature.
WHNMON-5 Lower Cranberry Creek Rainbow Trout Abundance/Biology Monitoring	A five-year study to asses the population status of Rainbow Trout in Lower Cranberry and the qualitative capacity to respond to potential habitat improvements from the minimum flow.	What is the status of the current Rainbow Trout population in Lower Cranberry Creek? What is the qualitative capacity of the population to respond to potential habitat improvements resulting from minimum flow releases?	Results indicate the Rainbow Trout population in Lower Cranberry Creek is healthy, with sizes, growth rates, and density typical of stream resident Rainbow Trout in other nearby Columbia River tributaries. The population is likely to benefit from the habitat improvements provided by the 0.1 m^3/s minimum flow. At higher flows benefits may be negated as velocities become less favourable.
WHNMON-6 Walter Hardman Generating Station Tailrace Habitat Monitoring	A five-year study on kokanee use of the Walter Hardman tailrace and nearby back channel and potential effects of powerhouse outflows on migration attraction and spawning success.	How do releases from the Walter Hardman powerhouse affect kokanee habitat in the tailrace channel (in Upper Arrow Lakes Reservoir)? In particular, how do releases from the powerhouse affect kokanee spawning behaviour and success?	Releases from the WHN powerhouse do not affect kokanee habitat in the tailrace. The tailrace channel is influenced mostly by Arrow Lakes Reservoir (ALR) levels. The area does not function as kokanee spawning habitat as the channel is typically inundated by ALR during kokanee spawning season. In years when ALR is <430 m, spawning habitat is very limited and of poor quality and discharge from the powerhouse has little influence on watered area. Even if kokanee were to spawn in the tailrace, outages at WHN in winter are very rare and therefore dewatering of the channel in winter by outages at WHN is not likely to occur.

Acknowledgements

This document and related monitoring projects were funded by BC Hydro Water Licence Requirements Walter Hardman Water Use Plan.

BC Hydro would like to acknowledge the unceded traditional territory of the Sylix Okanagan Nation, Secwepemc, shaSinixt and in ʔamakʔis Ktunaxa within which the Walter Hardman Generating facility operates.

BC Hydro would like to thank the following for their contributions to the project: Speers Construction, the Canadian Columbia River Inter-Tribal Fisheries Commission (CCRIFC), Triton Environmental Consultants Ltd., and Okanagan Nation Alliance (ONA).

Table of Contents

List of Figures

List of Tables

List of Abbreviations

CC	Consultative Committee
CWR	Comptroller of Water Rights
HWOG	Headworks Operating Gate
MPSR	Management Plan Synthesis Report
TOR	Terms of Reference
WHN	Walter Hardman
WLR	Water Licence Requirements
WUP	Water Use Plan
WUW	Weighted Useable Widths

Glossary of Terms

WUW – a calculation of how much of the wetted area of a channel is suitable for a particular fish life stage based on habitat suitability criteria

Walter Hardman Water Use Plan
Monitoring and Physical Works Program Synthesis Report

1.0 PURPOSE

The Walter Hardman (WHN) Water Use Plan (WUP) was initiated in 2003 and finalized in 2004. On March 22, 2006, the Comptroller of Water Rights (CWR) issued an Order (the "WUP Order") under the *Water Act*[2] in response to the Walter Hardman WUP that included implementing six monitoring projects and two physical works projects.

This document summarizes the outcomes from the monitoring projects and outlines whether the management questions have been addressed (Table E-1).

The purpose of the WUP Order Review is to determine whether the ordered facility operational constraints and the physical works in lieu of operation changes are achieving the specific environmental and social objectives identified in the WUP.

Both the draft MPSR and draft WUP Order Review Report are shared with government agencies, First Nations and key stakeholders for review and comment. The WUP Order Review process will enable BC Hydro to recommend to the Comptroller of Water Rights how the WUP Order and its conditions may be concluded, clarified, modified, or confirmed for future operations.

The specific objectives of the Monitoring and Physical Works Program Synthesis Report are to:

1. Provide a summary of the objectives, activities, and results for each of the six monitoring projects and two physical works;
2. Relate monitoring project findings to the objectives of the Walter Hardman WUP and provide any updates to these project findings from other work conducted after the projects were completed;
3. Where management questions were not addressed, identify the data gaps that persist.

2.0 PROJECT BACKGROUND

2.1 Hydroelectric Facilities

BC Hydro's Walter Hardman hydroelectric project is located 25 kms south of Revelstoke on Cranberry Creek, a large, glacial tributary to the Columbia River (**Figure 2.1a**). The facility was constructed in 1961 by the City of Revelstoke and purchased by BC Hydro in 1972. BC Hydro operates the Walter Hardman facility under Final Water Licence 121741 and Conditional Water Licence 121742.

The project consists of a diversion dam, diversion channel with control structures, headpond, earthfill dam, spillway, intake, penstocks, powerhouse, and switchyard (**Figure 2.1b**).The diversion dam in Cranberry Creek redirects a

[2] The *Water Act* was replaced by the *Water Sustainability Act* in February 2016; however, Orders and Water Licenses continue to be valid and are governed by the new *Water Sustainability Act*.

portion of the creek flow into a diversion channel and to the headpond for generation. The remaining flow continues to be passed into Lower Cranberry Creek. Flow into the headpond is regulated by two structures in the diversion channel: a hydraulic gate (Headworks Operating Gate or HWOG) near the upstream end and a concrete Orifice Control Structure near the downstream end. Flow into the headpond must be controlled to manage headpond levels and turbine capacity of 4.3 m^3/s (maximum). Use of the spillway, located at the southwest end of the headpond, is avoided to prevent erosion downstream that could adversely affect Lower Cranberry Creek. The Walter Hardman facility structures are operated manually and access in the winter months to the powerhouse and the diversion area is limited. The area receives significant snowfall and roads to the facilities are not cleared for vehicle use.

A minimum flow release facility was constructed in 2008 consisting of two drywell intakes at the upstream end of the diversion channel and a straight pipe that exits through the diversion dam into Cranberry Creek. This addition to the facility was an outcome of the Water Use Plan and additional details are provided in subsequent sections.

The impoundment of Coursier Lake, approximately 11 km upstream of the headpond on South Cranberry Creek, was part of the original design and provided some flow regulation and storage for the Walter Hardman project. In 2003, however, the Coursier Lake Dam was decommissioned for dam safety reasons. Since then, two Independent Power Producers (IPP) were constructed upstream of the Walter Hardman facility by Advanced Energy Systems Inc., one on each of the South and North forks of Cranberry Creek.

Note that the creek upstream of the diversion dam is also referred to as Upper Cranberry Creek, including both the South and North forks, and downstream of the diversion is referred to as Lower Cranberry Creek.

Figure 2.1a Site map of Walter Hardman Facility

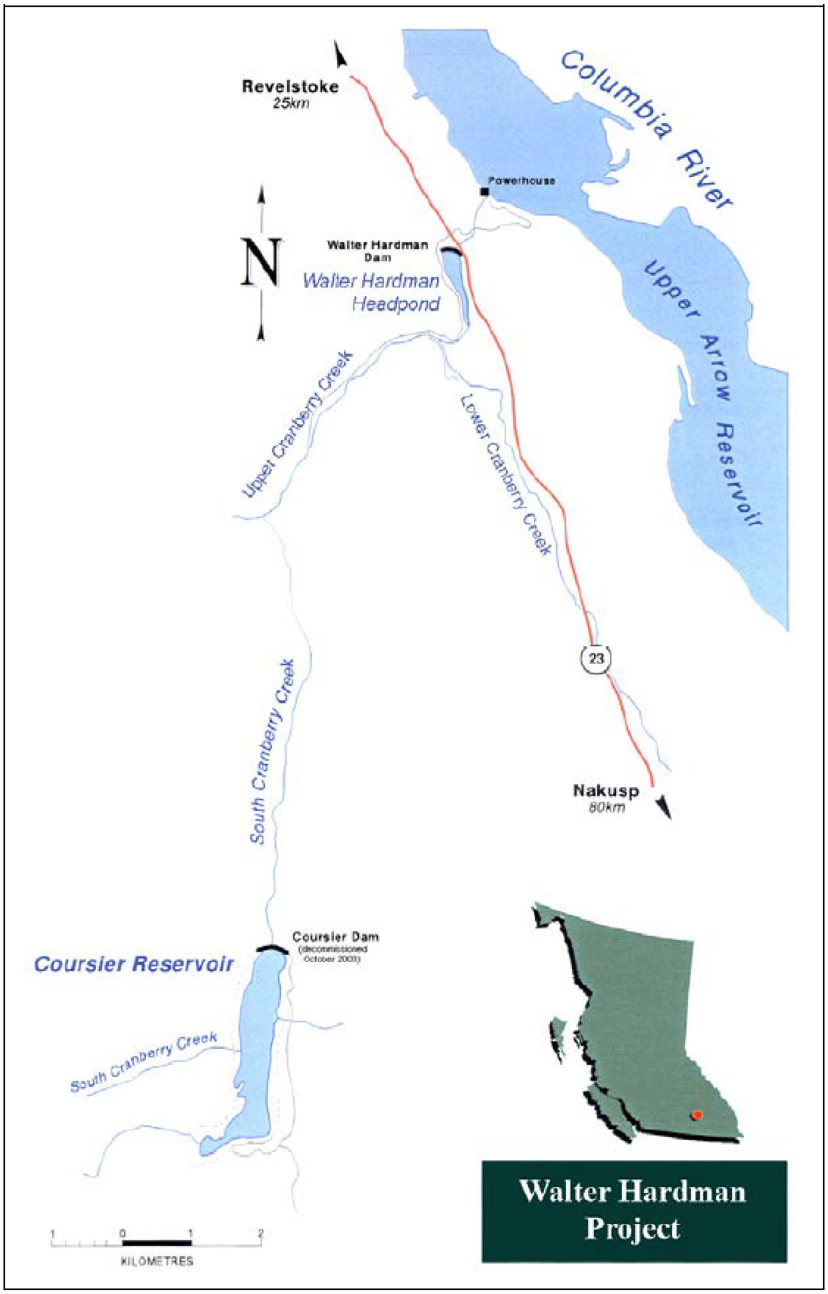


Figure 2.1b Overview of Walter Hardman facility structures

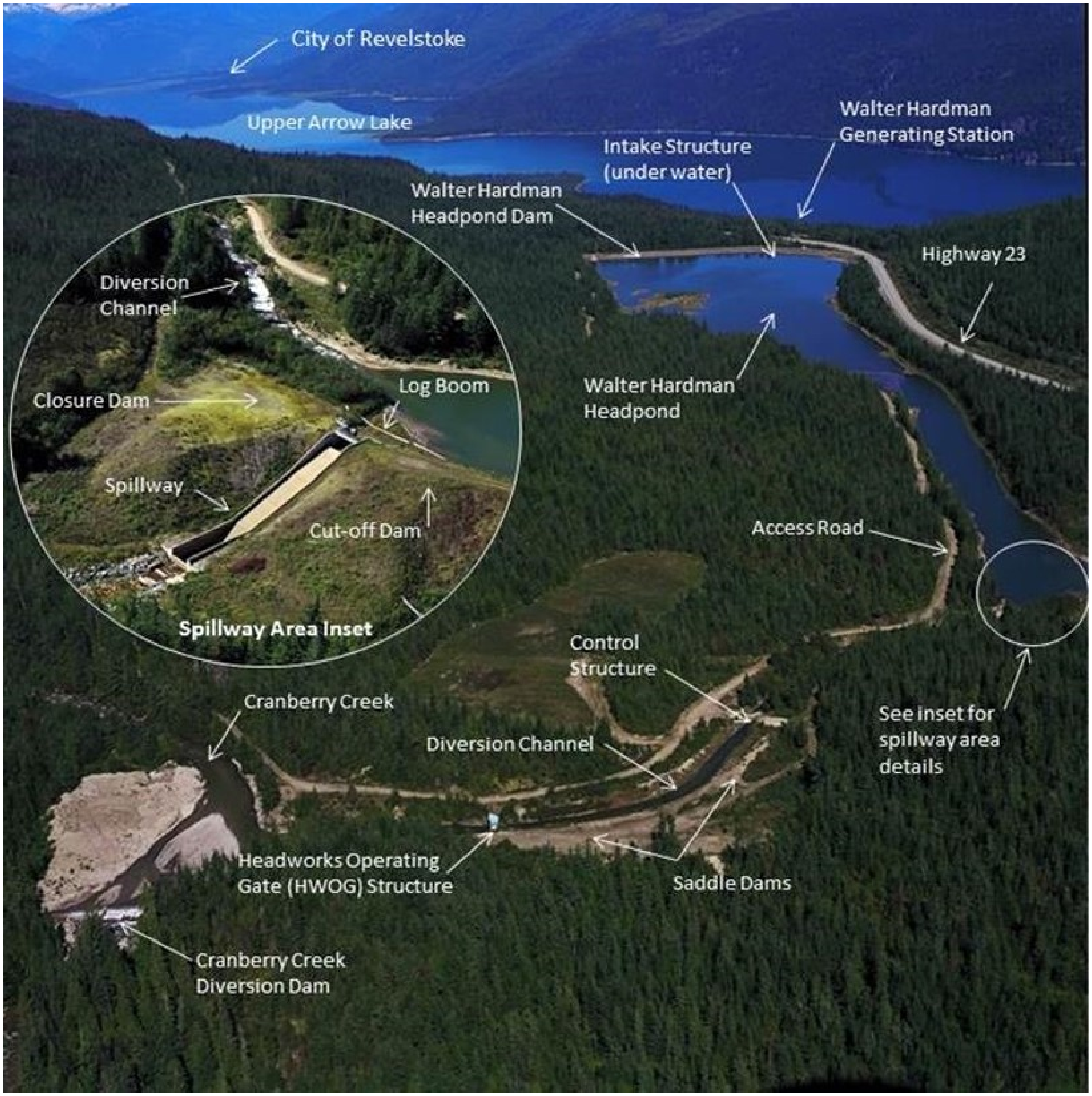


Table 2.1. Walter Hardman Project general information.

