Campbell River Project Water Use Plan

Salmon River and Quinsam River Smolt and Spawner Abundance Assessments

Implementation Year 2

Reference: JHTMON-8

Year 2 Annual Monitoring Report

Study Period: March 1, 2015 to April 30, 2016

Laich-Kwil-Tach Environmental Assessment Ltd. Partnership and Ecofish Research Ltd.

October 12, 2016

JHTMON-8: Salmon River and Quinsam River Smolt and Spawner Abundance Assessments

Year 2 Annual Monitoring Report

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EXECUTIVE SUMMARY

Water Use Plans (WUPs) were developed for BC Hydro's hydroelectric facilities through a consultative process and there is expected to be monitoring to address outstanding management questions in the years following the implementation of a WUP. As the Campbell River Water Use Plan process reached completion, a number of uncertainties remained with respect to the effects of BC Hydro operations on aquatic resources. The JHTMON-8 monitoring program focuses on the Salmon and Quinsam rivers, which both have high fisheries values and include diversion infrastructure that diverts a portion of natural flow elsewhere in the Campbell River watershed for hydroelectric power generation.

The JHTMON-8 objectives, management questions, hypotheses and current status are presented in Table i.

Table i. Status of JHTMON-8 objectives, management questions and hypotheses after Year 2.

Study objective	Management questions	Management hypotheses	Year 2 (2015) status
Reduce uncertainty about factors that limit fish abundance in the Salmon and Quinsam rivers.	1. What are the primary factors that limit fish abundance in the Campbell River system and how are these factors influenced by BC Hydro operations? 2. Have WUP-based operations changed the influence of these primary factors on fish abundance, allowing carrying capacity to increase? 3. If the expected gains in fish abundance have not been fully realized, what factors if any are masking the response and are they influenced by BC Hydro operations?	$H_0 1$ Annual population abundance does not vary with time (i.e., years) over the course of the Monitor. $H_0 2$ Annual population abundance is not correlated with annual habitat availability as measured by Weighted Usable Area (WUA). $H_0 3$ Annual population abundance is not correlated with water quality. $H_0 4$ Annual population abundance is not correlated with the occurrence of flood events. $H_0 5$ Annual population abundance is not correlated with food availability as measured by aquatic invertebrate sampling. $H_0 6$ Annual smolt abundance is not correlated with the number of adult returns (Quinsam River) .	Year 2 of this ten year study has been successfully completed. Where historical comparisons have been made, results show that $H_0 1$ can be rejected since population abundance varies between years. The study is on track to answer the management questions following analysis of data to be collected in future years.

The three management questions in Table i will be addressed by testing six null hypotheses that seek to test whether juvenile fish abundance varies between years ($H_0 1$) and, if so, whether abundance is related to the following drivers: habitat availability ($H_0 2$), water quality ($H_0 3$), floods ($H_0 4$), food abundance ($H_0 5$), and the abundance of returning adult fish ($H_0 6$). Species of primary interest are Chinook Salmon (*Oncorhynchus tshawytscha*) Coho Salmon (*O. kisutch*) and steelhead (*O. mykiss*), although the study involves compiling adult escapement data for a wider range of anadromous salmonid species for both rivers, as well as collecting abundance data for life stages (predominantly juveniles) of a range of species in the Quinsam River, at the salmon counting fence.

Table ii below summarizes the field sampling programs scheduled to be undertaken annually as part of JHTMON-8. All sampling programs were successfully completed in Year 2 (2015).

Table ii. Summary of field sampling programs undertaken for JHTMON-8.

River	Sampling program	Lead organization[1]	Method	Timing
Salmon	Adult Steelhead survey	LKT	Snorkel surveys	March – April
	Juvenile Steelhead abundance	LKT	Closed site multi-pass electrofishing	September
	Juvenile Coho abundance	DFO/LKT	Closed site multi-pass netting	October
	Salmon escapement surveys	DFO	Various	September – November
	Water quality sampling	LKT	*In situ* and laboratory analysis	May – October
	Invertebrate sampling	LKT	Drift sampling	May – October
Quinsam	Quinsam River Hatchery juvenile downstream migration (various species)	DFO/LKT	Fish fence	March – June
	Salmon escapement surveys	DFO	Various	September – November
	Water quality sampling	LKT	*In situ* and laboratory analysis	May – November
	Invertebrate sampling	LKT	Drift sampling	May – October

[1]LKT, Laich-Kwil-Tach Environmental Assessment Ltd. Partnership; DFO, Fisheries and Oceans Canada

Although the study is at an early stage, fish abundance data so far support rejection of H_01 for at least some species; i.e., fish abundance measured in Year 2 exhibited inter-annual variability relative to historic data, in cases where historical comparisons were made. Key results were:

- Adult steelhead counts were generally higher than in 2014, although counts were low relative to historical counts. The total count for the primary index reach (Lower Index; 72 fish) was substantially higher than in 2014 (39 fish; the lowest recorded count), yet it was still approximately equal to only the 25th percentile of historical counts;
- Juvenile steelhead fry abundance in the Salmon River (10.5 fish per 100 m^2 (FPU)) was the lowest yet recorded (1998–2015), and considerably lower than the target of 60 FPU set by provincial biologists. This low abundance at least partly reflects the relatively low adult returns, as indicated by the low adult counts in spring 2015. However, the ratio of FPU to the peak corresponding adult count was also below average, suggesting that recruitment per spawner was relatively low and, therefore, below average environmental conditions may have also contributed to low fry density Abundance was substantially lower upstream of the diversion (8.9 FPU) compared with downstream of the diversion (62.1 FPU), although the higher value partly reflects a particularly high count at a single site;
- Estimated juvenile Coho Salmon biomass in the Salmon River in 2015 was comparable to estimates in 2014 at sites downstream of the diversion, although biomass estimates at sites upstream of the diversion were lower in 2015;
- Salmon escapement data for 2014 (i.e., Year 1) show that Pink Salmon (*O. gorbuscha*) escapement was particularly high, especially in the Quinsam River where Pink Salmon escapement (1.42 million) was the highest on record; and
- Despite the record high Pink Salmon escapement in 2014, estimates of out-migrating Pink Salmon fry in 2015 were approximately eight times lower than the previous year, suggesting

poor spawning and/or incubation success. Estimated wild Chinook Salmon fry abundance was ~97% lower in 2015 than in 2014.

Water quality data collected at a single index site on both rivers were broadly consistent with Year 1 results. Results so far show that both rivers are oligotrophic at the sampling sites, with most water quality variables in the optimum ranges for salmonid growth. A notable exception is the occurrence in both rivers of high water temperatures during the growing season that exceed optimum ranges for several salmonid species and life stages. Also, dissolved oxygen concentrations were recorded on both rivers that were below the provincial guideline for the protection of buried embryos/alevins. These measurements overlapped with incubation periods for Chinook Salmon (Salmon River), steelhead (Salmon River) and Pink Salmon (Quinsam River), with low measurements recorded more frequently on the Quinsam River.

In addition to annual water quality sampling, a background review of historical water quality data for both rivers was completed during Year 2 (Dinn *et al.* 2016, Appendix A). This review identified opportunities to use data collected as part of several historical and ongoing monitoring programs to help to test $H_0 3$ (regarding water quality) and $H_0 5$ (regarding food availability).

Invertebrate drift sampling was undertaken throughout the growing season at a single index site on both rivers. Invertebrate drift was sampled approximately monthly from May through October, with the exception of July when sampling was undertaken weekly. Invertebrate biomass for the Quinsam River was highest during the spring and early summer, followed by a decline during late summer and fall. This is consistent with Year 1, when this trend was observed on both rivers. No clear seasonal pattern in invertebrate biomass was observed on the Salmon River during Year 2. The invertebrate communities (in terms of biomass) on both rivers were generally dominated by mayflies and true flies, although community composition varied considerably throughout the season.

The management questions have not been addressed at this stage, although we outline proposed analytical methods that should be used when further data are collected. Proposals to improve and develop the study are also provided.

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1. INTRODUCTION

1.1. Background to Water Use Planning

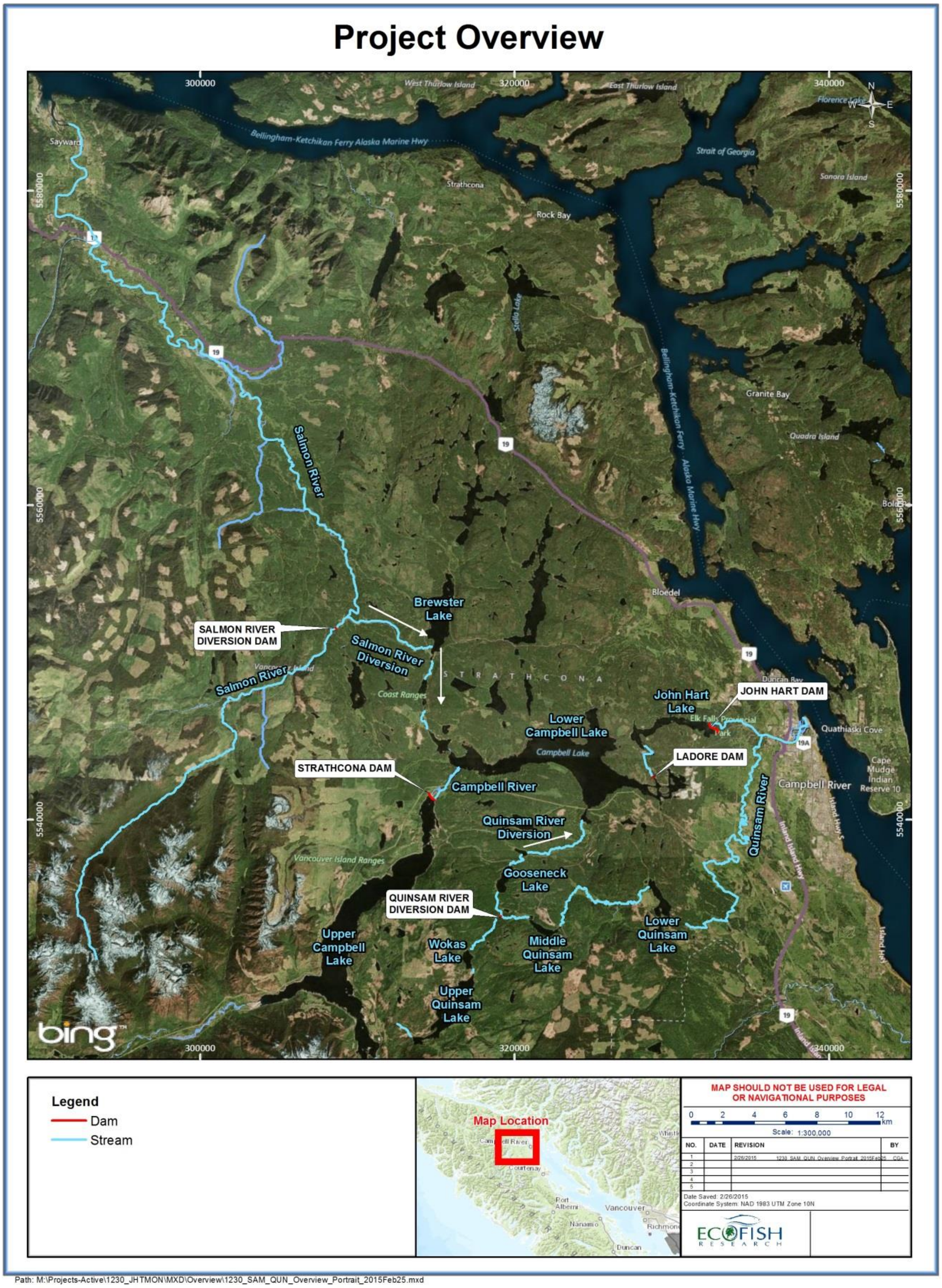
Water use planning exemplifies sustainable work in practice at BC Hydro. The goal is to provide a balance between the competing uses of water that include fish and wildlife, recreation, flood protection, public safety and power generation. Water Use Plans (WUPs) were developed for BC Hydro's hydroelectric facilities through a consultative process involving local stakeholders, government agencies and First Nations. The framework for water use planning requires that a WUP be reviewed on a periodic basis and there is expected to be monitoring to address outstanding management questions in the years following the implementation of a WUP.

As the Campbell River Water Use Plan process reached completion, a number of uncertainties remained with respect to the effects of BC Hydro operations on aquatic resources. A key question throughout the WUP process was "what limits fish abundance?" For example, are fish abundance and biomass limited by available habitat, food, environmental perturbations or ecological interactions? Answering this question is an important step to better understanding how human activities in the watershed affect fisheries, and to effectively manage water uses to protect and enhance aquatic resources. To address this uncertainty, monitoring programs were designed to assess whether fish benefits are being realized under the WUP operating regime, and to evaluate whether limits to fish production could be improved by modifying operations in the future. The *Salmon River and Quinsam River Smolt and Spawner Abundance Assessments* (JHTMON-8) is one of the monitoring studies that are part of wider monitoring of the Campbell River WUP. JHTMON-8 focuses on monitoring fish populations and environmental factors that may influence fish abundance in the Salmon and Quinsam rivers; this will help to better understand the potential biological effects of BC Hydro operations.

1.2. BC Hydro Infrastructure, Operations and the Monitoring Context

The Salmon and Quinsam rivers are both located to the west of the city of Campbell River on the east coast of Vancouver Island, British Columbia. Both the Salmon River and the Quinsam River diversion dams divert a portion of water from the river mainstems to generate hydroelectricity downstream at Ladore and John Hart generation stations (Map 1). Details of the diversion infrastructure and operations are provided in the Campbell River System WUP (BC Hydro 2012).

Map 1. Overview of the Salmon River and Quinsam River watersheds.



1.2.1. The Salmon River and Diversion

The Salmon River flows from headwaters in Strathcona Provincial Park in a general northwards direction to the ocean at Sayward. Major tributaries include Grilse Creek, the Memekay River and the White River, all of which drain the western side of the Salmon River watershed. The area of the watershed is approximately 1,300 km^2 and mean annual discharge (MAD) near the mouth is 63 m^3/s (Burt 2010). The Salmon River has high fisheries values and the river supports a range of salmonid and non-salmonid fish species, including those that are both anadromous and resident (Burt 2010). The Salmon River supports all five species of Pacific salmon (*Oncorhynchus* spp.) as well as both resident and anadromous Rainbow Trout (*Oncorhynchus mykiss*), Cutthroat Trout (*Oncorhynchus clarkii*) and Dolly Varden (*Salvelinus malama*). Lamprey (*Lampetra* spp.) and Sculpin (*Cottus* spp.) species are also present.

The Salmon River Diversion infrastructure was initially constructed in 1958. The diversion dam is a 69 m long rock-filled timber crib dam that diverts water into the Campbell River watershed. Water is diverted from the mainstem of the Salmon River via an intake channel, through a radial gate and into a concrete-lined canal that conveys water to Brewster Lake, which is upstream of Lower Campbell Lake Reservoir. Non-diverted water is returned to the mainstem downstream, either via the main spillway, an undersluice, a trimming weir, or the fishway.

A total of 493.39 million m^3 is licensed to be diverted annually, and the 7.8 km diversion canal has a maximum design discharge capacity of 45 m^3/s. The Campbell River System WUP stipulates maximum down ramping rates for the Salmon River and the Diversion Canal (Table 1), maximum diversion flows to enhance fish screen efficiency (Table 2), and minimum flows that must be maintained in the Salmon River downstream of the diversion dam when sufficient flows are naturally available (4.0 m^3/s).

Blasting was undertaken in 1975 and 1976 to remove a rock obstruction in a canyon at river km 38 that formed both a velocity and vertical obstruction to fish migrating upstream (Ptolemy *et al*. 1977 cited in Burt 2010). Subsequent surveys showed that juvenile steelhead were present upstream of the canyon where they were previously absent. A fish (smolt) screen was installed in 1986 to prevent out-migrating smolts from being diverted into the Campbell River watershed. The fishway was installed in 1992 to aid upstream passage of fish past the diversion dam.

There have been issues with the performance of both the fish screen and the fish way (Burt 2010). BC Hydro has evaluated options to address these issues and their preferred option is to decommission the facility. The timeline for a decommissioning process has yet to be determined.

Table 1. Salmon River maximum permitted down ramping rates (BC Hydro 2012).

Stream	Salmon River discharge (m^3/s)	Salmon River maximum down ramping rate ($m^3/s/h$)
Salmon River	< 8.0	1.0
	8.0 to 10.0	2.0
	>10.0	10.0
Salmon River Diversion	0 to 43.0	10.0

Table 2. Salmon River maximum permitted diversion flows (BC Hydro 2012).

Date	Maximum diversion (m^3/s)	Fish screen operation
Jan 1 to Mar 31	43	N/A
Apr 1 to Dec 31	15	On

Nutrient enrichment for salmonid enhancement has occurred in the Salmon River watershed since 1989 (Pellett 2011). Fertilization locations, methodology and application rates have varied throughout this period, as the project changed from an experimental study to an operational-scale program that was designed to improve habitat suitability (food abundance), primarily for winter run steelhead and Coho Salmon. Monitoring has primarily focused on Grilse Creek (upstream of the diversion dam), which was the only site where nutrients were continuously applied throughout 1989–2010. Enrichment was not undertaken during 2011 through 2013 so that unenriched conditions could be monitored to better quantify the effects of fertilization. Enrichment was again undertaken in 2014 and 2015; however, funding for the enrichment program in subsequent years has since been discontinued (Pellet, pers. comm. 2015). Further information about the enrichment program is presented as part of the background water quality review that was undertaken as part of Year 2 of JHTMON-8 (see Section 2.2.3 and Appendix A).

1.2.2.The Quinsam River and Diversion

The Quinsam River is the only major tributary of the lower Campbell River, entering the Campbell River approximately 3.5 km upstream of the mouth. The Quinsam flows through a series of lakes and has a mainstem length of 45 km (excluding lakes), a watershed area of 283 km^2, and a mean annual discharge near the mouth of 8.5 m^3/s. The river has high fisheries values, supporting the same assemblage of native salmonid species that is found in the Salmon River (Burt 2003). The Quinsam River Hatchery was constructed in 1957 and is located 3.3 km upstream from the confluence with the Campbell River. The hatchery has been active in the watershed, augmenting populations of Chinook Salmon, Pink Salmon, Coho Salmon, Cutthroat Trout and steelhead (DFO

2009). Smolt and fry life stages that are ready for downstream migration to the ocean are released from the hatchery during the spring. In addition, juvenile Coho Salmon, steelhead and (less frequently) Chinook Salmon have been outplanted to the upper watershed since 1978 to promote adult returns upstream of the hatchery (Burt 2003).

The Quinsam River Diversion comprises a small concrete gravity storage dam, a concrete gravity diversion dam, a concrete flume and the natural waterways that convey water to Lower Campbell Lake Reservoir. Non-diverted water is conveyed to the Quinsam River via an undersluice gate or the free crest weir. The dams were both constructed in 1957.

A total of 100 million m^3 is licensed to be diverted annually and the design capacity of the Quinsam River Diversion is 8.50 m^3/s. As for the Salmon River Diversion Dam, the WUP stipulates maximum down ramping rates (Table 3) and minimum flows (when naturally available) in the Quinsam River downstream of the diversion dam (Table 4).

Table 3. Quinsam River maximum permitted down ramping rates (BC Hydro 2012).

Stream	Discharge (m^3/s)	Maximum down ramping rate ($m^3/s/h$)
Quinsam River	> 4.0	8.5
	≤ 4.0	1.0
Quinsam Diversion	> 2.0	N/A
	≤ 2.0	1.0

Table 4. Minimum permitted discharge in the Quinsam River (BC Hydro 2012).

Date	Minimum discharge in Quinsam River (m^3/s)
Jan 1 to Apr 30	2.0
May 1 to Oct 31	1.0
Nov 1 to Dec 31	0.6

1.3. Management Questions and Hypotheses

The JHTMON-8 monitoring program aims to address the following three management questions:

1. What are the primary factors that limit fish abundance in the Campbell River System and how are these factors influenced by BC Hydro operations?
2. Have WUP-based operations changed the influence of these primary factors on fish abundance, allowing carrying capacity to increase?

3. If the expected gains in fish abundance have not been fully realized, what factors if any are masking the response and are they influenced by BC Hydro operations?

In addressing the questions, the monitoring program is designed to test the following five null hypotheses separately for both the Salmon and Quinsam rivers:

$H_0$1: Annual population abundance does not vary with time (i.e., years) over the course of the Monitor.

$H_0$2: Annual population abundance is not correlated with annual habitat availability as measured by Weighted Usable Area (WUA).

$H_0$3: Annual population abundance is not correlated with water quality.

$H_0$4: Annual population abundance is not correlated with the occurrence of flood events.

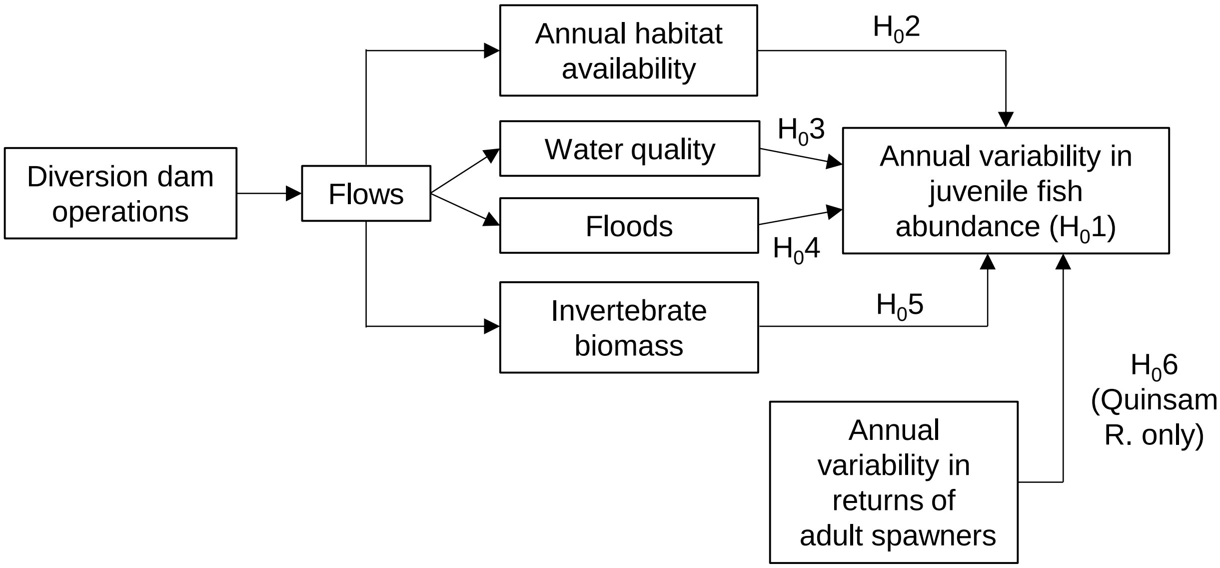
$H_0$5: Annual population abundance is not correlated with food availability as measured by aquatic invertebrate sampling.

There is one additional null hypothesis to be tested for the Quinsam River System where adult escapement and smolt abundance data are collected separately for a wide range of species:

- $H_0$6: Annual smolt abundance is not correlated with the number of adult returns.

The basis of JHTMON-8 is outlined conceptually in Figure 1. The monitoring program is designed to first establish whether there is among-year variability in fish abundance ($H_0$1). The program is then designed to collect data to examine whether inter-annual variability in fish abundance is related to important environmental factors that could be influenced by BC Hydro operations, specifically: Weighted Usable Area of habitat ($H_0$2); water quality ($H_0$3); an accumulated flood risk index during the spawning and incubation periods ($H_0$4), or; invertebrate abundance (food availability; $H_0$5). The study will also investigate whether annual variability in juvenile fish abundance is affected by annual variability in salmon spawner escapement ($H_0$6) – a factor that is influenced by marine survival and not by diversion dam operations. At present, it has been proposed to test $H_0$6 using data only for the Quinsam River (LKT 2014) because data collected at the Quinsam River Hatchery salmon counting fence are expected to have higher precision and accuracy. By contrast, the methods employed to measure fish abundance on the Salmon River have a higher level of error and may not provide data that are precise and accurate enough to test $H_0$6. Nonetheless, we propose that effort is also made to test $H_0$6 using data collected for the Salmon River once monitoring is complete (Abell *et al.* 2015a).

Figure 1. Effect-pathway diagram showing the context of the six hypotheses that the JHTMON-8 monitoring program sets out to address.



1.4. Scope of the JHTMON-8 Study

1.4.1. Overview

The JHTMON-8 study has been designed to build upon monitoring that is already occurring in the Quinsam and Salmon watersheds. This allows the study to integrate established work programs and provides an opportunity to incorporate historical data into the analyses. Table 5 summarizes the field sampling programs that were undertaken during Year 2 of JHTMON-8, and are set to continue annually for a total of ten years.

Table 5. Summary of field sampling programs undertaken for JHTMON-8.

River	Sampling program	Lead organization[1]	Method	Timing
Salmon	Adult Steelhead survey	LKT	Snorkel surveys	March – April
	Juvenile Steelhead abundance	LKT	Closed site multi-pass electrofishing	September
	Juvenile Coho abundance	DFO/LKT	Closed site multi-pass netting	October
	Salmon escapement surveys	DFO	Various	September – November
	Water quality sampling	LKT	*In situ* and laboratory analysis	May – October
	Invertebrate sampling	LKT	Drift sampling	May – October
Quinsam	Quinsam River Hatchery juvenile downstream migration (various species)	DFO/LKT	Fish fence	March – June
	Salmon escapement surveys	DFO	Various	September – November
	Water quality sampling	LKT	*In situ* and laboratory analysis	May – November
	Invertebrate sampling	LKT	Drift sampling	May – October

[1]LKT, Laich-Kwil-Tach Environmental Assessment Ltd. Partnership; DFO, Fisheries and Oceans Canada

The species of primary interest on the Salmon River are anadromous Rainbow Trout (steelhead) and Coho Salmon; surveys to enumerate juvenile Coho Salmon and both juvenile and adult steelhead provide the majority of the fisheries data for the Salmon River for JHTMON-8. Fisheries data for the Quinsam River are primarily obtained via operation of a fish fence at Quinsam River Hatchery to enumerate downstream juvenile migration of a range of species. Species of primary interest in the Quinsam River include Chinook Salmon, Coho Salmon and steelhead, while data for Pink Salmon smolt outmigration are also considered. In addition to these data, escapement data for a range of Pacific salmon species obtained by Fisheries and Oceans Canada (DFO) during routine monitoring are also considered for both rivers as part of JHTMON-8.

Further information about the scope and objectives of specific sampling programs is provided below.

1.4.2. Fish Population Assessments

Accurate and precise measures of fish abundance are core requirements of JHTMON-8. It is necessary to employ a range of scientifically robust methods with sufficient effort to adequately quantify abundances of the numerous species that are of primary interest for the program (see Section 1.4). The fish sampling program was therefore designed to ensure that the error associated with fish sampling methods is sufficiently small that any between-year variability in fish abundance can be detected.