Dam Name	Walter Hardman Coursier (decommissioned in 2003)
Year of Completion	1961
Water Licence	121741, 121742
Dam Type	Earth-fill (Walter Hardman)
Dam Use	Run of river
Dam Height	12 m (Walter Hardman)
Spillway Type	Concrete, free overflow
Max. Discharge Capacity of Spillway	11.3 m^3/s at El. 702.87 m
Generating Station	Walter Hardman
Nameplate Capacity	8 MW
Storage	
Reservoir Name	Cranberry Lake, also known as Walter Hardman headpond
Reservoir Area at Max. Normal Level	15.8 ha (headpond)
Water Course	Cranberry Creek
Drainage Area	100 km^2 above diversion
Reservoir Operating Range	698 m to 701 m
Upstream Project	Two upstream facilities operated by IPPs
Downstream Project	Keenleyside
Nearest City	Revelstoke

3.0 Walter Hardman WUP Process

The Walter Hardman WUP consultative process was conducted over two years starting in 2003. Following the Water Use Plan Guidelines developed by the Province (Province of British Columbia 1998), the process created the following outputs (in chronological order):

- Walter Hardman WUP Consultative Committee Report (BC Hydro 2004) – documentation of the structured decision-making process that evaluated operating alternatives against objectives represented by the WUP Consultative Committee, as well as uncertainties recommended for monitoring studies under the WUP implementation.
- Walter Hardman WUP (BC Hydro 2006) – submitted by BC Hydro to the CWR as the summary of WUP Consultative Committee recommended operating constraints and implementation commitments (monitoring and physical works projects) to be appended to the Water Licences.
- Walter Hardman Facility Order (Comptroller of Water Rights 2006) – the *Water Act* Order issued by the CWR to implement the WUP as a condition of the Final Water Licence 12174 and Conditional Water Licence 121742 associated with the Walter Hardman project. Water Licence Requirements (WLR) Terms of Reference (TOR; BC Hydro 2006) – Terms of Reference documents for monitoring projects and physical works ordered by the CWR

including management questions and hypotheses to address uncertainties identified in the WUP consultative process. All Terms of Reference, including any revisions and addenda, are circulated to agencies and First Nations for review and comment prior to submission to the Comptroller of Water Rights for final approval that is issued as a Leave to Commence.

- Annual Project reports – reports submitted to the CWR summarizing progress on monitoring studies and physical works for ordered projects.
- Study reports – detailed results of ordered monitoring studies and physical works projects.

These reports are available on BC Hydro's WUP website:

https://www.bchydro.com/toolbar/about/sustainability/conservation/water_use_planning/southern_interior/walter_hardman.html

3.1 Outcome of Water Use Plan

Operating constraints, two physical works projects, and six monitoring studies were ordered as a result of the WUP. Operational constraints included provision of a continuous minimum flow release to Lower Cranberry Creek and headpond operating levels related to provision of minimum flows and avoidance of spills (Table 3.1). Construction of the physical works project to provide a minimum flow release at the diversion dam (WHNWORKS-1) was key to implementation of the WUP.

Table 3.1. Operating conditions of the WUP Order for the Walter Hardman Project (Comptroller of Water Rights 2006).

System Component	Constraint	Time of Year	Purpose
Minimum flow bypass (Schedule B, Clause 1)	Release a minimum flow of 0.1 m^3/s, or all the natural inflow if it is less than 0.1 m^3/s, from Cranberry Creek into Cranberry Creek downstream from the diversion dam.	All year	Fisheries benefits
Cranberry Lake Reservoir (Schedule B, Clause 2)	When inflows are 0.25 m^3/s or higher, operate Cranberry Lake Reservoir (Walter Hardman headpond): a) Within 0.5 metres of a 700.3 metre elevation b) Within 0.5 metres of a 701.0 metre elevation When inflows to the reservoir are less than 0.25 m^3/s, the reservoir may be drafted to the minimum operating elevation of 698.0 metres.	a) March 15 to November 15 b) November 16 to March 14	Fisheries benefits
Cranberry Lake Reservoir (Schedule B, Clause 3)	If the elevation of the reservoir reaches or exceeds 701.5 metres the licensee must adjust the stop log and orifice control structures to minimize spill from Cranberry Lake.	All year	Fisheries benefits

The WUP Consultative Committee identified uncertainty of the benefits associated with the following operating conditions:

- Minimum flow for kokanee spawning and incubation habitat;
- Minimum flow for Rainbow Trout rearing habitat;
- Headpond drawdown impacts on fish stranding and winter dissolved oxygen concentrations;
- Minimum flow for water temperature; and
- Releases from Walter Hardman powerhouse and effects on fish habitat in the tailrace channel.

Six monitoring studies recommended by the Consultative Committee were ordered to address data gaps and uncertainties in the Walter Hardman WUP and to assess whether anticipated benefits from changes made under the WUP were achieved. Results from monitoring studies are reviewed upon completion as part of BC Hydro's WUP Order Review process and the results are used to inform decisions regarding any changes that may be considered during the WUP Order Review.

The key water use decisions affected are the magnitude and timing of a minimum flow to Lower Cranberry Creek, headpond operating levels, and the timing of powerhouse operations.

The following projects were implemented under BC Hydro's Water Licence Requirements program according to approved Terms of Reference (TOR):

- WHNWORKS-1 Walter Hardman Diversion Dam Minimum Flow Release Facility: A flow release facility to be installed at Walter Hardman to provide continuous discharges into Cranberry Creek below the diversion dam.
- WHNWORKS-2 Walter Hardman Annual Gravel Placement: The annual placement of gravel directly below the diversion dam for distribution downstream to improve aquatic habitat.
- WHNMON-1 Lower Cranberry Creek Kokanee Spawning and Incubation Habitat Monitoring: A one-year study to provide an estimate of changes to kokanee spawning habitat suitability in Lower Cranberry Creek to ascertain the effectiveness of a minimum flow.
- WHNMON-2 Lower Cranberry Creek Rainbow Trout Rearing Habitat Monitoring: A one-year study to provide an estimate of changes to Rainbow Trout rearing habitat as a function of discharge in Lower Cranberry Creek to ascertain the effectiveness of a minimum flow.
- WHNMON-3 Walter Hardman Headpond Drawdown Impacts (Fish) Monitoring: A one-year study to support future decisions regarding operation of Walter Hardman headpond.
- WHNMON-4 Lower Cranberry Creek Temperature Effects Monitoring: A five-year study to evaluate the potential effects of minimum flow release on water temperature in Lower Cranberry Creek.

- WHNMON-5 Lower Cranberry Creek Rainbow Trout Abundance/Biology Monitoring: A five-year study on the effect of flow levels on the resident Rainbow Trout population in Lower Cranberry Creek.
- WHNMON-6 Walter Hardman Generating Station Tailrace Habitat Monitoring: A five-year study on Kokanee use of the Walter Hardman tailrace and nearby back channel kokanee and potential effects of powerhouse outflows on kokanee migration attraction and spawning success.

4.0 ORDERED PHYSICAL WORKS SUMMARY

4.1 WHNWORKS-1 Walter Hardman Diversion Dam Minimum Flow Release Facility

4.1.1 Project Summary

The objective of this physical works project was to install a flow release facility capable of providing a continuous minimum flow of 0.1 m^3/s to Lower Cranberry Creek below the Walter Hardman diversion dam to increase benefits to aquatic life.

Objectives	Source of Requirement	Outcome
Within 12 months, prepare and submit for approval, plans for the installation of a release facility that will release a minimum flow into Cranberry Creek downstream from diversion dam which is suitable to make the controlled release of water as specified in Schedule B(1) (e.g., 0.1cubic metres per second (m^3/s) or natural inflow if less than 0.1 m^3/s.	Schedule A of *Water Act* Order Section 88 dated March 22, 2006, Clause 1 and Schedule B, Clause 1.	Terms of Reference submitted on March 22, 2007 CWR issued Leave to Commence on June 8, 2007.
On written approval by the CWR, and upon receiving leave to commence construction, install the release facilities at Walter Hardman to provide continuous discharges of minimum flow of 0.1 m^3/s into Cranberry Creek below the diversion dam.	Schedule A of *Water Act* Order Section 88 dated March 22, 2006, Clause 2 CWR issued Leave to Commence on June 8, 2007.	First construction: April 30, 2008 Modification 1: October 2008 Modification 2: Excavation and installation of graduated rock fill around drywells 8-15th December 2008 Modification 3: Excavation and installation of coarse material around drywells and change in HWOG mechanism in November 2009 achieved 0.1 m^3/s minimum flow.

4.1.2 Project Approach

The following were key phases and activities of the project:

1. Feasibility phase:

- Project feasibility was determined at the Consultative Committee table (see section 5.1.3.1 for background).

2. Design phase:
   - Confirmed CWR budget and approval to proceed to design and costing;
   - Prepared detailed design drawings; and
   - Acquired permits and regulatory approvals.
3. Implementation / Construction phase:
   - Development of environmental management, safety plans; and
   - Constructed the project to design specifications ensuring appropriate safety and environmental management.
4. Completion phase:
   - Developed record drawings, construction report, and added to the facility operating orders.

4.1.3 **Project Outcomes**

4.1.3.1 *Identification / Feasibility Phase*

The Terms of Reference for WHNWORKS-1 were developed in two stages. A preliminary TOR (BC Hydro, 2006) described how the project would be developed, the scope, and timeline. The final TOR (BC Hydro, 2007) included the final design, cost estimate, and construction schedule.

The preliminary design and estimates for the minimum flow facility were completed by BC Hydro Engineering Services. While the Order specified a 0.1 m^3/s flow, the preliminary TOR for the project (BC Hydro, 2006) committed to inclusion of a design option for a minimum flow of 0.5 m^3/s, to reflect Consultative Committee interests.

The WHNWORKS-1 final TOR (BC Hydro, 2007) summarized four design options for a 0.1 m^3/s minimum flow release facility. All options were comprised of a valved intake off the diversion channel (upstream of the existing stoplog (now HWOG) structure), a pipeline running through the diversion dam, and an outlet structure. One option was capable of providing up to 0.5 m^3/s. Operation of all systems would be manual. The recommended option was chosen based on cost and functionality.

4.1.3.2 *Design*

The selected design option included a 128 m pipeline with a maximum discharge capability of 0.25 m^3/s and an intake within the diversion channel to avoid excess gravel deposition in the area. To ensure that a 0.1 m^3/s minimum flow could be delivered at all Cranberry Creek flows, it was determined that a facility with a design discharge capacity of 0.25 m^3/s would be required to ensure compliance with the ordered flow. The selected design:

- Met the set budget;

- Had a design basis of 0.25 m^3/s discharge which exceeded the Order requirement of a 0.1 m^3/s flow; and
- Provided a conservative approach to ensure that the Ordered 0.1 m^3/s flow was achieved at all Cranberry Creek flows.

On 18 June 2007, the CWR provided BC Hydro leave to commence for construction of the facility to provide a continuous 0.1 m^3/s minimum flow to Lower Cranberry Creek.

4.1.3.3 *Implementation / Construction Phase*

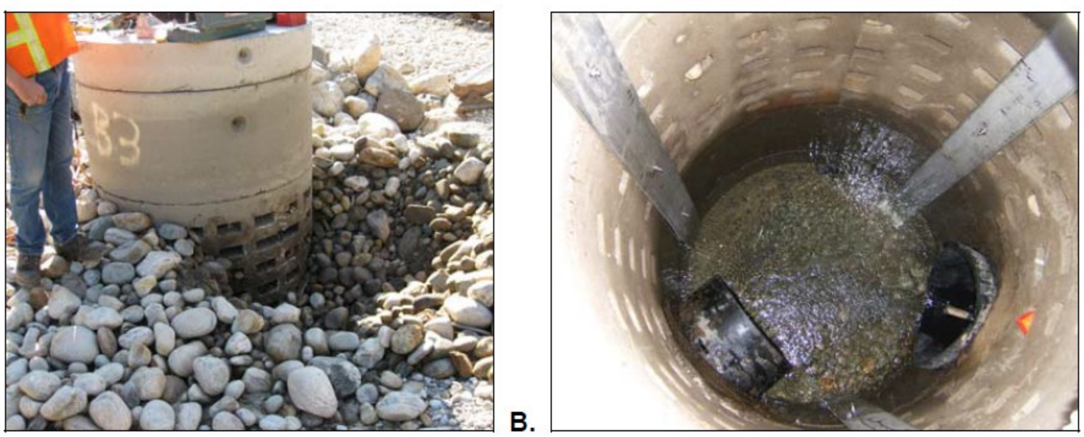
Construction began in April 2008 and was completed within a month by BC Hydro's Construction Business Service (CBS).

The minimum flow release facility design consists of two drywell intakes with perforated lower sections (**Figure 4.1.a**) to passively divert water from the diversion channel into a valved ~128 m underground pipe cut through the diversion dam with a barred outlet and a flow measuring device. Operation of the valve is manual, and it has always remained fully open. The 508 mm (20") diameter pipe has a design capacity of 0.25 m^3/s, a necessary overbuild to ensure a continuous 0.1 m^3/s flow.

It was recognized during the design phase that latent site conditions may affect the final as-built facility. During installation of the drywells, bedrock was encountered at the site and the final drywell elevations were roughly 0.5 m (0.49 m to 0.64 m) above the design elevation. The consequence of this was a reduced contact between the perforated sections of drywell with water in the diversion channel and difficulty maintaining the required flow.

Figure 4.1.a Drywell showing the lower perforated section (A) externally and (B) internally.

(Figure 3 from Bray 2009)



A. B.

Two subsequent modifications to the facility necessary to achieve the required discharge occurred in late 2008 followed by a year of monitoring through the winter base flow, freshet, and low summer flow periods. A final modification was completed in conjunction with another project to replace the stoplog structure with a Headworks Operating Gate (HWOG) in the diversion channel in late 2009 (BC Hydro, 2009).

A final construction report is available at BC Hydro's WUP website at:

https://www.bchydro.com/content/dam/hydro/medialib/internet/documents/planning_regulatory/wup/southern_interior/whnworks-1_construction.pdf

Figure 4.1.b Overview of the minimum flow facility looking east (Sept. 18, 2008). (A) Cranberry Creek, (B) Diversion channel, (C) HWOG (replaced former stoplog structure), (D) Drywells (intakes), (E) Diversion dam and arrow indicating minimum flow outlet.
(Figure 5 from Bray 2009).

4.1.3.4 *Sustainment / Ongoing Maintenance*

The headworks operating gate is reduced to a sufficiently small opening in low inflow periods to backwater the drywell intakes and maintain the required minimum flow of 0.1 m^3/s downstream of the diversion dam. Minimum flows are often surpassed during the spring and summer months when natural inflows are higher than both generation and minimum flow needs and pass over the diversion dam. The minimum flow pipe outlet at the diversion dam is checked periodically by BC Hydro staff to ensure it is in good working order. Snow and ice accumulations can impede confirmation of flow at the intake. Maintenance requirements are included in operating orders for the Walter Hardman facility.

4.1.4 Completion

The minimum flow facility was brought into service in November 2009. Deliverables on project completion included record drawings, a construction report, and inclusion in the operating orders for site works.

4.2 WHNWORKS-2 Cranberry Creek Annual Gravel Placement Program

4.2.1 Project Summary

The diversion dam acts as a barrier and settling area for gravel migrating down Cranberry Creek. An annual program to excavate the gravel is required to ensure diversion structures can function properly and enable redirection of flow over the diversion dam. Up to 5,000 m^3 of excavated gravel is placed on the downstream side of the diversion dam and the remainder stockpiled on site. Placement of gravel downstream of the diversion was anticipated to improve the supply of bedload material to the river and improve fish habitat.

Objectives	Source of Requirement	Outcomes
The annual placement program which transfers up to 5000 m^3 of gravel deposited into the diversion dam pond into the Cranberry Creek downstream of the diversion dam	Schedule B, Clause (5) of *Water Act* Order Section 88, dated March 22, 2006 Terms of Reference approved on June 8, 2007 for six years (2007 to 2012)	Annual gravel placement completed from 2007-2012 as part of WUP project. Since 2012 annual works have continued under regular BC Hydro operations.

4.2.2 Project Approach

The program under the WUP continued the annual gravel excavation and placement downstream of the diversion dam. The Consultative Committee confirmed that the program should continue as part of the Walter Hardman WUP as it was anticipated to provide downstream benefits (BC Hydro, 2004).

Few modifications were made to the gravel placement program when it transitioned to the WUP.

As per prior practice, the Terms of Reference (TOR) specified that up to 5,000 m^3 of gravel per year were to be placed into Cranberry Creek directly below the diversion dam. Any amount exceeding 5,000 m^3 is stockpiled. In years where the amount excavated from the diversion is less than 5,000 m^3, gravel is taken from the stockpile (BC Hydro, 2006). Construction of the minimum flow facility has necessitated minor modifications to the gravel placement program such that the volume of material placed downstream of the diversion area is slightly reduced to avoid covering the new flow channel.

Gravel excavation is conducted in early spring to minimize environmental risk and to be complete in time for freshet to naturally redistribute the material into Lower Cranberry Creek.

4.2.2.1 *Implementation*

Gravel placement took place annually as part of the WUP from 2007 through 2012, as per the TOR. Speers Construction Inc. (Revelstoke) was retained to perform the work for all years of the project except 2008 when it was conducted by BC Hydro Construction Business Services in tandem with the minimum flow facility construction.

The work typically occurred in the following sequence:

- Snow removal as needed to clear the road, work area, and stockpile;
- Construction of a berm to separate Cranberry Creek flow from the work area;
- Ramp construction over the diversion dam;
- Gravel excavation, placement, and stockpiling as needed; and
- Ramp deconstruction and berm removal and demobilization of equipment.

Figure 4.2 Aerial view looking east over the work site, showing the diversion channel, gravel stockpile, drywells (intakes to provide the minimum flow to Cranberry Creek) and diversion dam and minimum flow outlet (October 10, 2008).

4.2.2.2 *Sustainment / Ongoing Maintenance*

Upon completion of the six-year WUP implementation period, the gravel program transitioned back to a BC Hydro maintenance program, where it continues annually.

5.0 ORDERED MONITORING PROJECT SUMMARY

5.1 WHNMON-1 Lower Cranberry Creek Kokanee Spawning and Incubation Habitat Monitoring

5.1.1 Project Summary

BC Hydro was ordered to release a 0.1 m^3/s minimum flow at the Walter Hardman Diversion Dam to Lower Cranberry Creek to improve kokanee production. The Lower Cranberry Creek Kokanee Spawning and Incubation Habitat Monitoring study was conducted over one-year to estimate effectiveness of the minimum flow on kokanee spawning habitat suitability.

Objectives	Management Questions[3]	Response
A one-year study to provide an estimate of changes to kokanee spawning habitat suitability (depth and velocity) in Lower Cranberry Creek to ascertain the effectiveness of a minimum flow.	1. Does the implementation of the 0.1 m^3/s minimum flow release improve the quality and quantity of spawning habitat (depth and velocity) for kokanee over that predicted for historical operating practice (no minimum flow)? 2. Would the implementation of a 0.5 m^3/s minimum flow release provide increased protection and/or enhancement of kokanee spawning habitat over that delivered by the 0.1 m^3/s minimum flow release?	1. The release of a 0.1 m^3/s minimum flow results in a small positive effect on pool habitat but a negative trend in riffle and glide habitats that improves spawning habitat for kokanee over the historical practice of no minimum flow. 2. The release of a 0.5 m^3/s minimum flow will not significantly increase protection or enhancement of suitable habitat for kokanee spawning over a 0.1 m^3/s minimum flow release.

5.1.2 Project Approach

The Lower Cranberry Creek Kokanee Spawning and Incubation Habitat Monitoring study (WHNMON-1) field sampling was conducted in September 2011 and a final report completed October 2012. Field work was originally scheduled for the fall of 2010 but was aborted due to high flows in Cranberry Creek. Annual kokanee escapement counts conducted by BC Hydro were also aborted that fall due to the high flows. The monitoring study was completed by Triton Environmental Consultants Ltd. (Kamloops, BC). and the final report is available on BC Hydro's WUP website:

https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/southern-interior/whnmon-1-yr1-2012-10-01.pdf

As per the TOR, the approach was to conduct a one-year physical habitat-based evaluation of kokanee spawning areas as a function of discharge.

In the fall of 2011, habitat conditions were measured across 15-16 transects representative of habitat type and across three flow conditions: low (0.13 m^3/s), moderate (0.56 m^3/s), and high (1.67 m^3/s). Habitat surveys were conducted over three field visits during kokanee spawning season, and included measurements

[3] BC Hydro 2006. WHNMON-1 Lower Cranberry Creek Kokanee Spawning and Habitat terms of reference. Prepared for the Comptroller of Water Rights, Victoria, BC.

of hydraulic conditions and redd characteristics, and monitoring spawner behaviour. Analysis included calculation of Weighted Useable Widths (WUWs) for each transect plotted against flow. WUW is a calculation of how much of the wetted channel is suitable for a particular life stage based on established habitat suitability criteria.

5.1.3 Interpretation of Data

Across the range of flows encountered, the highest WUWs for kokanee spawning were measured at the lowest flow for riffles and glide habitats, with the opposite measured for pools (Figure 5.1 a. pool; b. riffle; c. glide). Kokanee distribution was restricted to low velocity areas (0-0.2 m^3/s) and where suitably sized substrate was found, either in pools or pockets of riffles and glides. At increasing flows, velocities across the channel increase and kokanee lose the ability to hold in the flow and become concentrated in the few pools. Glide habitats, more than riffles or pools, are the most suitable for kokanee spawning and incubation success.

Flows of 0.5 m^3/s or greater do not benefit kokanee spawning habitat suitability or availability. Natural Lower Cranberry Creek discharge is normally above minimum flows during the kokanee spawning season and the magnitude of daily discharge variation can be greater than the incremental change evaluated. The high variability of natural discharges is likely more influential in limiting habitat suitability and availability for kokanee spawning and incubation.

Answers to Management Questions

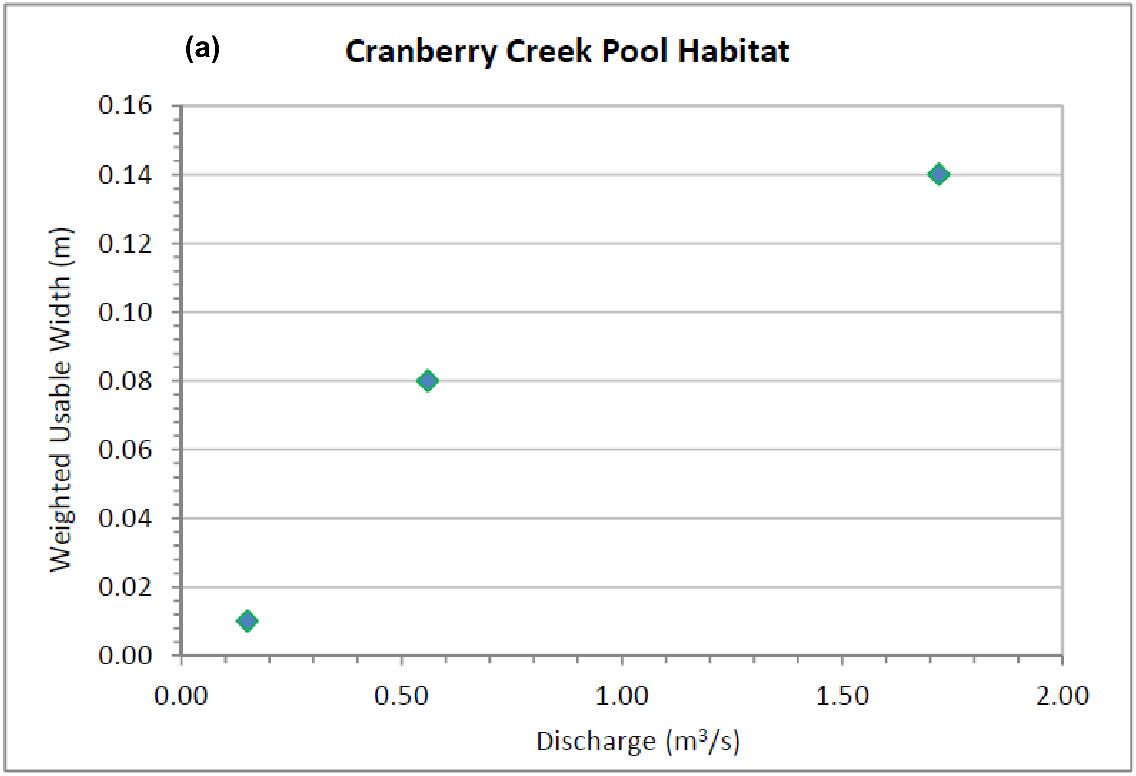
1. Does the implementation of the 0.1 m^3/s minimum flow release improve the quality and quantity of spawning habitat for kokanee over that predicted for historical operating practice (no minimum flow)?