The fish abundance data will first be used to test $H_0$1: '*annual population abundance does not vary with time (i.e., years) over the course of the Monitor*' (Section 1.3). Analysis will be undertaken towards the end of the ten-year monitor to examine whether there are statistically significant variations in fish abundance between years. This analysis will consider the two rivers and individual species separately. Where possible, suitable historical data will be incorporated into the analyses to extend the datasets and provide context to any variability observed during the monitor.

Furthermore, the program was designed to enumerate both adult and juvenile life stages to allow relationships between the numbers of adult spawning fish and juvenile recruitment to be examined. This enables testing of $H_0$6: *'annual smolt abundance is not correlated with the number of adult returns'*, which will help to tease apart the extent to which any variations in abundance reflect either variations in adult returns (dependent on marine conditions and harvest) or variations in juvenile survival (dependent on freshwater conditions). Testing this hypothesis will therefore examine whether the watershed is fully 'seeded for each species. This hypothesis is proposed to only be formally tested for the Quinsam River where operation of the salmon counting fence is expected to provide the precise and accurate data that are necessary. Consideration will, however, also be given to deriving spawner-recruitment relationships using the Salmon River data to improve understanding of the extent to which any variability in fish abundance may be caused by environmental factors that could potentially be influenced by BC Hydro operations, and factors that are independent of this (see Abell *et al.* 2015a for further details). Testing $H_0$6 will involve comparing the productivity of naturally-spawned Coho and Chinook salmon with the productivity of colonization programs that out-plant juvenile fish to areas in the upper Quinsam River watershed, e.g., Lower Quinsam Lake. This comparison will further help to examine whether spawning areas are fully seeded. This will need to consider the potential for lower fitness of hatchery-reared fish compared with wild fish, as has been observed during previous field studies in the watershed (Burt, pers. comm. 2016).

Based on initial consideration of historical data for the Salmon River (Abell *et al*. 2015a), we anticipate that significant variability in annual population abundance will be detected (i.e., the null hypothesis will be rejected) for at least some of the species and life stages that are monitored. It will therefore be necessary to use these data to test four of the five remaining hypotheses to determine whether there are any relationships between the observed variability in fish abundance, and variations in key environmental factors, namely: habitat ($H_0$2), water quality ($H_0$3), floods ($H_0$4) and food availability ($H_0$5).

1.4.3. Water Quality

Healthy fish populations require water quality to be within a confined range. This range of suitable conditions varies depending on the individual variable, fish species and life stage. The objective of the JHTMON-8 water quality monitoring is to measure biologically important water quality variables to provide data to test $H_0$3: '*annual population abundance is not correlated with water quality'* (Section 1.3). Analysis will later be undertaken towards the end of the ten-year monitor to examine whether there is a relationship between fish abundance and water quality. If a relationship is detected (i.e., the null hypothesis is rejected), then further work would be required to examine whether water use activities in the watershed affect water quality and, if so, how this may impact fish communities, both positively and negatively.

Thus, a key objective of this aspect of the study is that water quality data are collected that suitably reflect variability of water quality in time and space, and are representative of the conditions experienced by fish communities. A single mainstem index site was selected on each river that was assumed to be representative of water quality in the wider watershed.

In addition, a separate background water quality review was undertaken as part of the Year 2 JHTMON-8 program. This was included in the scope of the Year 2 program following suggestions that it would be valuable to characterize the extent of historical and current water quality monitoring undertaken in the watersheds by other parties (Abell *et al*., 2015a, b). It was suggested that any synergies between the JHTMON-8 program and other monitoring programs were identified to help to better address the JHTMON-8 management questions, e.g., by extending the temporal or spatial extents of the data available for analysis. Outcomes from this background review are summarized in Section 3.2.1, and presented in more detail in Dinn *et al*. 2016 (Appendix A).

1.4.4. Invertebrate Drift

Invertebrates typically form the bulk of the diet of both juvenile and resident adult salmonids in rivers (Quinn 2005). Invertebrate populations can vary due to a range of factors and therefore variability in the abundance and biomass of invertebrates can be an important factor that limits the growth of salmonids in rivers. The objective of the JHTMON-8 invertebrate sampling is to provide data to test $H_0$5: "*annual population abundance is not correlated with food availability as measured by aquatic invertebrate sampling*" (Section 1.3). Analysis will later be undertaken towards the end of the ten-year monitor to examine whether there are any relationships between fish abundance and food availability, as inferred from invertebrate sampling. If a relationship is detected (i.e., the null hypothesis is rejected), then further work would be required to examine whether water use activities in the watershed affect invertebrate communities and, if so, how this may impact fish communities, both positively and negatively.

A key objective is therefore to collect invertebrate data that reflect variability of watershed invertebrate communities in time and space, and are therefore representative of the food available to fish communities. Invertebrate drift includes: dislodged benthic invertebrates, terrestrial invertebrates entrained in the stream, and invertebrates originating from riparian areas. A single mainstem index site was selected on each river that was assumed to be representative of the invertebrate communities present in the wider watershed. Invertebrate drift biomass is measured as a proxy for food availability, although invertebrate community composition is also examined to provide information on food quality. Drift sampling is undertaken during the growing season when salmonid juveniles have the greatest potential for growth. In addition, a single kick net sample is collected from each river in September. Kick sampling targets benthic invertebrates, and is therefore less representative of the total abundance of food available to fish. However, kick sampling based on the CABIN protocol (MoE 2009) has been used more widely to characterize stream invertebrate communities throughout Canada. Data collected using this method can be used to evaluate the quality of invertebrates as food for fish as well as the wider ecological integrity of the streams, based on comparisons with the Environment Canada database of Georgia Basin reference sites (e.g., see Strachan *et al.,* 2009).

2. METHODS

2.1. Fish Population Assessments

2.1.1. Salmon River Adult Steelhead Survey

Annual spring snorkel surveys have been conducted as part of adult steelhead stock production monitoring on the Salmon River since 1998. These have historically been undertaken by British Columbia Conservation Foundation (BCCF) and Ministry of Environment (MoE) staff. Since 2014, this work has been led by LKT, with BCCF (K. Pellett) providing supervision in Year 1 and Year 2 to ensure ongoing consistency of methods. Surveys of an index reach ('Lower Index') is the primary stock assessment method, with surveys typically undertaken during the second week of March. Surveys of two additional index reaches ('Rock Creek' and 'Upper Index') have also been undertaken in April during most of the years since 2000. These reaches are upstream of the Lower Index reach: the Rock Creek reach extends upstream of the diversion dam and the Upper Index reach extends downstream of the dam (Map 2).

These surveys provide valuable information to inform the JHTMON-8 study, and they will be analyzed alongside juvenile steelhead data (see Section 2.1.2) at a later stage to examine spawner-recruitment relationships.

All three reaches were successfully surveyed in 2015, with survey timings consistent with historical surveys. The Lower Index was surveyed on March 18, and both the Rock Creek and Upper Index reaches were surveyed on April 09. Each reach was snorkelled during a single day by two experienced technicians. Surveys were conducted in a downstream direction with particularly steep and potentially dangerous sections bypassed on foot. Surveyors recorded the number, length and condition of adult steelhead, in addition to associated variables (Table 6).

Table 6. Variables measured during snorkel surveys of adult steelhead.

Variable	Unit/Classification
Weather	Observation
Water temperature	°C
Effective Visibility	Measured or estimated in metres
Fish size class	fry/parr/adults; 150–250 mm, 251–350 mm, 351–450 mm, and > 450 mm
Fish species	Steelhead (ST)/Cutthroat Trout (CT)/Resident Rainbow Trout (RB)
Fish condition	Bright/moderately coloured/mid-spawn/post-spawn/undetermined
Redd observations	Location/size/number/species

2.1.2. Salmon River Juvenile Steelhead Abundance

2.1.2.1. Field Methods

Juvenile steelhead[1] populations were sampled with multipass removal electrofishing at five sites upstream and five sites downstream of the Salmon River Diversion (Table 7; Map 2). Site locations matched those historically sampled by BCCF during 1998–2013, with minor adjustments made to the positions of stop nets to account for changes in stream morphology. Sites were historically selected to specifically target fry (not parr) habitat. The main criteria used to select sampling locations were:

- Water depth (maximum 1.0 m, average 0.1 to 0.4 m);
- Water velocity (maximum 1.0 m/s, average 0.1 to 0.5 m/s);
- Cover and substrate (non-embedded boulder, cobble, and/or gravel);

[1] For consistency with the historical sampling program, we use the term 'juvenile steelhead' to refer to juvenile (fry and parr) Rainbow Trout. We acknowledge that this may include resident and anadromous individuals.

- Area of site (target 100 m^2); and
- Proximity to previous sampling location (as close as possible).

Table 7. Details of juvenile steelhead sampling sites in the Salmon River.

Location	Site	Historic Site #	Historic Site Name/Description	Site Ref. (km)	Date	Mesohabitat	UTM		
							Zone	Easting	Northing
Below Diversion	SAM-EF01	1	Pallans (23.94 KM)	23.94	11-Sep-15	Riffle	10U	297922	5570705
	SAM-EF02	2	WSC Station (Kay Creek)	35.44	10-Sep-15	Riffle	10U	304030	5564241
	SAM-EF03	3	Memekay Mainline Bridge	52.60	11-Sep-15	Riffle	10U	309310	5556475
	SAM-EF04	4	Smolt Screen	58.02	10-Sep-15	Riffle	10U	309036	5552478
	SAM-EF07	7	Memekay River (lower bridge)	27.93	10-Sep-15	Riffle	10U	302056	5566097
Above Diversion	SAM-EF05	5	Washout, old bridge 5km u/s/ diversion	67.73	10-Sep-15	Riffle	10U	304267	5548471
	SAM-EF06	6	Washout 500 m u/s of Grilse confluence	69.25	2-Sep-15	Riffle	10U	301417	5546997
	SAM-EF08	8	Grilse Ck (100 m u/s of lower bridge)	70.77	2-Sep-15	Riffle	10U	300741	5547323
	SAM-EF09	9	Grilse Ck (300 m d/s of upper bridge)	74.27	2-Sep-15	Riffle	10U	297133	5546961
	SAM-EF10	10	Grilse Ck (500 m d/s of upper bridge)	75.91	2-Sep-15	Riffle	10U	296773	5546524

Fish were captured using closed-site multipass removal electrofishing methods in accordance with guidelines (Lewis *et al.* 2004; Hatfield *et al.* 2007). Sites were enclosed using stop nets (15.2 m long × 1.2 m deep, mesh size = 3.2 mm). Each pass consisted of two full circuits of the enclosure, and two to three passes were conducted at each site. Data collected included:

- Sampling effort (seconds) expended during each pass;
- The number, species, length (+/- 1 mm) and mass (+/- 0.01 g) of each fish caught per pass;
- Scales samples from a sub-sample of fish that were close to size/age class boundaries;
- Wetted width (three or four measurements) and site length; and
- Physical stream characteristics (cover types, substrate size, habitat type, stream gradient, compaction, sand in substrate, and roughness).

After electrofishing was complete, hydraulic habitat variables were measured along a transect placed across the width of the sampling site. A minimum of ten wetted stations spaced a minimum of 0.25 m apart were placed along each transect. The following was measured at each station: distance from wetted edge, water depth, water velocity, available cover, and net locations. If a single transect was not long enough to accommodate 10 wetted stations, an additional transect was completed at the site.

Water temperature and conductivity were measured using in situ meters calibrated prior to sampling. Photographs from standardized locations were also taken at each sampling site.

2.1.2.2. Data Analysis

Individual Fish Data

For juvenile steelhead, we defined age class structure and described length-weight relationships, Fulton's condition factor (K), and length at age. Fulton's condition factor (K) was calculated for all captured fish as:

$$K = weight * length^{-3} * 100{,}000$$

where weight was recorded in g and length in mm. Scale samples were examined under a dissecting microscope to age individual fish: representative scales were photographed and apparent annuli were noted on a digital image. Fish age was determined by two independent observers using a double blind methodology. The data produced by each observer were then compared to identify any discrepancies. Where discrepancies occurred, they were discussed and final age determination was based on professional judgement of the senior biologist.

Fish were separated into age classes for fish abundance and biomass analysis. To define discrete age class size bins (size classes), the length-frequency histograms for fish captured during electrofishing were reviewed along with all of the length at age data from the scale analysis. Based on these data, discrete fork length ranges were defined for each of the following age classes: fry (0+), parr (1+), parr (2+) and adult (≥3+), although no parr or adult fish were captured during sampling in 2015. These discrete fork length ranges allow all fish to be assigned an age class based on fork length for population analysis. This needs to be conducted annually as size ranges of age classes may differ from year to year. Summary statistics of fish length, weight, and Fulton's condition factor are presented for these age classes for both the upstream and downstream reaches.

Population Analysis

Total abundance and biomass were calculated for steelhead fry (0+) using removal depletion algorithms in MicroFish V3.0 (Van Deventer 2006). Fish abundance and biomass by age class at individual sites were then standardized to fish per 100 m^2.

Abundance and biomass estimates were also adjusted to account for differences in habitat suitability of each sampling site. The habitat suitability of each electrofishing site was determined using the transect data for each sampling enclosure and habitat suitability indices (HSI) for steelhead fry (0+) from BC Water Use Planning (WUP) projects (curves dated February 2001 provided by R. Ptolemy, MoE). Habitat suitability is expressed as a usability percentage, which is calculated by computing the weighted usable width (WUW) of each transect within the sampling enclosures, and dividing by the wetted width of the transect. The transect usability at each site was then used to adjust the fish density estimates. Results are expressed in terms of fish per unit area (FPU: fish/100 m^2), and are reported as both non-adjusted (FPU_{obs}) and usability-adjusted estimates (FPU_{adj}), and as non-adjusted and adjusted biomass per unit area (BPU_{obs} and BPU_{adj}: g/100 m^2). Abundance and biomass densities are presented for individual sites and as averages for upstream and downstream of the diversion reaches.

Results were compared with historical data collected at the same sites by BCCF from 1998 to 2013, and by Ecofish in 2014.

2.1.3.Salmon River Juvenile Coho Salmon Abundance

2.1.3.1. Field

The abundance of juvenile Coho Salmon has been measured in the Salmon River during the fall by DFO since 2008. This work has been integrated into the JHTMON-8 study to support continued collection of abundance data for a species of primary interest in the study. Continuation of this established monitoring program means that historical data collected between 2008 and 2013 can be used to increase the time span considered during analysis to address JHTMON-8 management questions.

In 2015, this component of the fieldwork was undertaken by LKT, supervised by a DFO biologist (S. Anderson) to ensure ongoing consistency with historical methods. Field data were recorded and quality assured by DFO prior to being stored on a secure database (Ecodat) maintained by Ecofish. Data from Year 1 were also uploaded to this database in 2015; note that reporting for this component of the study was led by DFO in Year 1 (Anderson 2014). The expectation is that all aspects of juvenile Coho Salmon field data collection and quality assurance will be led by LKT throughout the remainder of the JHTMON-8 study.

As part of LKT's standardized approach to data collection and quality assurance, new site names were assigned to the sampling sites for data recording purposes. Correspondence between these and existing site names is shown in Table 8, although note that precise sampling areas have varied within stream reaches between years in response to differences in water levels and channel morphology.

Sampling was conducted on September 24, September 24 and October 01 at the six sites. Three sites are upstream of the diversion and three are downstream (Table 8; Map 2). Sites were selected that were representative of the juvenile Coho Salmon habitat generally present. Sites were typically ~ 20 m long and comprised pools.

Sites were isolated using barrier nets placed at the upstream and downstream ends to form full enclosures that included the full width of the channel (Figure 2). Multi-pass beach and pole seine netting were then used to remove fish. Two to four passes were undertaken with the objective of observing declining catches to permit estimation of capture efficiency to allow estimation of total fish abundance. Fish caught were retained until sampling was complete. Fork lengths of all juvenile Coho Salmon were tallied using 1 mm size bins. Mass (g) of individual fish in each size bin was recorded, with a maximum of three measurements recorded per size bin for each pass. Scales were retained for a subsample (n = 26) of fish. These were analyzed at DFO's Pacific Biological Station laboratory in Nanaimo to establish fork length categories that corresponded to age classes. Length categories were established separately for each site.

The length of each site was measured and width was measured at two to four locations. Both wetted width and width of the channel with depth > 10 cm were measured. The latter width measurements were used to calculate the area of each site when estimating fish density as they are more representative of the habitats used by juvenile Coho Salmon.

2.1.3.2. Data Analysis

The weighted mean mass (g/fish, $\widehat{m}_j$) was calculated for each age class (0+, 1+ and 2+) at each site as:

$$\widehat{m}_j = \frac{\sum_{i_{min}}^{i_{max}} (n_{i,j} \cdot \overline{m}_{i,j})}{N_j}$$

where i_{max} is the maximum fork length (±1 mm) measured at a site, i_{min} is the minimum fork length (±1 mm) measured at a site, n_i is the number of fish recorded in size bin *i* for age class *j*, $\overline{m}_i$ is mean mass of fish in size bin *i* for age class *j* and N_j is the total number of fish caught at a site in age class *j*.

A total weighted mean mass (g/fish, $\widehat{M}$) at each site was calculated as:

$$\widehat{M} = \frac{\sum_{0+}^{2+} (\widehat{m}_j \cdot N_j)}{N}$$

where *N* is the total number of fish caught at a site.

Total juvenile Coho Salmon abundance ($\widehat{N}$) was estimated at each site using DFO's standard capture efficiency model for analyzing multiple pass removal data. Total biomass at each site (g/m^2) was subsequently estimated as:

$$Biomass = \frac{\widehat{N} \cdot \widehat{M}}{Area_{>0.1\,m}}$$

where $Area_{>0.1\,m}$ is the area (m^2) of the site with depth > 0.1 m.

Table 8. Juvenile Coho Salmon sampling site details and correspondence with historical site names.

Location relative to diversion	Site	Historic name	Stream	Coordinates (NAD 83) Zone	E (m)	N (m)
Upstream	SAM-BS01	Crowned	Crowned Creek	10U	301818	5543950
Upstream	SAM-BS02	G02	Grilse Creek	10U	300117	5547376
Upstream	SAM-BS03	Gmain	Grilse Creek	10U	300124	5547313
Downstream	SAM-BS04	Pater	Paterson Creek	10U	309986	5552605
Downstream	SAM-BS05	Mari	Marilou Creek	10U	307472	5557836
Downstream	SAM-BS06	BTCKFlCh	Big Tree Creek	10U	303387	5566520

Figure 2. Establishing stop nets at Grilse Main juvenile Coho Sampling site on September 23, 2015.

2.1.4. Salmon and Quinsam River Salmon Escapement

Annual salmon spawner escapement counts have been undertaken on the Salmon and Quinsam rivers since the 1950s by DFO and its predecessors. Although these data are collected as part of wider salmon stock assessment work, they provide an important source of data to support the JHTMON-8 study. The results of fall 2014 surveys were finalized during Year 2. These were obtained from DFO's New Salmon Escapement Database (nuSEDS) and are reported here to provide data to support analysis scheduled for later during JHTMON-8 to examine relationships between abundance of adult spawning fish and corresponding counts of juvenile fish in successive years.

Methods used in the 2014 surveys are summarized in Table 9 and Table 10 for the Salmon and Quinsam rivers respectively, based on information provided in the nuSEDS database (DFO 2016). Surveys of individual species conducted by DFO conform to one of six types, ranging from Type-1 (most rigorous, almost every fish counted individually) to Type-6 (least rigorous, determination of presence/absence only). The survey types used for the 2014 counts are reported in the two tables of methods, with further general details about survey types provided in Table 11.

Table 9. Methods used during 2014 salmon spawner escapement counts on the Salmon River (DFO 2016). See Table 11 for descriptions of survey types.

	Salmon species				
	Chinook	Chum	Coho	Pink	Sockeye
Survey type	3		3	3	
Number of surveys	6		8	9	
Date of first inspection	July-31	Not inspected	July-18	July-11	Not inspected
Date of last inspection	October-07		October-07	September-29	
Estimation method	Area under the curve		Area under the curve	Area under the curve	

Table 10. Methods used during 2014 salmon spawner escapement counts on the Quinsam River (DFO 2016). See Table 11 for descriptions of survey types.

	Salmon species				
	Chinook	Chum	Coho	Pink	Sockeye
Estimate classification	2	3	2	2	3
Number of surveys	10	UNK	UNK	UNK	UNK
Date of first inspection	August-02	July-20	August-02	July-17	August-02
Date of last inspection	November-30	November-21	December-15	November-30	December-15
Estimation method	Mark and recapture: Petersen	Fixed site census	Fixed site census	Fixed site census	Fixed site census

Table 11. Summary of definitions of salmon spawner escapement estimate classification types reported in Table 9 and Table 10 (DFO 2016).

Estimate classification type	Abundance estimate type	Resolution	Analytical methods	Reliability (within stock comparisons)	Units	Accuracy	Precision
2	True	High resolution survey method(s): high effort (5 or more trips), standard methods (e.g. equal effort surveys executed by walk, swim, overflight, etc.)	Simple to complex multi-step, but always rigorous	Reliable resolution of between year differences >25% (in absolute units)	Absolute abundance	Actual or assigned estimate and high	Actual estimate, high to moderate
3	Relative	Medium resolution survey method(s): high effort (5 or more trips), standard methods (e.g. mark-recapture, serial counts for area under curve, etc.)	Simple to complex multi-step, but always rigorous	Reliable resolution of between year differences >25% (in absolute units)	Relative abundance linked to method	Assigned range and medium to high	Assigned estimate, medium to high

2.1.5. Quinsam River Salmon Counting Fence Operation to Enumerate Downstream Juvenile Migration

Technical staff provided by LKT worked under the instruction of DFO hatchery staff to enumerate fish at the Quinsam River Hatchery counting fence during 2015. Methods were based on those described in Ewart and Kerr (2014); specific details about 2015 operations are based on information provided by the hatchery Enhancement Technician (Fortkamp, pers. comm. 2015). Data were collated and quality assured by Quinsam River Hatchery.

Fish were caught using inclined plane traps (Wolf traps) that catch a proportion of the fish that migrate downstream through the fence, with the aim to catch salmonid fry and smolts as they out migrate to the ocean (Figure 3). Sampling was undertaken from March 12 to June 22, 2015, with traps deployed continuously during this period. The proportion of the river that was 'fished' varied depending on fish abundance, with a smaller number of traps (three) used during March and April when Pink Salmon fry were out-migrating and highly abundant. Specifically, three traps were installed from March 12 to April 23, with two additional traps then added for the remainder of the period. Pink Salmon fry typically migrate at night and therefore traps were set overnight from approximately 15:00 to 09:00 during sampling in March 12 to April 23. For the remainder of the sampling period, traps were set constantly during the times when fish were not being processed. Target species during this time were: steelhead (kelts and smolts), Coho Salmon (smolts), Chinook Salmon (fry), Chum Salmon (fry), Sockeye Salmon (fry), Cutthroat Trout (kelts and smolts) and Dolly Varden (smolts).

Total downstream migration estimates for individual species and life stages were derived by multiplying count data by catch coefficients, which were derived using mark recapture techniques to measure catch efficiency. For Pink Salmon fry, catch efficiency was estimated based on the results of five releases of fish marked with Bismarck brown dye, approximately 350 m upstream of the fence. The resulting catch coefficients were used to estimate the abundance of Pink Salmon fry, in addition to incidental catches of other species during the Pink Salmon fry trapping period. Separate catch efficiency estimates were derived for Coho Salmon smolts based on four releases of wild and hatchery-reared Coho Salmon smolts marked with pelvic fin clips. These estimates were also applied to other species caught after April 23. Further details about the mark recapture methods are provided in Ewart and Kerr (2014).

For Coho Salmon, separate counts were recorded for wild and 'colonized' smolts. 'Colonized' refers to fish that were incubated at the hatchery and transplanted to the upper Quinsam River watershed as fry. 20% of transplanted fish are marked (adipose fin clipped) and, therefore, the numbers of colonized fish in traps were estimated by multiplying the number of marked fish by five.

Figure 3. View downstream towards the salmon counting fence. Reproduced from Ewart and Kerr (2014).

2.2. Water Quality

2.2.1. Water Chemistry

2.2.1.1. Salmon River and Quinsam River Water Chemistry Monitoring

One water quality site was established in the Salmon River (SAM-WQ; Map 2) and one in the Quinsam River (QUN-WQ; Map 3). Both sites were selected based on the guidelines of the British Columbia Field Sampling Manual (Clarke 2003) and the Ambient Fresh Water and Effluent Sampling Manual (RISC 2003).

The Salmon River site (SAM-WQ) was located downstream of the Salmon River Diversion, in a run immediately downstream of a braided section of the river with sandy banks. Representative photos of SAM-WQ are provided in Figure 4 and in Appendix B.

The Quinsam River site (QUN-WQ) is located ~950 m downstream of the confluence with the Iron River, and downstream of the Quinsam Coal Mine and the salmon carcass nutrient enhancement site. Representative photos of QUN-WQ are provided in Figure 5 and in Appendix B. Coordinates, site elevation, and sampling dates (in situ and laboratory samples) for both sites are provided in Table 12.

Table 12. Water quality index site details and sampling dates in Year 1 and 2.

Waterbody	Site Name	UTM Coordinates (Zone 10)		Elevation	Sampling Dates
		Easting	Northing	(m)	
Salmon River	SAM-WQ	309308	5556385	172	21-May-14; 17-Jun-14; 23-Jul-14; 18-Aug-14; 23-Sep-14; 03-Nov-14; 13-May-15; 16-Jun-15; 22-Jul-15; 12-Aug-15; 17-Sep-15; 15-Oct-15
Quinsam River	QUN-WQ	327433	5534757	193	23-May-14; 18-Jun-14; 22-Jul-14; 19-Aug-14; 24-Sep-14; 04-Nov-14; 12-May-15; 17-Jun-15; 23-Jul-15; 13-Aug-15; 16-Sep-15; 14-Oct-15

Figure 4. Looking upstream to SAM-WQ on September 17, 2015.

Figure 5. Looking upstream to QUN-WQ on September 16, 2015.

In Year 2, water quality was monitored six times at each site on a monthly basis during May through October, 2015. Standard methods were employed to measure and collect water chemistry data. Sample collection and analyses were completed according to procedures set out in the Guidelines for Designing and Implementing a Water Quality Monitoring Program in British Columbia (RISC 1998). Water chemistry variables were chosen based on provincial standards (Lewis *et al.* 2004). The variables sampled in Year 1 and 2 are presented in Table 13 (in situ) and Table 14 (laboratory), although total gas pressure (TGP) was not sampled in Year 2 based on a proposal following Year 1 (Abell *et al.* 2015b). Laboratory method detection limits (MDL) occasionally differ (Table 14) due to matrix effects in the sample, or variations in laboratory analytical instruments.