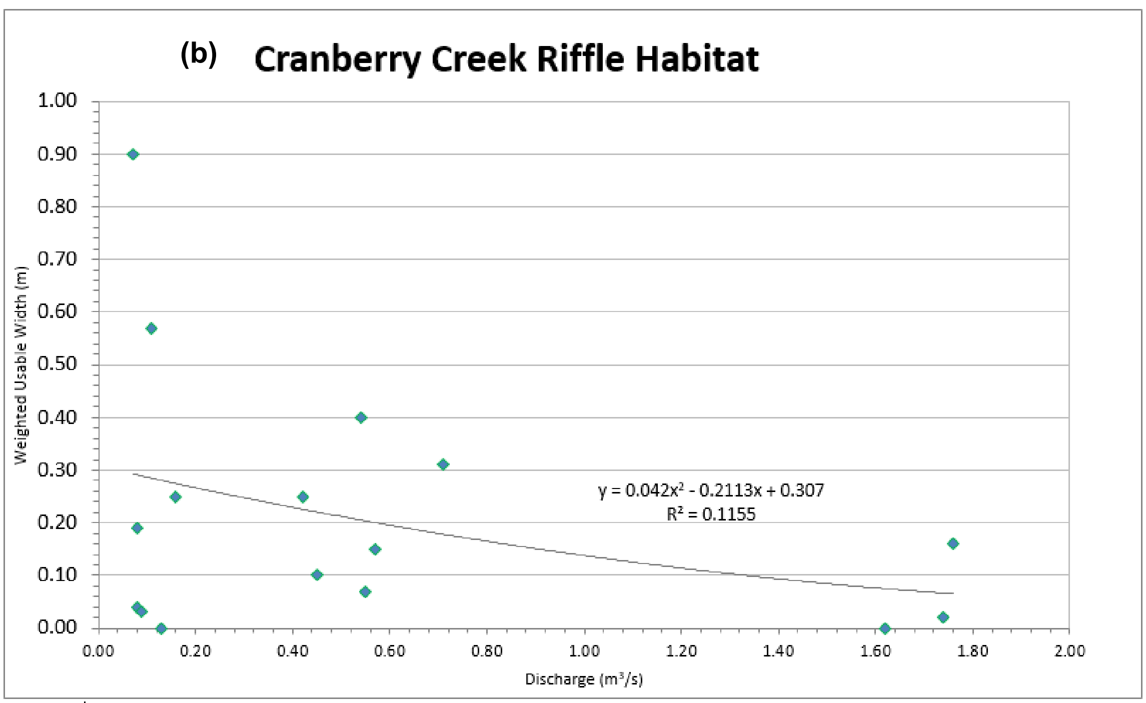
   The release of a 0.1 m^3/s minimum flow (low flow scenario) resulted in a positive effect in amount of pool habitat, but a negative effect in riffle and glide habitats. The changes, however, are minimal and the main constraint to for kokanee spawning success appears to be the naturally high variability of flows during the kokanee spawning period. Cranberry Creek is susceptible to highly variable flows due to rain events and can be quite flashy.

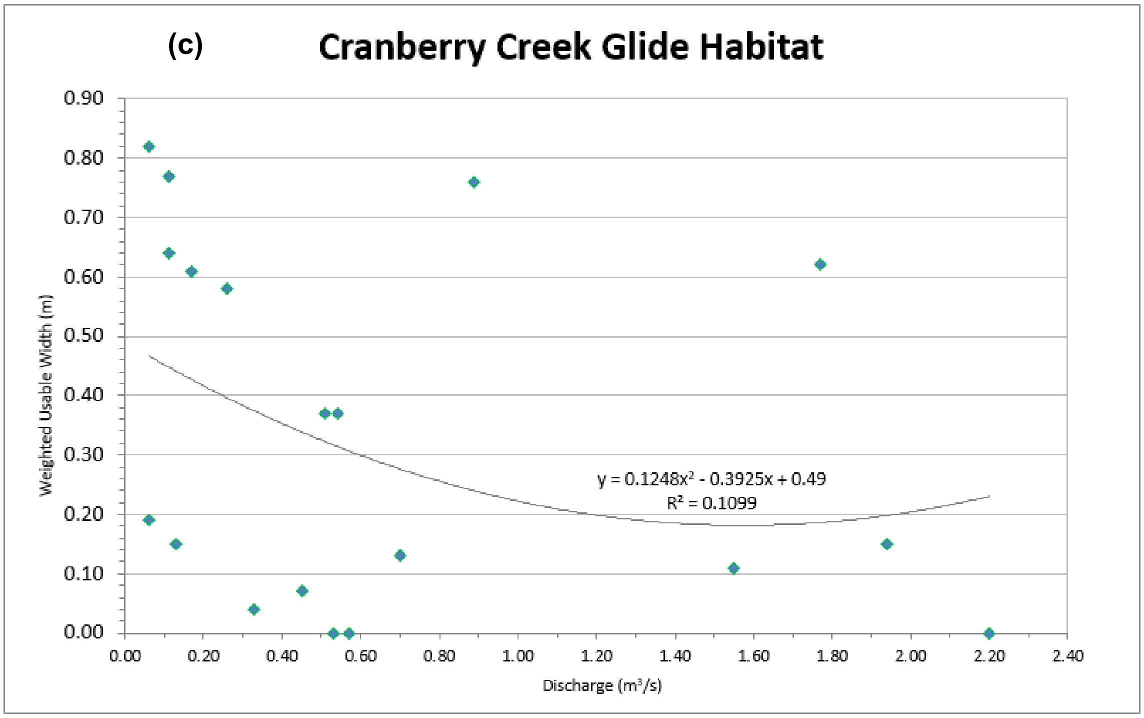
2. Would the implementation of a 0.5 m^3/s minimum flow release provide increased protection and/or enhancement of kokanee spawning habitat over that delivered by the 0.1 m^3/s minimum flow release?

   The release of a 0.5 m^3/s minimum flow will not result in a significant increase in suitable kokanee spawning and incubation habitat area.

Figure 5.1 WUWs for kokanee spawning in (a) pool, (b) riffle and (c) glide habitats in Lower Cranberry Creek (Triton 2012)







5.2 WHNMON-2 Lower Cranberry Rainbow Trout Rearing Habitat Monitoring

5.2.1 Project Summary

Prior to the development of the Walter Hardman Water Use Plan a physical habitat assessment of the impacts of flow on Rainbow Trout fry and parr habitat suggested that a minimum flow would generally improve habitat conditions for Rainbow Trout (Summit 2000). The assessment, however, did not provide the resolution required to determine the appropriate magnitude of minimum flows within the range under consideration in the WUP (0.1 m^3/s to 0.5 m^3/s). This one-year study was developed to evaluate the effectiveness of the ordered 0.1 m^3/s minimum flow release for improving Rainbow Trout rearing habitat in Lower Cranberry Creek and to estimate potential benefits of the higher minimum flow.

Objectives	Management Questions[4]	Response
A one-year study to provide an estimate of changes to Rainbow Trout rearing habitat as a function of discharge in Lower Cranberry Creek to ascertain the effectiveness of a minimum flow.	1. Does the implementation of the 0.1 m^3/s minimum flow release improve the quality and quantity (depth and velocity) of effective rearing habitat for Rainbow Trout over	1. The release of a 0.1 m^3/s minimum flow does result in a significant increase in suitable habitat area in key Rainbow Trout rearing locations but only within a range of flows above baseline

[4] BC Hydro 2006. WHNMON-2: Lower Cranberry Creek Rainbow Trout Rearing Habitat Monitoring terms of reference. Prepared for the Comptroller of Water Rights, Victoria, BC.

	that predicted for historical operation of no minimum flow release provision? 2. Would the implementation of a 0.5 m^3/s minimum flow release provide increased protection and/or enhancement of Rainbow Trout rearing habitat over that delivered by the 0.1 m^3/s minimum flow release?	levels. An optimal discharge was determined for both fry and juveniles after which habitats begin to decline because of increased water velocity. 2. The release of a 0.5 m^3/s minimum flow will not result in a significant increase in suitable habitat area for Rainbow Trout rearing.

5.2.2 Project Approach

Field sampling for the Lower Cranberry Creek Rainbow Trout Rearing Habitat Monitoring study (WHNMON-2) was initiated in September 2010 but then suspended until November 2010 due to high flows in Cranberry Creek. Field work was continued the following year, completing in September 2011. The monitoring study was conducted by Triton Environmental Consultants Ltd. (Kamloops, BC). and the final report is available on BC Hydro's WUP website:

https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/southern-interior/whnmon-2-yr1-2012-10-01.pdf

As per the TOR, the approach was to conduct a one-year physical habitat-based evaluation of Rainbow Trout rearing habitat as a function of discharge. The Consultative Committee had originally included assessment of overwintering habitat in this study; however, during the TOR development this element was not included due to technical issues and budget constraints. It was communicated to all parties involved in the TOR review that fish densities were so low that past winter observations were not meaningful and instead, results from the suite of monitoring studies might allow for an assessment of habitat connectivity at the Ordered minimum flow.

In the fall of 2010 and 2011, habitat conditions were measured across 15 transects representative of Rainbow Trout rearing habitat and across three flow conditions: historic low (0.01 m^3/s), moderate (0.7 m^3/s), and high (2.06 m^3/s). Surveys included measurements of hydraulic conditions and substrate characteristics. Analysis included calculation of Weighted Useable Widths (WUWs) for each transect plotted against flow to assess optimal conditions. WUW is a calculation of how much of the wetted channel is suitable for a particular life stage based on established habitat suitability criteria.

5.2.3 Interpretation of Data

Increased flows from "base" flows of ~0.01 m^3/s resulted in increased useable habitat for all three habitat types (Figure 5.2 a. pool, b. riffle, and c. glide) in Lower Cranberry Creek. However, the rate of habitat improvements diminishes as flows are incrementally increased due to velocities surpassing suitability thresholds, leading to a conclusion that there are limited benefits to higher minimum flow releases (i.e. 0.5 m^3/s) over modest minimum flow releases (i.e., 0.1 m^3/s).

Answers to Management Questions

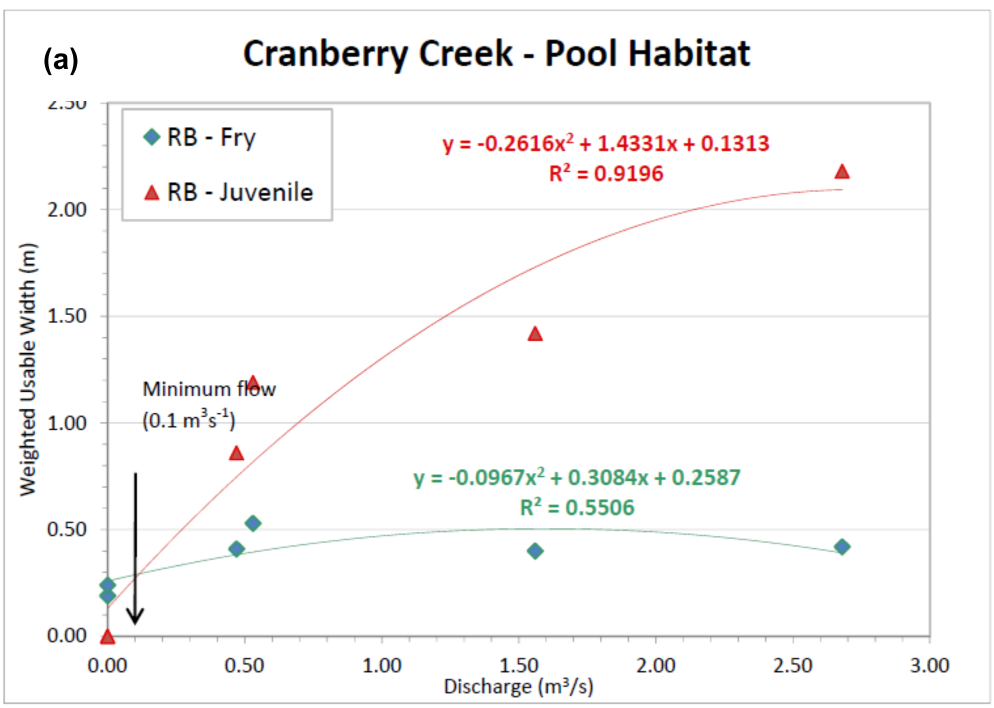
1. Does the implementation of the 0.1 m^3/s minimum flow release improve the quality and quantity of effective rearing habitat for Rainbow Trout over that predicted for historical operation of no minimum flow release provision?

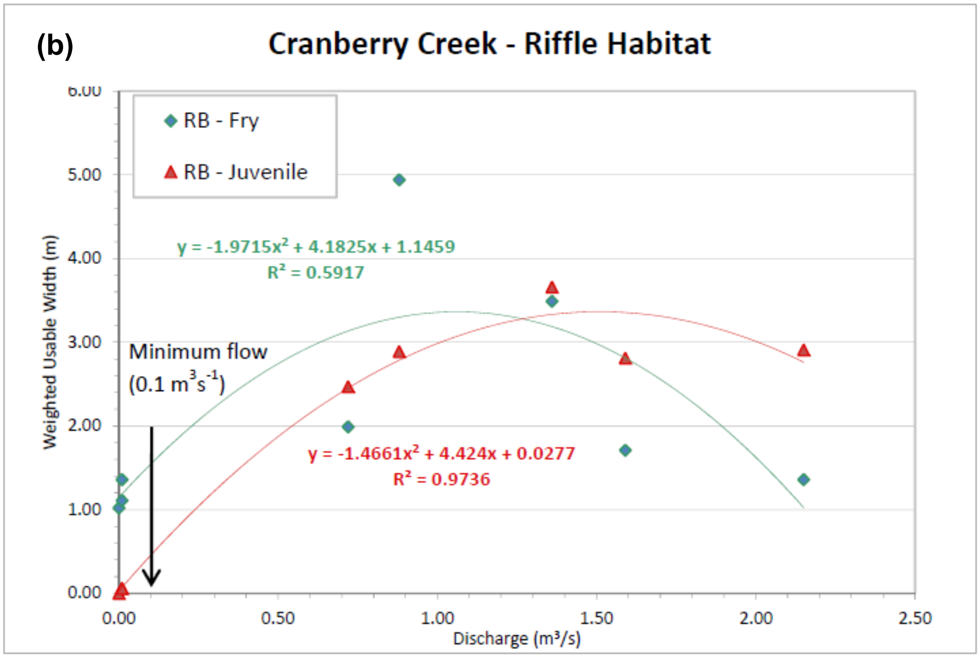
   The study results indicate that the release of a 0.1 m^3/s minimum flow would result in a significant increase in the suitable (depth and velocity integrated) habitat area in key Rainbow Trout rearing locations but only within a range of flows above baseline (historic low) levels. An optimal discharge was determined for both fry and juveniles after which habitat suitability begins to decline because of increased water velocity.

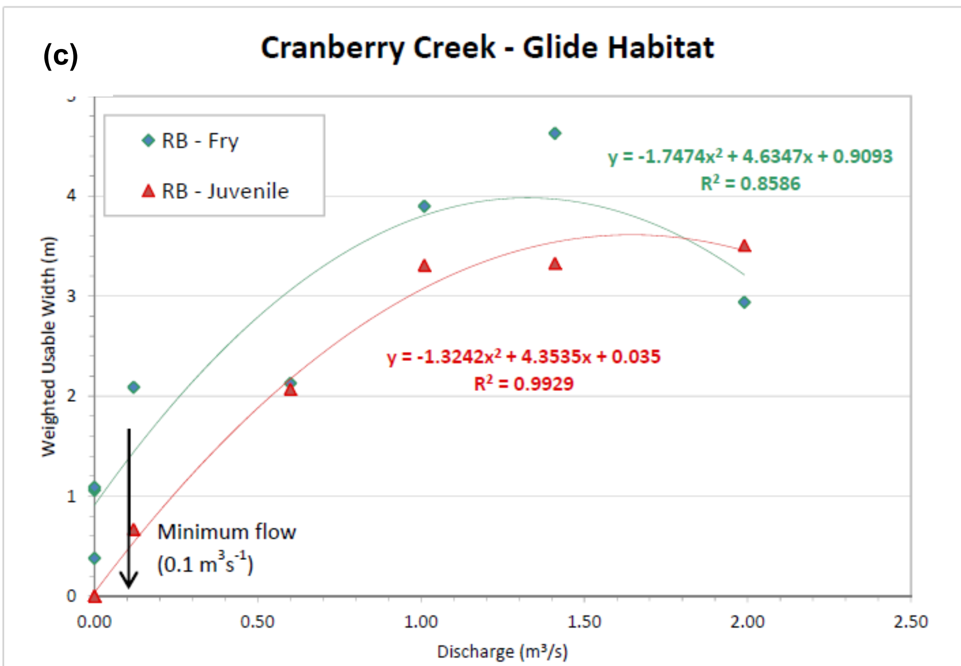
2. Would the implementation of a 0.5 m^3/s minimum flow release provide increased protection and/or enhancement of Rainbow Trout rearing habitat over that delivered by the 0.1 m^3/s minimum flow release?

   The release of a 0.5 m^3/s minimum flow will not result in a significant increase in the suitable (depth and velocity integrated) habitat area in key Rainbow Trout rearing locations.

Figure 5.2 Data plots for (a) Pool, (b) Riffle and (c) Glide habitats in the Lower Cranberry Creek (Triton 2012b)







5.3 WHNMON-3 Walter Hardman Headpond Drawdown Impacts

5.3.1 Project Summary

The Walter Hardman Water Use Planning Consultative Committee recommended a continuous minimum flow release (0.1 m^3/s) at the diversion dam to Lower Cranberry Creek as a means of benefiting fish habitat. Delivery of this minimum flow was expected to potentially reduce inflows to the headpond, particularly during winter low flow periods, that would result in less circulation and lower headpond levels[5]. To avoid spilling and associated environmental impacts, the headpond is maintained below its licenced maximum level.

This raised two key concerns regarding the effect of headpond drawdown: risk of fish stranding and potential effects on dissolved oxygen conditions during winter. The headpond was known to support Rainbow Trout, but information was insufficient to understand the implications of drawdown on these fish, particularly during low inflow periods.

The Consultative Committee recommended a one-year monitoring study to determine whether drawdown of the Walter Hardman headpond affected fish by stranding or winter dissolved oxygen concentration. The monitoring study was scheduled after the initiation of the 0.1 m^3/s minimum flow and during a period of low inflow when the headpond would be drawn down.

Objectives	Management Questions[6]	Response
A one-year study to support future decisions regarding operation of the Walter Hardman headpond.	What is the effect of drawdown on fish and fish habitat conditions in the headpond?	The effect of drawdown on fish stranding risk was assessed as low based on the number of pools with stranded fish and those without (3 vs. 27). Winter levels of dissolved oxygen were low in the two headpond locations assessed in February 2010 (point samples). It is not known whether these low levels were representative of the whole season or of the area in general.

5.3.2 Project Approach

The objectives of the WHNMON-3 Walter Hardman Headpond Drawdown Impacts (Fish) Monitoring study were to identify where fish stranding occurs, or has the potential to occur in the headpond during drawdown, and to undertake water quality measurements, particularly dissolved oxygen, in winter when inflows are lowest.

The monitoring study was conducted from 2008 to 2010 by the Canadian Columbia River Inter-Tribal Fisheries Commission (CCRIFC) (Cranbrook, BC) and the final report is available on BC Hydro's WUP website at:

https://www.bchydro.com/content/dam/hydro/medialib/internet/documents/planning_regulatory/wup/southern_interior/2010q4/whnmon-3_yr1_2010-12-01.pdf

[5] The minimum and maximum elevation ranges for storage are 698.0 and 701.95 m, and the targeted headpond elevations are 700.3m (March 16- November 15) and 701.0 m (November 16 – March 15).

[6] BC Hydro. 2006. Walter Hardman Project Water Use Plan Monitoring Program Terms of Reference. WHNMON-3 Walter Hardman Headpond Drawdown Impacts (Fish) Monitoring.

As per the TOR, the approach to this one-year monitoring study was to assess evidence of fish stranding during a fall drawdown and to measure water quality at two locations in the headpond during a winter low inflow period.

The fish stranding survey in November 2009 was timed to coincide with a maintenance drawdown during the fall low flow period when the headpond was lowered to its minimum level of 698 m. The headpond was divided into three areas (Low, Middle, and Upper) based on numbers of isolated pools (potential for fish stranding), with the Middle basin having the highest concentration of pools (26 pools), and the Low and Upper basins with low stranding potential at pools in total. After an initial reconnaissance, pools where fish were observed were more closely examined and fish salvage efforts completed along with physical habitat measurements. The stranding crew assessed 30 pools (**Figure 5.35.1**), during a time corresponding to a total drawdown of approximately 3 m (from 701.1 to 698 m).

Profiles for temperature, pH, conductivity, and dissolved oxygen were completed through the ice in February 2010 at two deep (4m, 6m) water locations in the lower basin when inflows were lowest. Measurements were taken at one-meter intervals from 0.5 m of the surface to within 0.5 m of the substrate. It was not possible to measure dissolved oxygen at a time when the headpond was drawn down during the low inflow winter period. Headpond levels were maintained at about 701 between November 16, 2009 and March 15, 2010, following the seasonal elevation targets of the Order.

5.3.3 Interpretation of Data

Three of the 30 pools (ranging from 32 to 776 m^2) contained fish, all Rainbow Trout. The effects of drawdown on fish stranding were assessed as low based on the number of stranded fishes recorded (seven juveniles) and the number of pools in which fish were present (3 out of 30) was very low. The middle section of the headpond was determined to have the greater number of potential stranding locations.

The dissolved oxygen profiles conducted at two locations during winter showed concentrations below those of the BC Water Quality Guidelines for the protection of aquatic life (<2 mg/L as compared to 5 mg/L for the latter).

Answers to Management Question

1. *What is the effect of drawdown on fish and fish habitat conditions in the headpond?*

The headpond drawdown was considered to potentially impact fish through stranding and low dissolved oxygen (DO) levels in winter.

The risk of fish stranding resulting from headpond drawdown was assessed as low, based on the number of stranded fish and on the area of the pools where fish were stranded. The reported area comparisons (0.53% of area susceptible to fish stranding, or 844 m^2 out of 15.8 ha total surface area) were based on the three pools where fish were found stranded and did not include the other 27 isolated pools.

Temperature and dissolved oxygen profiles were relatively constant from the water surface under ice to the bottom at the deepest part of the headpond (~4 and 6m), indicating that the water column was thoroughly mixed (**Figure 5.3.b**). Dissolved oxygen levels (median of 1.9 mg/L) were below the established BC Water Quality Guidelines for the protection of aquatic life (5.0 mg/L – instantaneous minimum for life stages other than embryo or alevin), suggesting that there is potential for winter kill within the headpond. It is unknown if these low DO levels commonly occur in winter; however, changing headpond operations to increase volume in winter is considered insufficient to substantially change DO levels.

Figure 5.3.a Locations of fish stranding areas and dissolved oxygen profiles. Modified from Figure 3, Clarricoates and Bisset (2010).