Table 13. Water quality variables measured in situ and meters used for measurement.

Parameter	Unit	Meter
General Water Quality		
Water Temperature	°C	YSI Pro Plus and P4 Tracker
pH	pH units	YSI Pro Plus
Specific Conductivity	µS/cm	YSI Pro Plus
Dissolved Gases		
Dissolved Oxygen	mg/L	YSI Pro Plus
Dissolved Oxygen	% Saturation	YSI Pro Plus
Total Gas Pressure	mm Hg	P4 Tracker
Barometric Pressure	mm Hg	P4 Tracker
Total Gas Pressure	%	P4 Tracker
Δ Pressure	mm Hg	P4 Tracker

Table 14. Variables analyzed in the laboratory by ALS Environmental and corresponding units and method detection limit (MDL).

Parameter	Unit	MDL
General Water Quality		
Specific conductivity	µS/cm	2
pH	pH	0.1
Total suspended solids	mg/L	1
Turbidity	NTU	0.1
Alkalinity, Total (as $CaCO_3$)	mg/L	2
Nutrients		
Ammonia, Total (as N)	mg/L	0.005
Nitrate (as N)	mg/L	0.005
Nitrite (as N)	mg/L	0.001
Orthophosphate-dissolved (as P)	mg/L	0.001
Total phosphorus	mg/L	0.002

2.2.1.1. Quality Assurance/Quality Control

In situ water quality meters were maintained and operated following manufacturer recommendations. Maintenance included calibration, cleaning, periodic replacement of components, and proper storage. Triplicate in situ readings were recorded from each meter at each site on each sampling date unless otherwise noted.

For samples collected for laboratory analysis, sampling procedures and assignment of detection limits were determined following the guidelines of the BC Field Sampling Manual (Clarke 2003) and the Ambient Fresh Water and Effluent Sampling Manual (RISC 1998). Duplicate samples were collected on each sampling date at each site. In Year 2, a field blank and travel blank were also collected during the May and June trips, resulting in 33% of Year 2 samples being quality assurance/quality control (QA/QC) samples. This exceeds guideline recommendations; the BC field sampling manual recommends that 20 to 30% of samples consist of QA/QC samples, while the RISC manual recommends a minimum of 10% of samples. Samples for laboratory analysis were collected in clean 1 L plastic bottles provided by a certified laboratory. Samples were packaged in clean coolers that were filled with ice packs and couriered to ALS Environmental in Burnaby within 24 to 48 hours of collection. Standard Chain of Custody procedure was strictly adhered to. ALS Environmental performed in house quality control checks including analysis of replicate aliquots, measurement of standard reference materials, and method blanks. Summaries of the quality assurance/quality control (QA/QC) qualifiers and comments from laboratory analysis are provided in Appendix C and Appendix D.

It is a common occurrence in Vancouver Island streams to have concentrations of a number of variables (notably nutrients) that are less than, or near, the MDL. When this occurs, there are a number of different possible methods that can be used to analyze these values. In this report, any values that were less than the MDL were assigned the actual MDL values and averaged with the results of the other replicates. In these cases the average is also less than the average reported.

2.2.1.2. Comparison with Guidelines for the Protection of Aquatic Life

Water quality guidelines for the protection of aquatic life and typical ranges of water quality variables in BC waters that were considered for this report are provided in Appendix E. Any results for water chemistry variables that approached or exceeded guidelines for the protection of aquatic life or ranges typical for BC are noted in Section 3.2.

For most water quality variables measured in this study, there are provincial water quality guidelines for the protection of aquatic life. For total phosphorus, there are no provincial guidelines; however, there are federal guidelines (CCME 2004). For the remaining variables without provincial guidelines (i.e., orthophosphate, alkalinity, and specific conductivity) there are no federal guidelines either.

2.2.2.Water and Air Temperature

2.2.2.1. Salmon River and Quinsam River Temperature Monitoring

Baseline water temperature was monitored at the water quality index sites on both rivers during 2015, although there is a gap in the Salmon River dataset from October 2014 to May 2015 due to lost temperature loggers. Air temperature was also measured to collect further information about environmental conditions at the sites, and these measurements provide data that could be used to model water temperatures elsewhere in the watershed if later required.

Water temperature was recorded at intervals of 15 minutes using self-contained Tidbit v2 loggers (Onset, MA, USA). The loggers are accurate to 0.2°C and have a resolution of 0.02°C. For most of the record duration, water temperature at each of the monitoring stations was concurrently logged by duplicate Tidbit loggers installed on separate anchors. This redundancy was to increase the likelihood of collecting data in case one of the loggers malfunctioned or was lost. However, at SAM-WQ both Tidbit loggers were lost during high flows in late October 2014, and monitoring did not resume until re-installation of Tidbit loggers in May 2015.

Air temperature was collected using one HOBO Air Temperature U23 Data Logger at each water quality index site. The temperature loggers recorded air temperature at a regular interval of 15 minutes. The loggers were placed on trees that were close (< 100 m) to each site. Temperature measurements were made near-continuously at each site during 2015.

2.2.2.2. Data Analysis

Water temperature data were analyzed as follows. First, outliers were identified and removed. This was done for each Tidbit logger by comparing temperature data from the duplicate station loggers and the loggers at the other stations. For example, occasional drops in water level that exposed the temperature loggers to the air were considered as outliers and removed from the dataset. Second, the records from duplicate loggers (when available) were averaged and records from different download dates were combined into a single time-series for each monitoring station. The time series for all stations were then interpolated to a regular interval of 15 minutes, starting at the full hour.

For data presentation, plots were generated from the 15-min temperature and air data. Statistical metrics summarized in Table 15 were chosen based on the water temperature guidelines for the protection of freshwater aquatic life (Oliver and Fidler 2001; Table 16).

Plots were generated of the hourly rates of change in water temperature. Analysis of the water temperature data involved computing the following summary statistics: mean, minimum, and maximum water temperatures for each month of the record, hourly rate of change of temperature, and days with mean daily temperature >18°C, >20°C , and <1°C. However, given that only spring and summer data were available at SAM-WQ, the number of days with temperatures less than 1°C could not be calculated for the Salmon River.

Similarly, the number of degree days in the growing season was not calculated for the Salmon River or Quinsam River due to a lack of temperature data for the start and end dates of the growing season (data were downloaded in October). Statistics were based on the data collected at, or interpolated to, intervals of 15 min.

Mean weekly maximum temperatures were calculated for both datasets and compared with provincial guidelines (Oliver and Fidler 2001).

Table 15. Statistical parameters calculated during analysis of water and air temperature data.

Parameter	Description	Method of Calculation
Monthly water- and air-temperature statistics	Average, minimum, and maximum temperatures on a monthly basis	Calculated from temperatures observed at or interpolated to 15-min intervals.
Rate of water temperature change	Hourly rate of change in water temperature	Calculated from temperatures observed at or interpolated to 15-min intervals. The hourly rate of change was set to the difference between temperature data points that are separated by one hour and was assigned to the average time for these data points.
Degree days in growing season	The beginning of the growing season is defined as the beginning of the first week that average stream temperatures exceed and remain above 5°C; the end of the growing season is defined as the last day of the first week that average stream temperature dropped below 4°C (as per Coleman and Fausch 2007).	Daily average water temperatures were summed over this period (i.e., from the first day of the first week when weekly average temperatures reached and remained above 5°C until the last day of the first week when weekly average temperature dropped below 4°C)
Number of days with extreme daily-mean temperature	>18°C , >20°C , and <1°C	Total number of days with daily-mean water temperature >18°C , >20°C , and <1°C
MWMxT	Mean Weekly Maximum Temperature	A 1-week moving-average filter is applied to the record of daily-maximum water temperatures inferred from hourly data; e.g., if MWMxT = 15°C on August 1, 2008, this is the average of the daily-maximum water temperatures for the 7 days from July 29 to August 4. MWMxT is calculated for every day of the year.

Table 16. Water temperature guidelines for the protection of freshwater aquatic life (Oliver and Fidler 2001).

Category	Guideline
All Streams	the rate of temperature change in natural water bodies not to exceed 1°C/hr
	temperature metrics to be described by the mean weekly maximum temperature (MWMT)
Streams with Known Fish Presence	mean weekly maximum water temperatures should not exceed ±1°C beyond the optimum temperature range for each life history phase of the most sensitive salmonid species present
Streams with Bull Trout or Dolly Varden	maximum daily temperatures should not exceed 15°C
	maximum spawning temperature should not exceed 10°C
	preferred incubation temperatures should range from 2°C to 6°C
	±1°C change from natural condition[†]
Streams with Unknown Fish Presence	salmonid rearing temperatures not to exceed MWMT of 18°C
	maximum daily temperature not to exceed 19°C
	maximum temperature for salmonid incubation from June until August not to exceed 12°C

[†] provided natural conditions are within these guidelines, if they are not, natural conditions should not be altered (Deniseger, pers. comm. 2009).

2.2.3. Compilation and Review of Historical Water Quality Data

A review of historical water quality data for the Salmon River and Quinsam River was conducted during Year 2. Details, including methods, are presented separately in Dinn *et al.* 2016 (Appendix A).

2.3. Invertebrate Drift

2.3.1. Sample Collection

One invertebrate drift sampling site was established on the Salmon River and one on the Quinsam River, both located close (<150 m) to the water quality index sites (Map 2 and Map 3). Representative photos of the Quinsam River and Salmon River invertebrate drift sites are provided in Figure 6 and Figure 7, respectively. Sites were located in the tail-out of a riffle, upstream of any obvious source of debris that could clog the nets or areas that receive frequent sediment disturbance. Invertebrate sampling was conducted on a monthly basis from May to October, with weekly sampling conducted during July. In total, sampling occurred on nine dates on each river.

Table 17 presents details of the sampling dates and times. The weekly sampling in July contrasts with Year 1 when weekly sampling was undertaken in June. We plan to rotate the month when weekly data are collected each year to quantify the variance associated with monthly data, i.e., to provide information about the extent to which a sampling trip during a single month is representative of the month as a whole.

Invertebrate drift sampling followed methods recommended in Hatfield *et al.* (2007) and Lewis *et al.* (2013). Upon arrival at site, local areas with velocities of 0.2 to 0.4 m/s were identified with a model 2100 Swoffer meter with a 7.5 cm propeller and a 1.4 m top-set rod. This range of velocities is ideal for sampling invertebrate drift as velocities are slow enough to prevent clogging of the nets. Due to flow conditions at the time of sampling, it was not always possible to deploy the nets in areas with velocities of 0.2 m/s to 0.4 m/s (as per Hatfield *et al.* 2007), and nets sampled higher water velocities at times.

Five drift nets were deployed simultaneously across the channel. The mouth of each drift net was positioned perpendicular to the direction of stream flow, and nets were spaced apart to ensure that each individual net did not obstruct flow into an adjacent net. The drift net mouth dimensions were 0.3 × 0.3 m and the nets (250 μm mesh) extended 1 m behind the mouth. Nets were anchored such that there was no sediment disturbance upstream of the net before and during deployment. All nets were deployed so that the top edge of the net was above the water surface so that both invertebrate drift in the water column and on the water surface could be sampled.

At the start of sampling, measurements were made of water depth in each net and the water velocity at the midpoint of the water column that was being sampled by each net. These measurements were repeated hourly to permit calculation of the volume of water sampled with each net. Any large debris (e.g., leaves) that had entered the nets was periodically removed from the nets (after it had been washed of any invertebrates which were returned to the nets). Nets were deployed for approximately four hours on each sample date (Table 17). Once the nets were removed, the contents of all five nets were transferred into sample jars (500 mL plastic jars with screw top lids) for processing as a single sample. This is a method change from 2014, when contents of each net were processed separately. Samples were preserved in the field with a 10% solution of formalin (formalin = 37-40% formaldehyde).

Additional invertebrate samples were collected using kick net sampling on September 16, 2015 at QUN-IV and September 17, 2015 at SAM-IV. At both sites, the CABIN standardized sampling method was followed (MoE 2009), with a single drift net (described above) used as a kick net. This required one crew member to hold the net flush with the stream bed immediately downstream of a second crew member undertaking the sampling. Sampling proceeded in upstream direction for a timed period of 3 minutes, covering a horizontal distance of approximately 10 m. During sampling, the sampler kicked the substrate to disturb it to a depth of 5-10 cm, while turning over any large cobbles or boulders in order to dislodge invertebrates. Once sampling was complete, the contents were sieved (250 µm mesh), transferred into a sample jar and preserved in the same manner as drift net samples.

Table 17. Invertebrate drift sample site locations, sample timing, and sampling duration during 2015.

Stream	Site	Sample Date	UTM Coordinate (Zone 10)		Start	Finish	Sampling
			Easting	Northing	Time[1]	Time[2]	Duration[3]
Salmon River	SAM-IV	13-May-15	309,304	5,556,468	6:35	10:37	4:02
		16-Jun-15	309,304	5,556,468	6:31	10:32	4:01
		08-Jul-15	309,304	5,556,468	6:40	10:40	4:00
		15-Jul-15	309,304	5,556,468	6:33	10:39	4:06
		22-Jul-15	309,304	5,556,468	6:44	10:54	4:10
		28-Jul-15	309,304	5,556,468	6:45	10:46	4:01
		12-Aug-15	309,304	5,556,468	7:19	11:26	4:07
		17-Sep-15	309,304	5,556,468	8:13	12:16	4:03
		15-Oct-15	309,304	5,556,468	8:45	12:52	4:07
Quinsam River	QUN-IV	12-May-15	327,361	5,534,796	6:44	10:47	4:03
		17-Jun-15	327,361	5,534,796	7:15	11:18	4:03
		09-Jul-15	327,361	5,534,796	6:26	10:28	4:02
		16-Jul-15	327,361	5,534,796	6:25	10:29	4:04
		23-Jul-15	327,361	5,534,796	6:45	10:48	4:03
		29-Jul-15	327,361	5,534,796	6:46	10:46	4:00
		13-Aug-15	327,361	5,534,796	7:00	11:01	4:01
		16-Sep-15	327,361	5,534,796	7:57	11:59	4:02
		14-Oct-15	327,361	5,534,796	8:32	12:38	4:06

[1] Indicates when the first net was set.