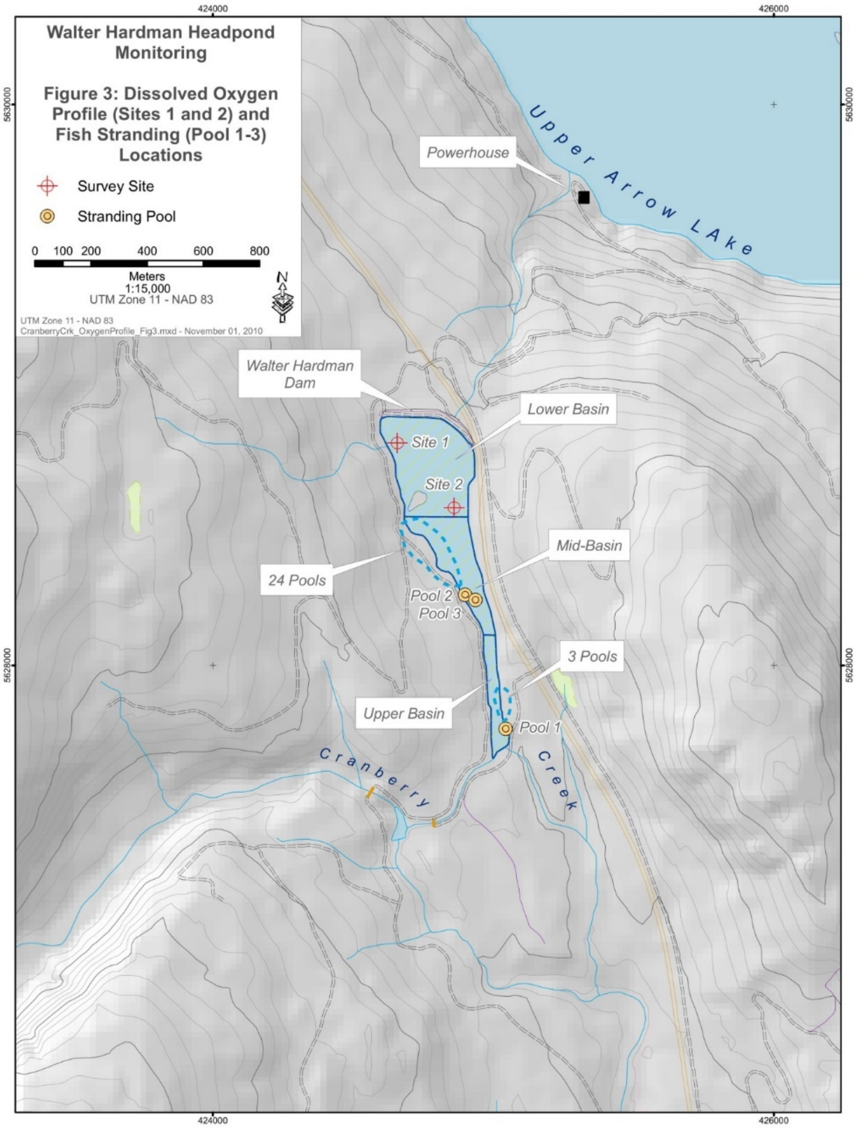
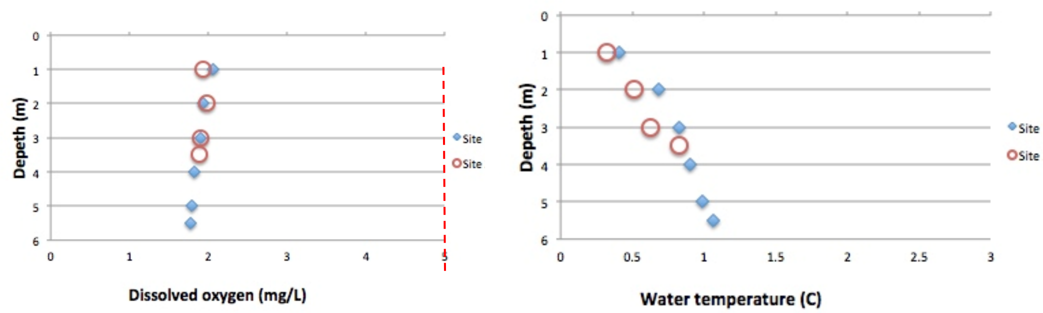


Figure 5.3.b Dissolved oxygen concentrations and water temperature, Walter Hardman headpond, February 5, 2010.



Data plotted from Table 2, Clarricoates and Bisset (2010). The dashed red line indicates BC Water Quality guidelines for dissolved oxygen levels.

5.4 WHNMON-4 Lower Cranberry Creek Temperature Effects

5.4.1 Project Summary

The WHN WUP Consultative Committee recommended implementation of a five-year water temperature monitoring program to evaluate the effectiveness of minimum flow releases on water temperature at three sites in Lower Cranberry Creek. The Consultative Committee expressed two hypotheses regarding the potential effects of regulation (diverting water) on water temperatures in Lower Cranberry Creek in the absence of a minimum flow:

1. Summer water temperatures in the upper and middle sections of Lower Cranberry Creek could warm enough to exceed critical levels for Rainbow Trout; and,
2. Fall and winter water temperatures in the lower section of Lower Cranberry Creek could cool enough to affect kokanee egg incubation.

An anticipated benefit of the minimum flow was an improvement in fish habitat, including the mitigation of suspected adverse water temperatures in Lower Cranberry Creek.

Objectives	Management Questions[7]	Response
A five-year study to capture the annual variation in water temperature to evaluate the potential effects of a minimum flow release in Lower Cranberry Creek.	Does a minimum flow affect water temperatures for fish in Cranberry Creek? Specifically, does implementation of a minimum flow release over the diversion dam mitigate warm temperatures during summer and cold temperatures over fall and winter to the benefit of fish in Lower Cranberry Creek?	There was no clear indication of changes in water temperatures in Lower Cranberry Creek following implementation of the minimum flow in 2009. There was no discernable relationship between discharge variations and water temperature.

[7] BC Hydro 2006; Walter Hardman Monitoring Program Terms of Reference. WHNMON-4 Lower Cranberry Creek Temperature Effects Monitoring

5.4.2 Project Approach

Data collection for this study was conducted from 2007 to 2010 by the Canadian Columbia River Intertribal Fisheries Commission (CCRIFC) (Cranbrook, BC). BC Hydro took over data collection for the remaining two years and retained Triton Environmental Consultants Ltd. (Kamloops, BC) to perform a quality assurance review of all the data, conduct data analysis, and provide a final summary report. The final summary report is available on BC Hydro's WUP website:

https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/southern-interior/whnmon-4-yr5-2014-03-01.pdf

As per the TOR, the approach to this five-year monitoring study was to conduct a comparison of water temperature in Lower Cranberry Creek before and after implementation of the minimum flow. Continuous temperature loggers were installed at three sites downstream of the diversion dam: Reach one (two loggers), Reach three (two loggers) and Reach six (two loggers) in April, 2007[8]. A fourth site (also with two loggers) was added in September 2009, upstream of the concrete diversion dam to act as a control (**Figure 5.4.a**). Data were downloaded from the loggers two to three times a year and timed to occur prior to freshet, during the summer after freshest, and prior to winter freezing in order to reposition the temperature loggers if needed. Most temperature loggers either malfunctioned (buried, broken or lost, in which cases they were replaced) or were dewatered at least once during the five-year span of the study as flows in the creek are highly variable (**Figure 5.4.b**).

Temperature data were also compared with flow data from the Water Survey of Canada station 08NE123 (upstream of the diversion dam) and with data from WHNMON-01 (Lower Cranberry Creek Kokanee Spawning and Incubation Habitat Monitoring) and WHNMON-02 (Lower Cranberry Creek Rainbow Trout Rearing Habitat Monitoring) to evaluate effects of discharge.

[8] The minimum flows were implemented in late 2008. The years 2007 and 2008 are thus pre-minimum flows, 2009-2012 post minimum flows.

Figure 5.4.a Location of temperature loggers, Cranberry Creek, WHNMON-04 (from Morrone and Triton (2014), figure 2-1)

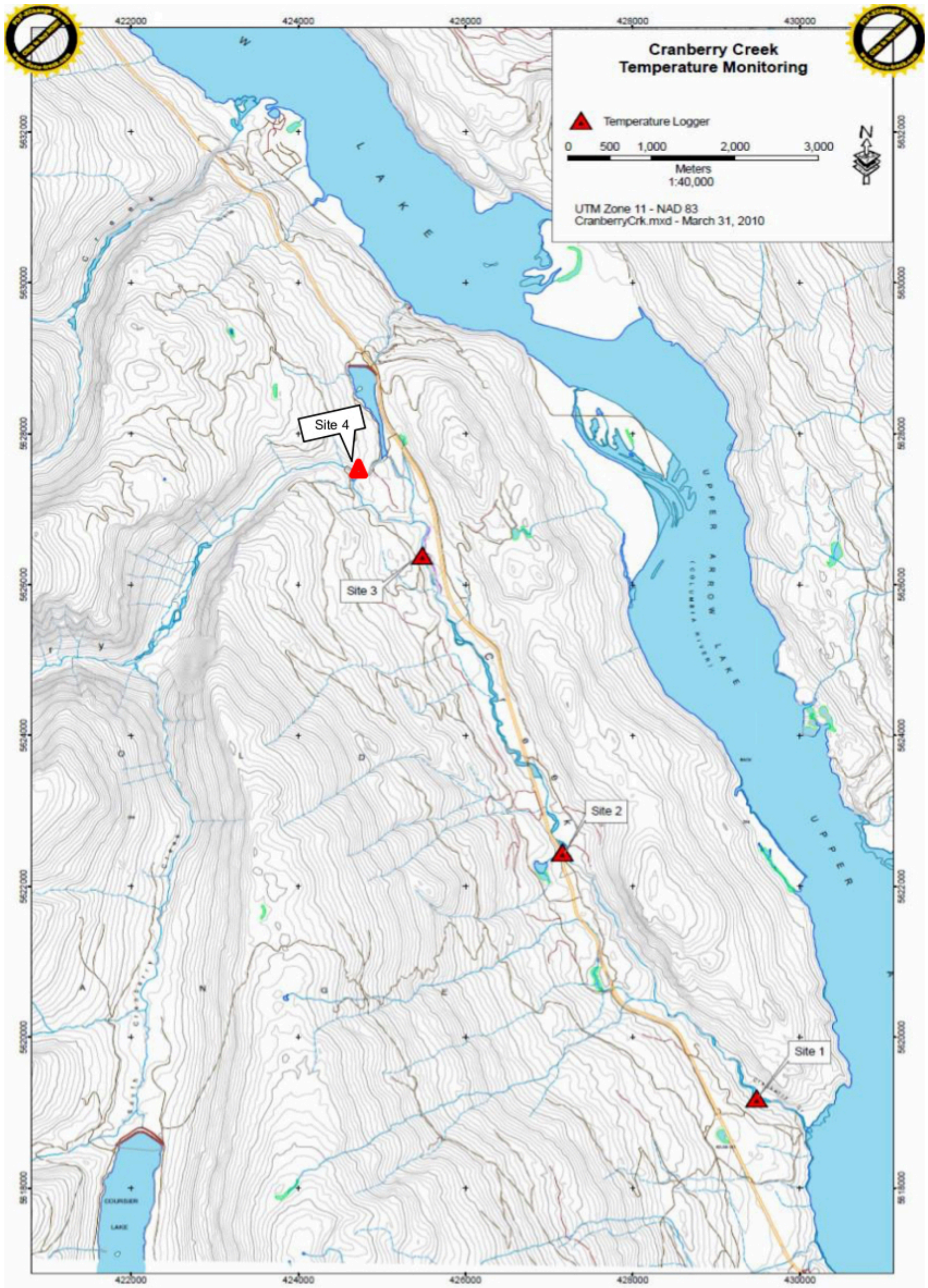


Figure 5.4.b: Temperature loggers in cinder block underwater and dewatered, Cranberry Creek, Sept 2009.


5.4.3 Interpretation of Data

There were no clear indications of changes in water temperatures in Lower Cranberry Creek after implementation of the minimum flow nor a clear relationship between discharge and water temperature. Temperature ranges recorded were suitable for Rainbow Trout rearing. While winter water temperatures recorded during kokanee egg incubation dropped below suitable values, these low temperatures are similar to other tributaries in the area that also support kokanee and likely do not reflect within-substrate conditions.

Answers to Management Question

1. Does a minimum flow affect water temperatures for fish in Cranberry Creek? Specifically, does implementation of a minimum flow release over the diversion dam mitigate warm temperatures during summer and fall and cold temperatures over winter to the benefit of fish in Lower Cranberry Creek?

There were several data gaps in water temperature records due to loggers being dewatered, broken, buried in the sand, or lost due to highly variable flows in Cranberry Creek. From April 2007 to September 2012, the percent of time loggers successfully functioned varied from nine to 68%. The only full years of data were for Sites one and two, both in 2008 and 2009[9].

Although there were large data gaps and the comparison between pre- and post-minimum flow is thus subject to uncertainties, there were no biologically significant trends (effect) of the flows on maximum summer temperatures. Moreover, the minimum winter temperatures in Lower Cranberry Creek were neither warmer nor colder after the implementation of the minimum flows (**Figure 5.4.c**) and were similar to those from the control site (Site four) upstream of the diversion dam (Morrone and Triton 2014, figures 22- 25).