[2] Indicates when the last net was removed

[3] Indicates the time duration between the first and last net retrieved.

[4] For data analysis, start and finish times for individual nets were used to calculate the volume of water filtered for each net.

Figure 6. View from river left towards SAM-IV, September 17, 2015.

Figure 7. View downstream towards QUN-IV, September 16, 2015.

2.3.2. Laboratory Processing

Samples were sent to Ms. Dolecki of Invertebrates Unlimited in Vancouver, BC for processing. Ms. Dolecki is a taxonomist with Level II (genus) certification for Group 2 (Ephemeroptera, Plecoptera, and Trichoptera (EPT)) and for Chironomidae from the North American Benthological Society.

The drift and kick net samples were first processed by removing the formalin (pouring it through a 250 μm sieve), followed by immediate picking of the very large and rare taxa. Samples were split into subsamples if the number of invertebrates was over 1,000. The invertebrates were enumerated using a Leica stereo-microscope with 6 to 8 × magnification, with additional examination of crucial body parts undertaken at higher magnifications (up to 400 ×) using an Olympus inverted microscope where necessary. Individuals from all samples were identified to the highest taxonomic resolution possible and it was noted whether a taxon was aquatic, semi-aquatic, or terrestrial. Life stages were also recorded.

Digitizing software (Zoobbiom v. 1.3; Hopcroft 1991) was used to measure the length and biomass (mg dry weight) of a sub-sample of individuals, with the average biomass of individuals in each taxon calculated. For abundant taxa, up to 25 randomly chosen individuals per taxon were digitized to address the variability in size structure of the group. For the rare taxa, all individuals in the taxon were measured. The damaged or partial specimens were excluded from the measurements. For pupae and emerging Chironomidae, up to 50 individuals were measured.

To provide QA/QC, all the samples were re-picked a second time to calculate the accuracy of picking. This assured that > 90% accuracy was attained, and the accuracy of the methods employed is expected to be over 95%.

2.3.3. Data Analysis

Variables were chosen and calculated as per Lewis *et al.* (2013), and all taxa (aquatic, semi-aquatic, and terrestrial) were considered. Density (# of individuals) and biomass (mg dry weight) of each sample were expressed as units per m^3 of water, where volume is the amount of water that was filtered through a single net during a set. Volume filtered by each net was calculated as follows:

- Time period durations (seconds) were calculated for each depth (m) and velocity (m/s) measurement:
    - The duration attributed to the first measurement was from the time the nets were set until halfway between the first and second measurements;
    - The second duration was from halfway between the first and second measurements until halfway between the second and third measurements. This was repeated up to the last measurements; and
    - The duration used for the last measurement was from halfway between the second to last and the last measurements associated with net retrieval.

- Average flow (m^3/s) was calculated for each net and time period by multiplying the depth (m) the width of the net (0.3 m) and by the velocity (m/s). This was then multiplied by the time attributed to that measurement. The volumes associated with individual time periods were added together to obtain the total volume filtered by a net over the entire sampling duration. The volumes filtered by all five nets on each sample date were added together to obtain the total volume filtered on that date.

Family richness (i.e., the number of families present) was calculated for each sample. Simpson's diversity (1-λ, Simpson 1949) was calculated from family level density data to provide a measure that reflects both richness and the relative distribution or 'evenness' of invertebrate communities. The Canadian Ecological Flow Index (CEFI) was calculated using family level data for aquatic taxa following Armanini *et al.* (2011). Taxa present in <5% of the samples were not excluded from the CEFI calculation (Armanini, pers. comm. 2013). Relative abundances of taxa at each site were calculated considering only aquatic taxa, and only aquatic taxa used to develop the CEFI index were considered when calculating the index. The top 5 families contributing to biomass at each site on each date were also identified.

PRIMER (Plymouth Routines in Multivariate Ecological Research) version 6 software was used to generate a Bray-Curtis similarity matrix for samples collected from each study stream. The similarity matrix was generated from square-root-transformed density data for aquatic, semi-aquatic, and terrestrial taxa at the highest taxonomic resolution available for each taxon. The square root transformation down-weights the effect of the most abundant taxa, allowing for a better representation of the invertebrate community as a whole, rather than having similarity measures dominated by only the most abundant taxa. The similarity matrix was generated by calculating a similarity coefficient for all possible pairs of sample dates with respect to the taxonomic composition and abundance of different taxa on both sample dates.

The resulting Bray-Curtis similarity matrices were then examined using cluster analysis dendrograms in PRIMER to detect similarities among samples. The clustering method used is a hierarchical clustering with group-average linking. The method takes a Bray-Curtis similarity matrix as a starting point and successively fuses the samples into groups, and the groups into larger clusters. The method starts with the highest mutual similarities, and then gradually lowers the similarity level at which groups are formed. The significance level for clustering was set at 5% using the SIMPROF tool in PRIMER (1000 permutations were used to calculate the mean similarity profile and 999 to generate the null distribution of the departure statistic). Further discussion of the cluster analysis can be found in Clarke and Warwick (2001) and Clarke and Gorley (2006).

The Bray-Curtis similarity matrices were also examined using non-metric, multi-dimensional scaling (MDS) ordination plots in PRIMER to detect trends in similarity among samples. MDS uses an algorithm that successively refines the positions of the points (samples) until they satisfy, as closely as possible, the dissimilarity between samples (Clarke and Warwick 2001). This algorithm was repeated 1,000 times for each similarity matrix (i.e., with density from each site on each date as samples). The result is a two-dimensional ordination plot in which points that are close together represent samples that are very similar in community composition with respect to the taxa present and their abundances. Conversely, points that are far apart represent samples with a very different community composition. Further discussion of the MDS analysis can be found in Clarke and Warwick (2001) and Clarke and Gorley (2006).

Results of drift net sampling and kick sampling undertaken on the same dates were compared for each river by quantifying the relative contribution of dominant taxa to the total biomass of each sample.

3. RESULTS

3.1. Fish Population Assessments

3.1.1. Salmon River Adult Steelhead Survey

All three reaches were successfully surveyed in 2015, with survey timings consistent with historical surveys. Surveys were conducted during near-baseflow conditions, with April surveys undertaken 11 days after a large (>200 m^3/s) rainfall-driven high flow event (Figure 8). Further details of survey timing and conditions are provided in Table 18. Visibility was 10–15 m and water temperatures were 5.0–7.5°C. Water temperatures were relatively warm for this time of year; e.g., water temperature during the Lower Index reach survey was 5.0°C (Table 18), whereas water temperatures during this survey over the last three years were 2.1–3.6°C (Pellett, 2013, 2014a, 2014b).

Survey observations are presented in Table 19 and 2015 adult steelhead counts are summarized in Figure 9. Adult steelhead density was highest in the lower sections of both the Lower Index reach (11.2 fish/km) and the Upper Index reach (9.1 fish/km; Table 19). Overall, adult steelhead density was lowest in the Rock Creek reach (11.2 fish/km; Table 19). Adult steelhead observed in the Lower Index reach (during March) were generally bright or moderately coloured, whereas individuals observed in the Upper Index and Rock Creek index reaches (during April) were predominantly moderately coloured or in mid-spawn condition (Figure 9). Low numbers (4–11) of steelhead redds were observed in each of the three index reaches (Table 19). Low numbers of adult Cutthroat Trout were incidentally observed downstream of the Salmon River Diversion, with the highest density (10.2 fish/km) observed in the lower section of the Lower Index reach. No other species were observed.

Comparisons with historical data are presented in Figure 10–Figure 12. Adult steelhead abundance was generally higher than 2014, although counts were low relative to historical data. The total count for the Lower Index reach (72) was substantially higher than the count for 2014 (39), yet it was only approximately equal to the 25th percentile of historical counts, which have been collected intermittently since 1982 (Figure 10). The total count for the Upper Index reach (73) was also higher than the count for 2014 (51), but it was the second-lowest count of the eight years since 2008 when the reach has been surveyed during April (Figure 11). The count for the Rock Creek index reach (12) was comparable to the count for 2014 (13). This reach has been surveyed during nine years since 1999, with high variability in counts observed (range = 0–70; Figure 12).

Figure 8. Instantaneous discharge upstream (top) and downstream (bottom) of the Salmon River Diversion during 2015 adult steelhead surveys (triangles). Hydrometric gauge locations are shown on Map 2. Data from WSC (2016).

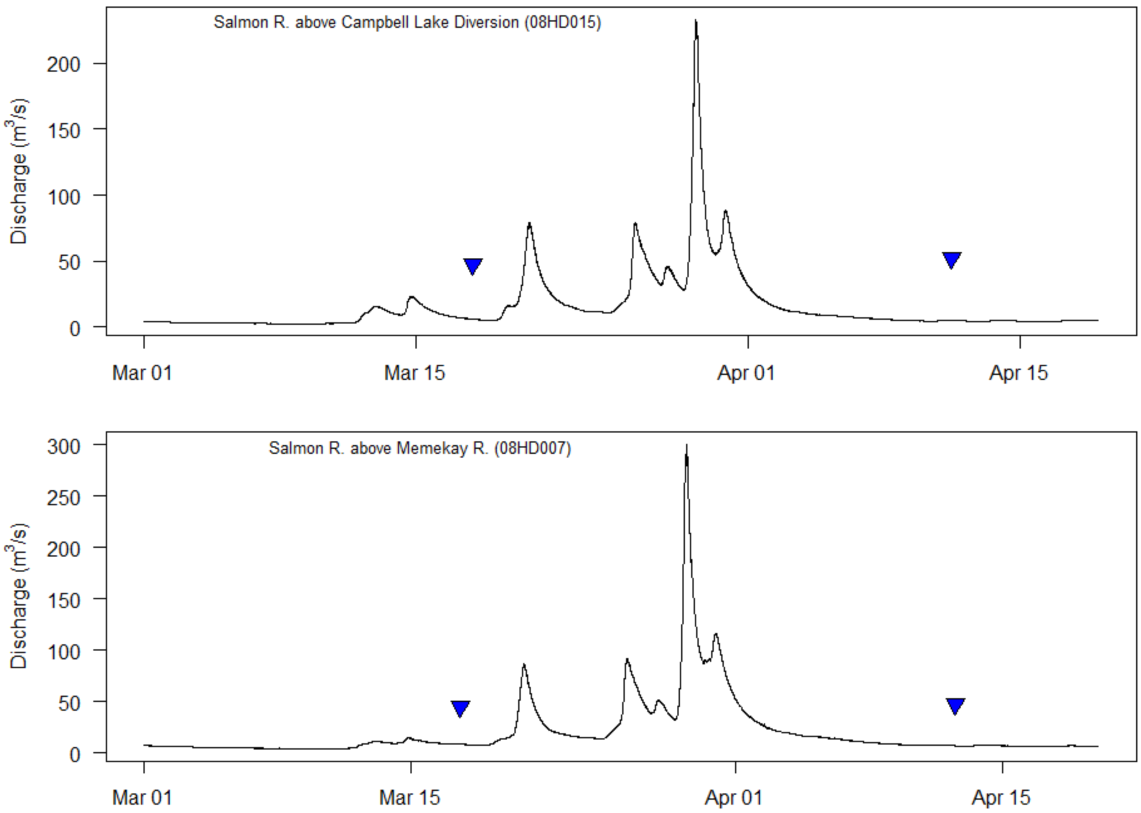


Table 18. Salmon River adult steelhead survey details and conditions, 2015.

Date	Section	Start	End	Distance (km)	Time in	Time out	Number of swimmers	Total effort (hrs)	Weather	Air temperature (°C)	Water temperature (°C)	Measured visibility (m)
2015-03-18	Lower Index: Upper	Cable crossing nr Kay Creek confluence	Big Tree Creek confluence	7.2	10:00	14:00	2	8:00	Overcast	6.0	5.0	10
	Lower Index: Lower	Big Tree Creek confluence	Pallans	4.3	10:30	13:45	2	6:30	Overcast	6.0	5.0	10
2015-04-09	Upper Index: Lower	Memekay Mainline bridge	Norberg Creek confluence	5.9	10:45	13:45	2	6:00	Sunny	10.0	7.0	15
	Upper Index: Upper	Diversion Dam	Memekay Mainline bridge	5.6	10:45	13:15	2	5:00	Sunny	10.0	7.5	13
2015-04-09	Rock Creek	Rock Creek Mainline Bridge	Diversion Dam	6.2	11:00	13:30	2	5:00	Sunny	7.0	5.0	15

Table 19. Salmon River snorkel survey observations, 2015. ST, steelhead; CT, Cutthroat Trout.