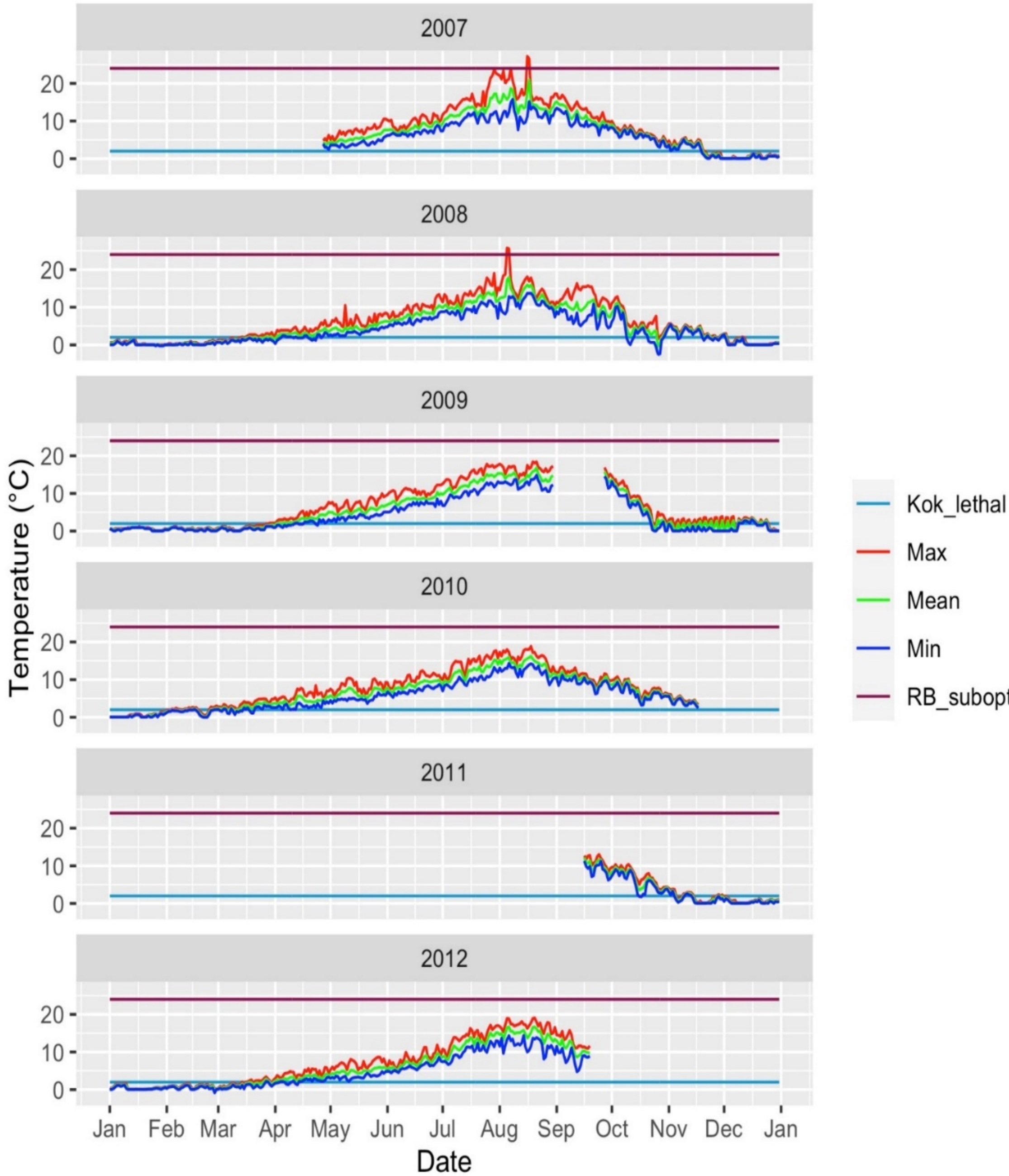
Summer temperatures. Average summer high temperatures at Site four (control site) were around 15^{o}C, and average seasonal summer temperatures in Lower Cranberry Creek (Sites one, two and three) ranged between 9^{o}C and 14^{o}C.

[9] Temperatures collected in September 2009, were from dewatered loggers and are not included in the analyses.

Hence the available data suggest that Rainbow Trout fry did not experience lethal temperatures, although temperatures above the optimal range did occur. The highest temperatures may have been records of air temperatures when the loggers were dewatered, as there were large diurnal variations. Dewatering often occurred during July and August, which reduced confidence in assessing water temperatures during these critical months for Rainbow Trout rearing.

Winter temperatures. Sites two and three are not accessible to kokanee, hence data from Site one was considered most relevant. Water temperatures regularly dropped below 2°C (the lower limit for kokanee incubation success (according to the literature) around mid-November and did not rise above this threshold until mid-March (**Figure 5.4.c**). Many minimum temperatures were consistently equal to 0.02°C which is not uncommon for similar tributaries in the region. The location of temperature loggers likely does not reflect incubation conditions as logger data were representative of surface water and not of in-gravel conditions. Temperatures in Lower Cranberry Creek were similar to those of the upstream control site, which would indicate that the implementation of a minimum flow did not influence winter temperatures.

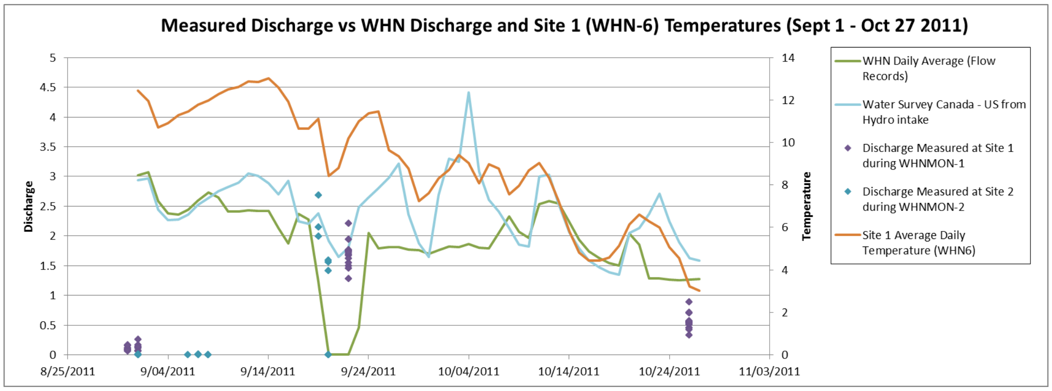
Figure 5.4.c: Water temperatures, Cranberry Creek, site WHN1. 2007 and 2008 are before minimum flows.



Kok_lethal: minimum temperature (2°C) for successful kokanee egg incubation; **Max, Mean and Min:** maximum, average and minimum temperature on a given day; **RB_subopt**: suboptimal temperature (24°C) for Rainbow Trout rearing. Max Min and Mean values are based on daily sample sizes varying from 24 to 48 for most days.

Effects of discharge on water temperature. If discharge directly affects the average daily water temperature, one would expect water temperatures to drop as discharge increases. However, there was no obvious trend between water temperature and discharge (**Figure 5.4.d**).

Figure 5.4.d: Relationship between discharge (points) and water temperatures at Site 1.



From Morrone and Triton (2014) Appendix 3, Figure 2.

5.5 WHNMON-5 Lower Cranberry Creek Rainbow Trout Abundance/Biology Monitoring

5.5.1 Project Summary

The Walter Hardman WUP Consultative Committee recommended a five-year study to address a data gap to aid in understanding results of WHNMON-2. The study was intended to document responses of the resident Rainbow Trout population over a range of natural flows and provide baseline data against which future results can be compared. The Consultative Committee acknowledged that any changes in the population could not be inferred as resulting from flow changes (BC Hydro 2004).

Prior data indicated that Rainbow Trout were present in Lower Cranberry Creek, however data were insufficient to predict the effects of minimum flow releases on the population. The Consultative Committee recognized that the response of the Rainbow Trout population could not be measured reliably because of the lack of baseline population data under the historical operation of the diversion, and therefore recommended conducting a habitat-based assessment of the potential benefits of minimum flows for Rainbow Trout in Lower Cranberry Creek. The specified monitoring was to be conducted for five years to generate an understanding of the status of the Lower Cranberry Creek Rainbow Trout population (i.e. generate baseline data) and characterize the capacity of the population to respond to minimum flow releases. Results of this study were intended to be combined with learnings from WHNMON-2 to better understand Rainbow Trout habitat use in Lower Cranberry Creek.

Objectives	Management Questions[10]	Response
A five-year study to asses the population status of Rainbow Trout in Lower Cranberry and the qualitative capacity to respond to potential habitat improvements from the minimum flow.	1. What is the status of the current Rainbow Trout population in Lower Cranberry Creek? 2. What is the qualitative capacity of the population to respond to potential habitat improvements resulting from minimum flow releases?	1. Results indicate the Rainbow Trout population in Lower Cranberry Creek is healthy, with sizes, growth rates, and density typical of stream resident Rainbow Trout in other nearby Columbia River tributaries. 2. The population is likely to benefit from the habitat improvements provided by the 0.1 m^3/s minimum flow. At higher flows benefits may be negated as velocities become less favourable.

5.5.2 Project Approach

The WHNMON-5 monitoring study was conducted over 5 years from 2008 to 2012, with a reconnaissance year in 2007. The first three years of the monitoring study was conducted by the Okanagan Nation Alliance (West Kelowna, BC) (2007-2010), and the final two years by Triton Environmental Consultants Ltd. (Kamloops, BC) (2011-2012 Annual data reports are available on BC Hydro's WUP website:

https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/southern-interior/whnmon-5-yr5-2013-04-01.pdf

As per the TOR, the approach to this five-year monitoring study was to systematically collect biological characteristics of the Rainbow Trout population and to qualitatively assess habitat values at representative sites in Lower Cranberry Creek (Figure 5.5.a). Sites were not always consistent among years due to changing conditions for sampling and a change in contractor in Year Four (2011).

In all years Rainbow Trout were sampled by electrofishing, snorkel surveys were used only in Year One (2008). Habitat assessments included measurements of gradient, residual pool depth, substrate composition, and cover as well as some water quality parameters. Representative photographs were taken at each site. In 2007, seven index sites were selected to assess Rainbow Trout densities, their size, and age structure. Two of the original sites selected in 2007 were not monitored in 2008 or 2009 as anthropogenic and natural barriers limited fish access, and as a result two new sites were added in 2008.

[10] BC Hydro. 2006. Walter Hardman Project Water Use Plan Monitoring Program Terms of Reference. WHNMON-5 Lower Cranberry Creek Rainbow Trout Abundance/Biology Monitoring

Figure 5.5.a: The WHNMON-5 study area with sites surveyed in 2011. From Triton (2013) Figure 2-1.

5.5.3 Interpretation of Data

Results indicate a healthy population of resident Rainbow Trout represented by multiple age classes with good density and growth. The capacity of the Lower Cranberry Creek Rainbow Trout population to respond to habitat improvements through minimum flow releases was assessed as high.

Answers to Management Questions

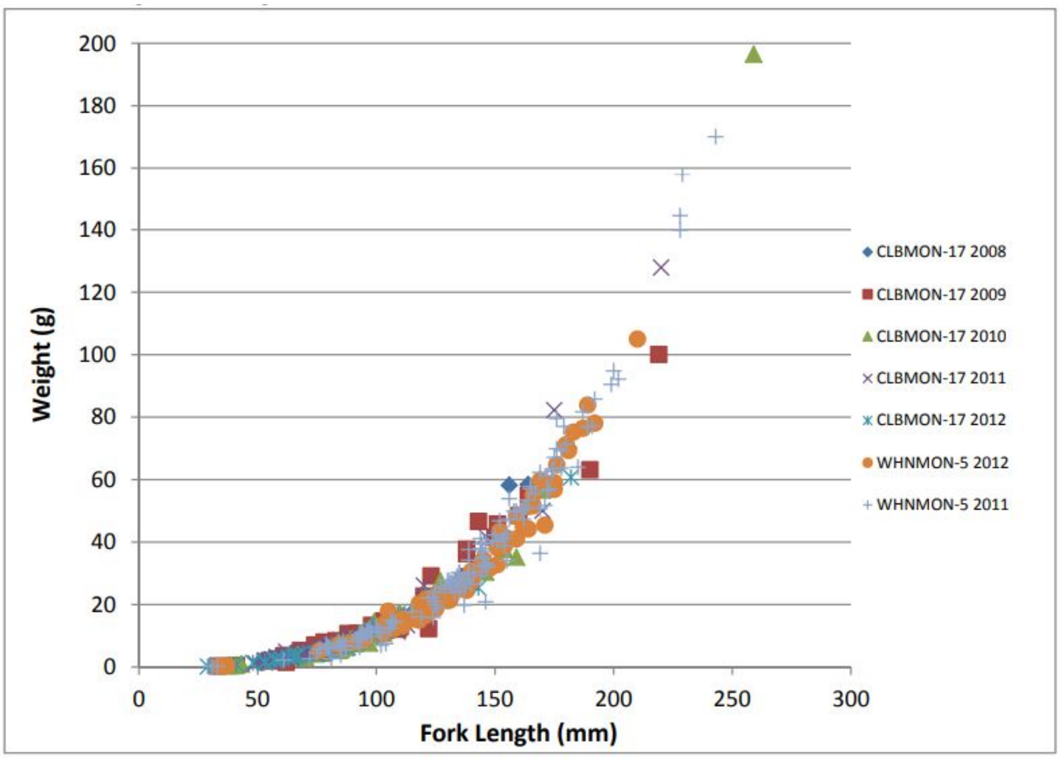
1. *What is the status of the current RB population in Lower Cranberry Creek?*

Results of WHNMON-5 indicate that Lower Cranberry Creek supports a healthy Rainbow Trout population, as measured by density, fish condition, and growth rates. It should be noted that the ability to compare densities between years is limited due to changes in sampling methodology and low catch numbers in some years.