Date	Reach	Section	Species	Total observed	Density (#/km)	Adult fork length (mm)						Marks	Redd count	Sex (ST only)		
						Fry	Parr	151–250	251–350	351–450	450+			M	F	UNK
Mar-18	Lower Index	Lower	CT	44	10.2	0	0	0	42	2	0	0	-	-	-	-
			ST	48	11.2	0	0	0	0	0	48	0	7	16	14	18
Mar-18	Lower Index	Upper	ST	24	3.3	0	0	0	0	0	24	0	0	13	11	0
			CT	3	0.4	0	0	0	3	0	0	0	-	-	-	-
Apr-09	Upper Index	Lower	ST	51	9.1	0	0	0	0	0	51	0	4	21	22	8
		Lower	CT	2	0.4	0	0	0	2	0	0	0	-	-	-	-
		Upper	ST	22	3.7	0	0	0	0	0	0	0	7	9	12	1
Apr-09	Rock Creek	-	ST	12	1.9	0	0	0	0	0	12	0	4	5	7	0

Figure 9. Salmon River adult steelhead total counts and condition, 2015. Note that counts were conducted on different dates (Table 18).

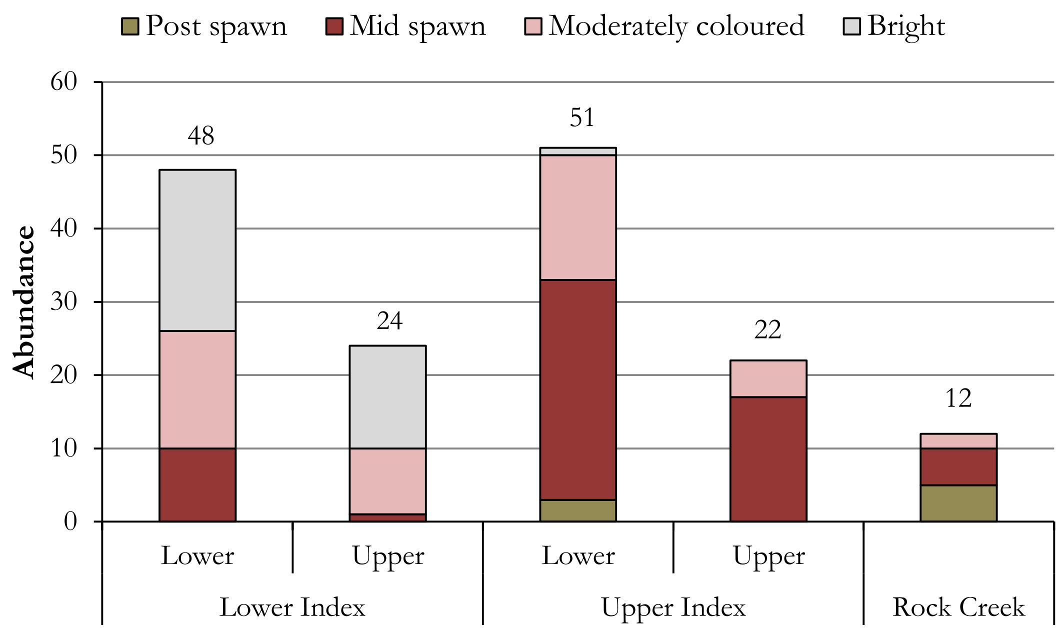


Figure 10. Historical and 2015 adult steelhead counts for the Lower Index reach, Salmon River. Absence of bars for some years indicates that no survey was conducted. Historical data from Pellett (2013). Dashed horizontal lines denote percentiles.

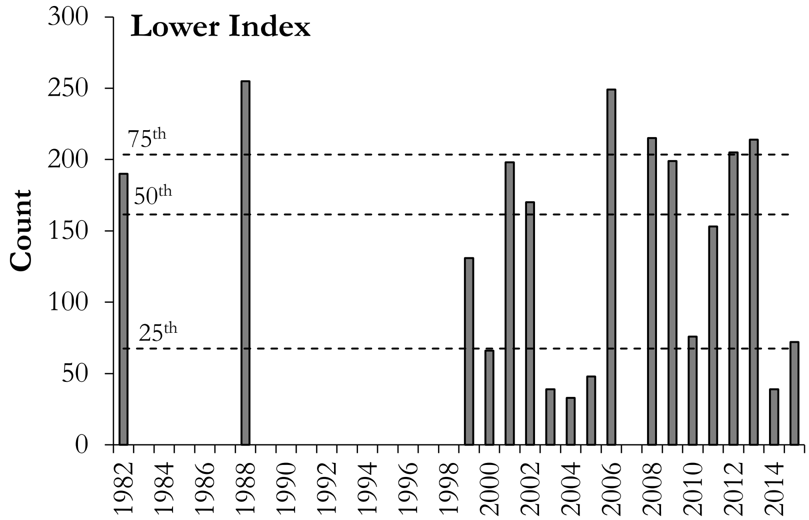


Figure 11. Historical and 2015 adult steelhead counts for the Upper Index reach, Salmon River. Historical data relate to surveys undertaken in April (Pellett 2013). Dashed horizontal lines denote percentiles.

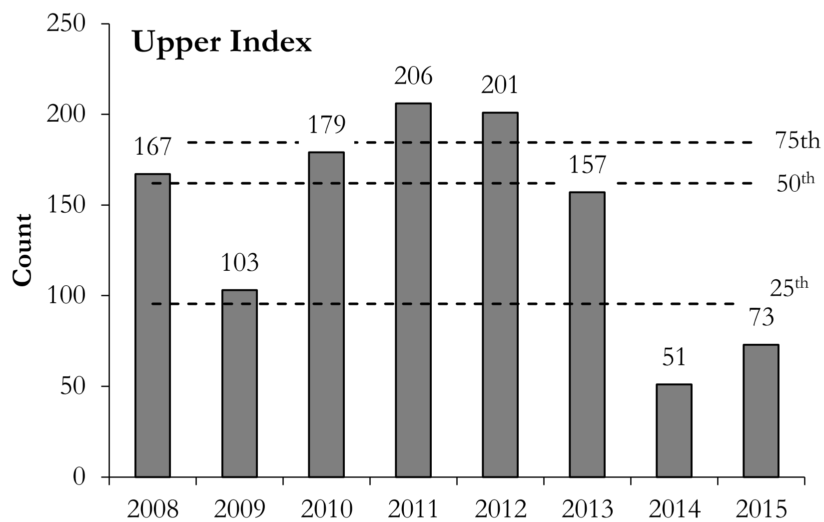
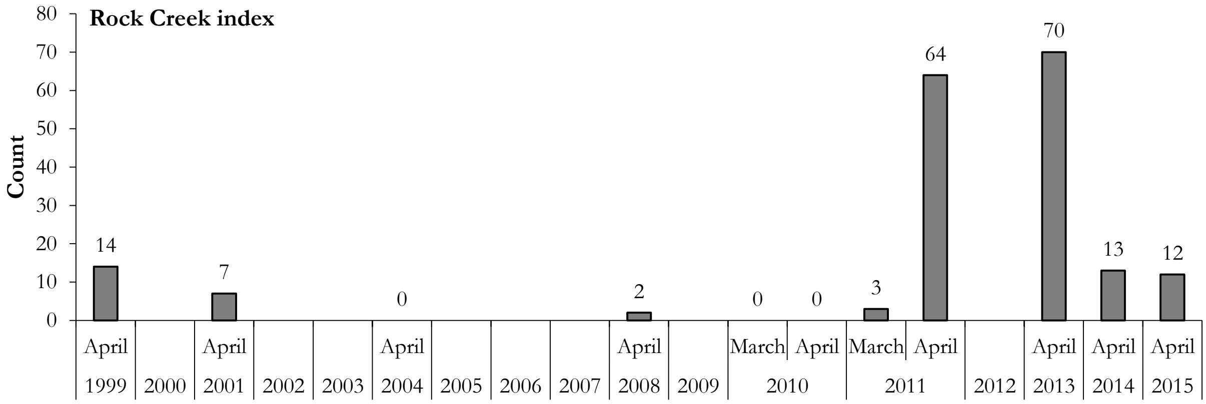


Figure 12. Historical and 2015 adult steelhead counts for the Rock Creek Index reach, Salmon River. Absence of bars for some years indicates that no survey was conducted, unless labelled '0'. Historical data from Pellett (2013).



3.1.2. Salmon River Juvenile Steelhead Abundance

3.1.2.1. Flow and Habitat

Abundance sampling was undertaken during the first and second weeks of September 2015. Four sites upstream of the diversion (SAM-EF6, 8–10) were sampled on September 02, when discharge was relatively high (~13.6 m^3/s; Table 20). Flows had declined when the remainder of the sites were sampled on September 10 and 11 (Table 20). Large rain events resulted in considerably higher flows later in the month.

Habitat characteristics of the ten sites sampled for juvenile steelhead in 2015 are shown in Table 21. Site areas ranged from 61.0 m^2 to 123.3 m^2. Gradient varied among sites from 0.5% to 2.5%; water temperature during sampling varied between 10.5°C and 16.0°C (Table 21). Cobble was most frequently the dominant substrate type (30% to 70%), followed by boulder (0% to 60%) and large gravel (5% to 60%). Overall, cobble and boulder were the dominant and subdominant cover types at all sites, except for SAM-EF01, where large gravel was dominant and cobble was the subdominant cover type.

Table 20. Discharge on abundance sampling dates (at 12:00) measured at Water Survey of Canada gauges (see Map 2; WSC 2016).

Location	Site	Date	Discharge (m^3/s)	
			Salmon R. above Campbell Lake Diversion (08HD015)	Salmon R. above Memekay R. (08HD007)
Below Diversion	SAM-EF01	11-Sep-15	2.204	3.183
	SAM-EF02	10-Sep-15	2.903	4.137
	SAM-EF03	11-Sep-15	2.204	3.183
	SAM-EF04	10-Sep-15	2.903	4.137
	SAM-EF07	10-Sep-15	2.903	4.137
Above Diversion	SAM-EF05	10-Sep-15	2.903	4.137
	SAM-EF06	2-Sep-15	13.641	8.737
	SAM-EF08	2-Sep-15	13.641	8.737
	SAM-EF09	2-Sep-15	13.641	8.737
	SAM-EF10	2-Sep-15	13.641	8.737

Table 21. Habitat characteristics for juvenile steelhead abundance sampling sites in the Salmon River watershed.

Location	Site	Mesohabitat	Site Length (m)	Site Width (m)	Site Area (m^2)	Gradient (%)	Water Temp. (°C)[1]	Cover Type[2,3]		Substrate Composition (%)[4]					
								D	SD	BR	BO	CO	LG	SG	F
Below Diversion	SAM-EF01	Riffle	12.8	8.0	102.0	1.5	n/c	CO	n/a	0	0	30	60	10	0
	SAM-EF02	Riffle	14.7	7.4	108.3	0.5	16.0	CO	BO	0	20	60	17	3	0
	SAM-EF03	Riffle	16.8	7.3	122.8	1.5	15.5	BO	OV	0	50	30	10	10	0
	SAM-EF04	Riffle	7.2	8.6	61.6	2.0	14.0	BO	CO	0	45	40	10	4	1
	SAM-EF07	Riffle	16.7	5.3	88.0	1.0	14.0	BO	CO	0	60	30	5	3	2
Above Diversion	SAM-EF05	Riffle	13.6	6.4	86.6	2.5	16.0	BO	CO	0	45	44	5	5	1
	SAM-EF06	Riffle	15.8	5.5	87.4	2.0	10.6	CO	BO	0	15	70	10	3	2
	SAM-EF08	Riffle	14.5	8.5	123.3	2.0	12.0	CO	BO	0	20	60	10	5	5
	SAM-EF09	Riffle	15.2	5.1	77.8	1.5	10.5	CO	BO	0	20	60	10	5	5
	SAM-EF10	Riffle	11.5	5.3	61.0	2.5	11.0	BO	CO	0	30	35	20	10	5

[1] "n/c" indicates where data were not collected.

[2] "n/a" indicates where not applicable.

[3] SWD = Small Woody Debris, LWD = Large Woody Debris, B = Boulders, LC = Large Cobble, SC = Small Cobble, U = Undercut Banks, DP = Deep Pools, OV = Overhanging Vegetation, VB = Velocity Breaks, IV = Instream Vegetation, N = None.

[4] BR = Bedrock, BO = Boulder, LC = Large Cobble , SC = Small Cobble, LG = Large Gravel, SG = Small Gravel, F = Fines.

3.1.2.2. Catch Summary

Electrofishing effort varied from 1,622 seconds to 2,865 seconds among sites, with three passes completed at seven sites, and two passes completed at three sites (Table 22). A total of 208 juvenile steelhead were captured; 178 fish were captured in sites downstream of the diversion and 30 fish were captured upstream of the diversion. The average catch per site was 36 fish downstream of the diversion and six fish upstream of the diversion.

Table 22. Sampling effort and catch summaries for juvenile steelhead sites sampled in the Salmon River watershed, September 2015.

Location	Site	Date	Total Electrofishing Effort (sec)[1]				Electrofishing Catch (# of RB)			
			Pass 1	Pass 2	Pass 3	Total	Pass 1	Pass 2	Pass 3	Total
Below Diversion	SAM-EF01	11-Sep-15	1,120	996	n/a	2,116	81	9	n/a	90
	SAM-EF02	10-Sep-15	937	685	n/a	1,622	2	0	n/a	2
	SAM-EF03	11-Sep-15	1,210	875	780	2,865	41	10	4	55
	SAM-EF04	10-Sep-15	1,002	803	587	2,392	14	5	5	24
	SAM-EF07	10-Sep-15	967	710	519	2,196	5	2	0	7
		Below Diversion Total				**11,191**				**178**
		Below Diversion Average				**2,238**				**36**
Above Diversion	SAM-EF05	10-Sep-15	1,004	798	583	2,385	4	2	0	6
	SAM-EF06	2-Sep-15	880	689	504	2,073	5	1	0	6
	SAM-EF08	2-Sep-15	1,000	800	600	2,400	3	1	0	4
	SAM-EF09	2-Sep-15	955	969	n/a	1,924	7	1	n/a	8
	SAM-EF10	2-Sep-15	1,008	804	605	2,417	4	2	0	6
		Above Diversion Total				**11,199**				**30**
		Above Diversion Average				**2,240**				**6**
	Combined Total					**22,390**				**208**
	Combined Average					**2,239**				**21**

[1] "n/a" indicates that an electrofishing pass was not completed.