The Rainbow Trout population in Lower Cranberry Creek consists of four age classes: 0+ to 3+. Estimated mean Rainbow Trout density ranged from 2.20 fish/100 m^2 to 6.34 fish/100 m^2.

Instantaneous growth rate (calculated within year, rather than across years) was estimated in 2011 and 2012 using the difference in mean fork length between the age classes. Differences were greater between each of the classes in 2011, suggesting that growing conditions may have been more favorable that year. Mean temperature at the sites was cooler in 2012 (10.4 °C vs. 12.8°C) which may have had an effect on growth rate. 2012 was also a significantly high freshet flow year in the region.

Figure 5.5.b Comparison of Rainbow Trout length-weight regression for WHNMON-5 (2011 and 2012) with data from nearby tributaries sampled under CLBMON-17 (2008-2012). From Triton (2013) Figure 3-3.



Rainbow Trout condition factor (which is a measure of overall health) in Lower Cranberry Creek was comparable to Rainbow Trout from other Columbia River tributaries near Revelstoke (data from CLBMON-17: Middle Columbia River Juvenile Fish Habitat Use; **Figure 5.5.b**) indicating a normal level of health for Rainbow Trout in the region.

2. *What is the qualitative capacity of the population to respond to potential habitat improvements resulting from minimum flow releases?*

The population of Rainbow Trout in Lower Cranberry Creek consists of individuals of good health with densities ranging from 0.66 to 13.68 fish per m^2. Individuals from multiple age classes were represented in each year of sampling suggesting that successful recruitment is occurring and that habitat suitable for different ages is present. Based on these observations it is expected that the population would be able to respond to habitat improvements resulting from minimum flow releases. The population is likely to benefit from the habitat improvements provided by the 0.1 m^3/s minimum flows, however, at higher flows benefits may be negated as velocities become less favourable.

5.6 WHNMON-6 Walter Hardman Generating Station Tailrace Habitat

5.6.1 Project Summary

The WHN WUP Consultative Committee expressed concern that the diversion of Cranberry Creek flows through the generating station may result in kokanee being attracted to the back channel fed by powerhouse outflows, and that WHN shutdowns and/or receding water levels from ALR would result in dewatering the area and thus affect kokanee spawning or egg to fry survival. Additionally, one consequence of the recommended minimum flow to Lower Cranberry Creek was that this may result in discharge from the WHN powerhouse being reduced to 0.25 m^3/s or less during periods of low inflows and therefore potentially also reduce water levels in the tailrace channel.

The Consultative Committee consequently recommended a five-year monitoring study to assess a data gap and determine whether kokanee was attracted to powerhouse outflows, assess their use of the tailrace and back channel, and the influence of WHN powerhouse outflows.

Objectives	Management Questions[11]	Response
A five-year study on kokanee use of the Walter Hardman tailrace and back channel and potential effects of powerhouse outflows on migration attraction and spawning success.	How do releases from the Walter Hardman powerhouse affect kokanee habitat in the tailrace channel in particular, how do releases from the powerhouse affect kokanee spawning behaviour and success?	The tailrace channel is influenced mostly by Arrow Lakes Reservoir (ALR) levels. The area does not function as kokanee spawning habitat as the channel is typically inundated by ALR during kokanee spawning season. ALR must be below 430m in September for the tailrace and channel to be outside ALR influence. This is rare and when this happens, kokanee spawning habitat is very limited and of poor quality. Outages at WHN in winter are very rare and therefore dewatering of the channel in winter by outages at WHN is not likely to occur.

[11] BC Hydro 2006. Walter Hardman Project Water Use Plan Monitoring Program Terms of Reference. WHNMON-6 Walter Hardman Generating Station Tailrace Habitat Monitoring

5.6.2 Project Approach

The Walter Hardman Generating Station Tailrace Habitat monitoring study was conducted from 2007 to 2012 by BC Hydro Environment (Revelstoke). The final report is available on BC Hydro's WUP website at:

https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/southern-interior/whnmon-6-yrs-1-to-5-2013-06-01.pdf

As per the TOR, the approach of this five-year monitoring study was to conduct surveys of the WHN tailrace area in September and October to obtain visual estimates of spawning kokanee abundance and distribution and to observe evidence of or the potential for redd dewatering in the tailrace during a plant shutdown.

The tailrace was monitored for five one-minute periods at intervals of fifteen minutes during peak kokanee spawning season. Numbers of kokanee observed, and their behaviour was recorded.

A scheduled plant outage on April 17, 2012, provided the opportunity to observe the back channel when the Arrow Lakes Reservoir (ALR) levels were low enough to expose it in its entirety and at a time when the WHN tailrace was accessible and snow free. Other checks for low water/dewatering were made opportunistically in conjunction with other projects in the area.

5.6.3 Interpretation of Data

The WUP Consultative Committee's primary concern was that kokanee might be attracted to the WHN tailrace, spawn in the back channel, and subsequently be affected by a winter plant shutdown through dewatering or freezing of the redds.

Answers to Management Questions

1. *How do releases from the Walter Hardman powerhouse affect kokanee habitat in the tailrace channel (in Upper Arrow Lakes Reservoir)? In particular, how do releases from the powerhouse affect kokanee spawning behaviour and success?*

For kokanee spawning success to be affected by releases from the WHN powerhouse through attraction to the tailrace or redd dewatering/freezing during a winter outage four conditions need to occur:

(i) suitable spawning habitat must be available,

(ii) spawners use the area,

(iii) WHN outages occur during fall or winter, and

(iv) the channel is dewatered as a result of outages

i) *Suitable spawning habitat.* Substrate in the back channel is for the most part unsuitable for kokanee redds: it is mostly thick soft sand and silt, with only a few very small gravel pockets at the base of the tailrace (**Figure 5.6.a**).

ii) *Spawners use*. Kokanee were observed at the tailrace outlet once in the five years of monitoring when ALR was at the elevation of the stilling basin at the outlet. Kokanee migrating up the Mid Columbia River may be attracted to the powerhouse outflow but are less likely to be Cranberry Creek spawners as the confluence of Cranberry Creek is 13 kms south of the WHN outlet.

iii) *WHN outages.* Complete WHN outages rarely occur during winter (November to March) when incubating eggs would experience freezing conditions. Winter outages did not occur during the study period.

iv) *Channel dewatered as a result of plant outages.* For WHN outages to have any effect on the channel, ALR levels need to be < 430 m. This occurred in only four out of 45 years of records (1968-2012) during kokanee spawning season. ALR levels were low (427 m) during the April 17, 2012, planned plant shutdown and the channel was not substantially backwatered. Only a very small section of substrate at the base of the tailrace outlet was dewatered and it was mostly composed of large cobble or gravel embedded in thick sand and silt (**Figure 5.6.a & b**).

Figure 5.6.a: Examples of substrate at the WHN powerplant outlet structure.

L: rubble with no gravel; R: cobble and gravel embedded in sand and silt. Stake is 3.7 x 58.6 cm. Modified from Bray (2013), figure 10.

Figure 5.6.b: WHN powerplant outlet structure and back channel, before and after plant outage, April 17, 2012.

L: before plant outage, discharge 1.2 m^3/s; R: one hour following outage. Modified from Bray (2013), figure 9. ALR is at 427 m.

6.0 SUMMARY OF CONCLUSIONS

The primary outcome of the Walter Hardman facility Water Use Plan was a physical works to deliver a continuous 0.1 m^3/s minimum flow into Lower Cranberry Creek for the benefit of fish and fish habitat.

It was uncertain if this operational change would achieve the intended benefits in Lower Cranberry Creek or result in any adverse effects for fish and fish habitat at the headpond. Five monitoring studies were initiated to assess the uncertainties and data gaps surrounding potential benefits or impacts of the WUP flow regime on fish habitat, particularly for Rainbow Trout and kokanee. One monitoring study was initiated to evaluate data gaps related to the potential for powerhouse outages to affect kokanee at the tailrace.

A second physical works project to continue the annual gravel placement at the diversion area was completed as ordered. There were no uncertainties or monitoring studies associated with this project and it continues to be implemented under regular facility operations. This activity is necessary to maintain proper function of the diversion area including the ability to divert flows into Lower Cranberry Creek.

The key water use decisions affected are the magnitude and timing of a minimum flow to Lower Cranberry Creek, headpond operating levels, and the timing of powerhouse operations.

Below is a summary of key findings of these studies and implications for operation of the Walter Hardman project.

6.1 Effect of minimum flows

Lower Cranberry Creek – Rainbow Trout and kokanee

The biological significance of the minimum flow implementation on Rainbow Trout rearing habitat appears low to moderate based on concurrent studies (WHNMON-2 & WHNMON-5) which report good rearing habitat and no change in the health of the Rainbow Trout population over five years of monitoring. Monitoring before and after implementation of the minimum flow demonstrated the population is composed of healthy individuals with good density and growth and represented by multiple age classes. While Rainbow Trout can benefit from improved habitat (e.g. pools, glides) with the Ordered 0.1 m^3/s minimum flow, there is an optimum discharge beyond which increased velocities render habitats less suitable. There was generally no significant improvement in habitat suitability for a minimum flow of 0.5 m^3/s over 0.1 m^3/s.

Kokanee typically access the first 1 km of Lower Cranberry Creek to spawn. Kokanee spawner abundance, size, and fecundity are influenced predominantly by conditions in Arrow Lakes Reservoir and spawning in Lower Cranberry Creek is limited by water velocity and availability of suitably sized substrate. Spawners using Lower Cranberry Creek benefit from the Ordered 0.1 m^3/s minimum flow that improves habitat availability over a no minimum flow scenario, however, kokanee are limited by the naturally variable discharge that limits the availability of suitably sized substrate and can produce unsuitably high water velocities.

Water temperatures in Lower Cranberry Creek were not altered by implementation of the minimum flow. There was no biologically significant effect of flows on water temperatures for Rainbow Trout rearing or kokanee incubation.

Consensus of the monitoring studies evaluating minimum flow to Lower Cranberry Creek is that 0.1 m^3/s provides benefits for Rainbow Trout rearing and kokanee spawning and incubation by increasing available habitat. Habitat suitability for both Rainbow Trout and kokanee is optimised at low to moderate flows in Cranberry Creek and the benefit of the minimum flow is most noticeable over the historic conditions of no minimum flow. Cranberry Creek discharge can be highly variable within and between years and a 0.1 m^3/s minimum flow is often surpassed by natural discharge. A higher minimum flow of 0.5 m^3/s would have an adverse effect on kokanee by reducing riffle and glide habitats used for spawning and would not substantially increase habitat for both Rainbow Trout fry and juveniles.

Headpond Elevation – Rainbow Trout

Headpond elevation targets appear sufficient to minimize fish stranding during drawdown events. The Rainbow Trout population in the headpond is resilient as fish are routinely documented in salvage operations, the population likely sustained by continuing recruitment from Cranberry Creek. Fish salvage work completed during two headpond drawdown events after completion of the Water Use Plan monitoring studies also recorded only Rainbow Trout. In October 2013 (Summit 2013) only fry was captured during a minor drawdown, but in September 2018, when the headpond was completely emptied for intake maintenance, fry, juveniles, and adults were salvaged, indicating the headpond supports all life stages.

Point sampled dissolved oxygen levels in winter 2010 were below threshold for Rainbow Trout; however, the biological significance of low dissolved oxygen levels in winter is likely low as the headpond Rainbow Trout population is persistent, as noted above. Circulation and mixing of dissolved oxygen in winter is likely limited by thick ice cover and could potentially be affected by reduced inflow during the winter low flow period.

6.2 Effects of Powerhouse Operations

Tailrace - kokanee

There is no effect of WHN powerhouse operations to potential kokanee spawning in the tailrace. The tailrace and back channel are typically inundated by Arrow Lakes Reservoir during kokanee spawning season. In years when ALR is <430m and the reservoir is not backwatering the channel, there is little to no suitable spawning habitat available.

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