3.1.2.3. Juvenile Steelhead Length-Weight Relationships

Juvenile steelhead fork length ranged from 45 to 125 mm below the diversion, and 50 to 120 mm above the diversion. The length-frequency distribution is presented in Figure 13. The distribution shows a clear peak between 40 and 80 mm. The low frequency of larger fish greater than 80 mm reflects the focus on sampling age 0+ fry.

Scale samples were analyzed for 20 juvenile fish at the Ecofish laboratory in Campbell River, BC. The results of the length-at-age relationship are presented in Figure 14. Based on a review of these aging data and the fork length histograms, discrete fork length ranges were defined for each age class and year (Table 23). Steelhead juveniles between 35 and 79 mm were classed as fry (0+), those measuring between 81 and 121 mm were classed as aged 1+ and fish measuring more than 122 mm were considered to be 2+ (Table 23). No fish had fork length of 79 mm to 81 mm; therefore, those size ranges were not included in the age assignment table. No fish larger than 121 mm were captured in 2015 and, therefore, size ranges above this length were not defined.

Figure 13. Fork length histogram for juvenile steelhead captured in the Salmon River watershed, September 2015.

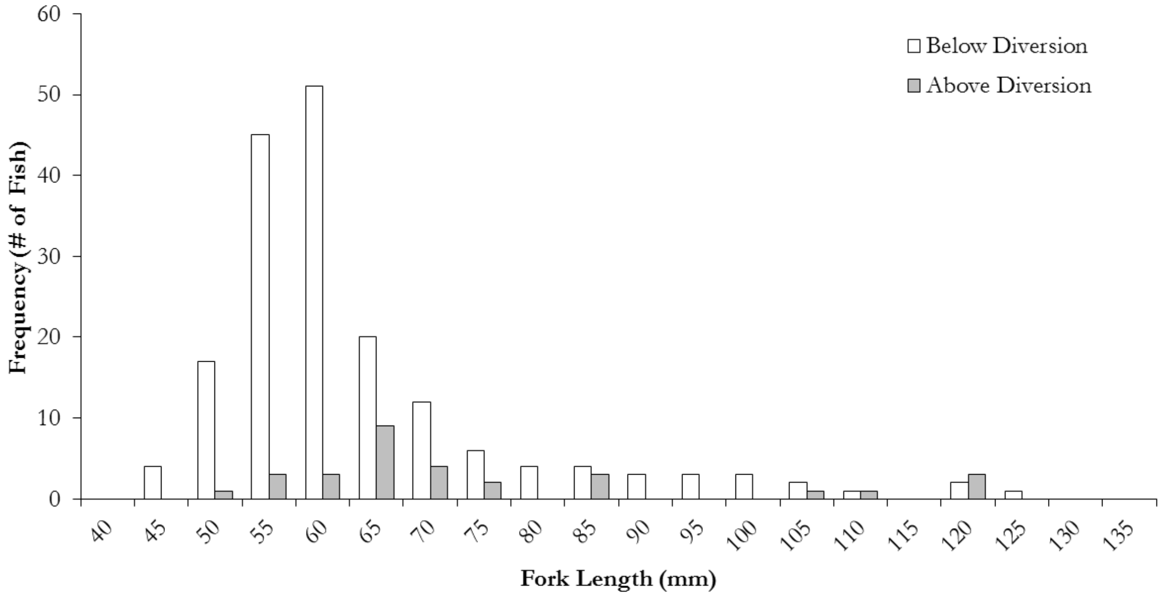


Figure 14. Length at age of juvenile steelhead captured in the Salmon River watershed, September 2015.

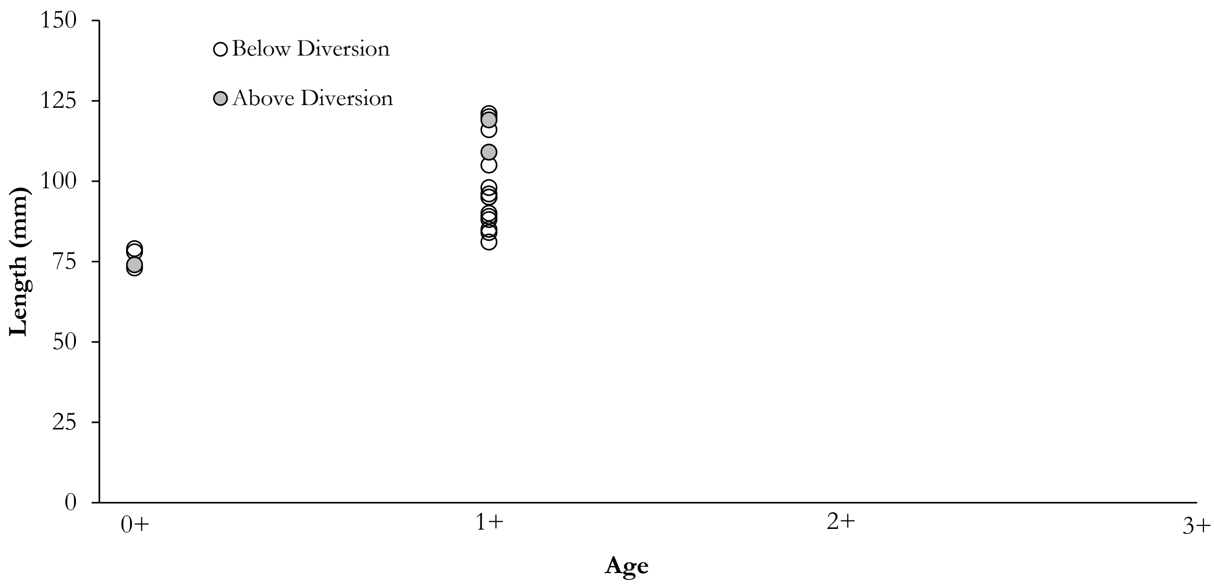


Table 23. Fork length ranges used to assign age classes for juvenile steelhead captured in the Salmon River watershed, September 2015.

Age Class	Fork Length Range (mm)
Fry 0+	35-79
Parr (1+)	81-121
Parr (2+)	122+

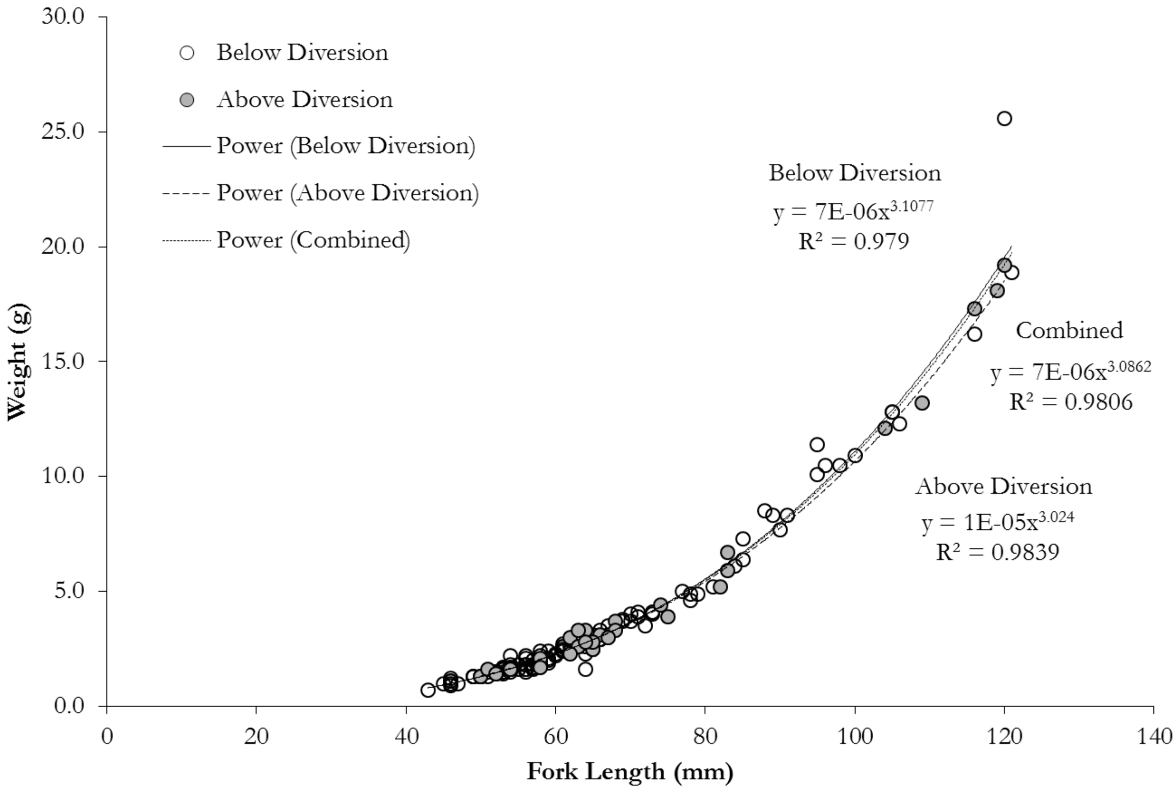
Fork length was measured for all 208 juvenile steelhead captured in 2015, and weight was also measured for 142 fish (Table 24). Length-weight relationships for the 142 fish are shown in Figure 15. These relationships are well described by a power function, which indicates that fork length accounts for 98% of the variance in juvenile steelhead weight. These relationships were used to estimate the weight of fish that were not weighed in the field; this allowed the total biomass of fish at sample sites to be estimated.

Table 24 shows the fork length, weight and condition of juvenile steelhead. Overall, the average condition was similar among age classes, and averaged 1.06 above and below the diversion. This value is slightly lower than the nominal condition factor of 1.10 that the BC Ministry of Environment deems representative of well-conditioned juvenile Rainbow Trout/steelhead (Ptolemy, pers. comm. 2016).

Table 24. Summary of fork length, weight and condition of juvenile steelhead captured during electrofishing at 10 sites in the Salmon River watershed in 2015.

Location	Age Class	Fork Length (mm)				Weight (g)				Condition Factor (K)			
		n	Average	Min	Max	n	Average	Min	Max	n	Average	Min	Max
Below Diversion	0+	159	57	43	79	93	2.2	0.7	5.0	93	1.05	0.61	1.40
	1+	19	97	81	121	19	11.0	5.2	25.6	19	1.13	0.98	1.48
Combined Total		178	62	43	121	112	3.7	0.7	25.6	112	1.06	0.61	1.48
Above Diversion	0+	22	62	50	75	22	2.7	1.3	4.4	22	1.06	0.87	1.32
	1+	8	102	82	120	8	12.2	5.2	19.2	8	1.07	0.94	1.17
Combined Total		30	73	50	120	30	5.2	1.3	19.2	30	1.06	0.87	1.32

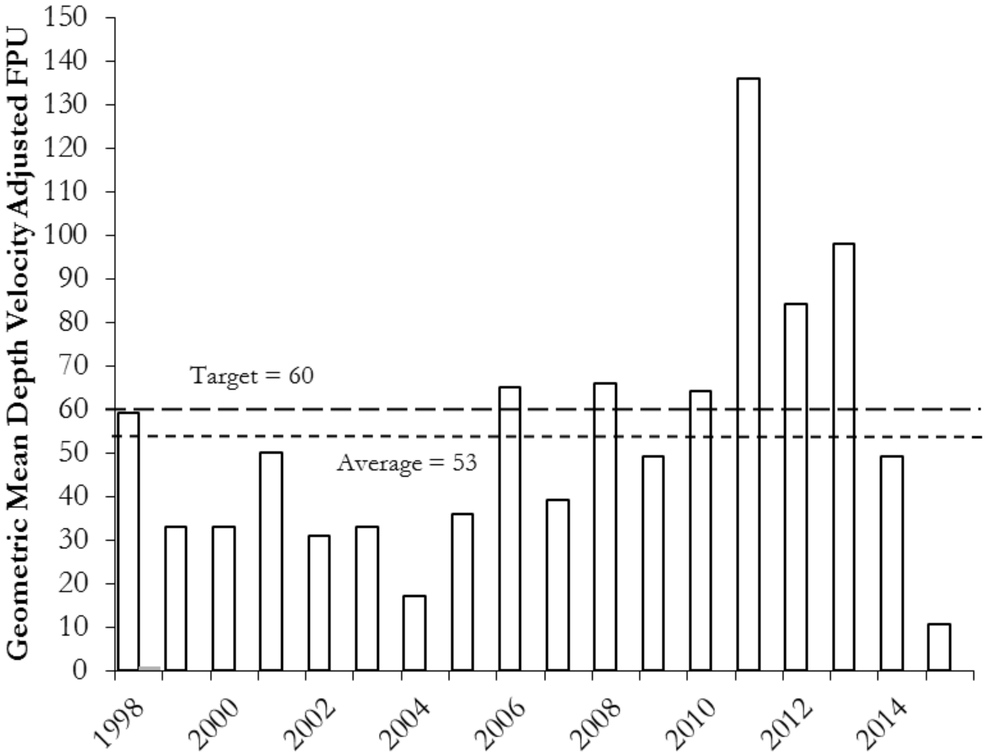
Figure 15. Length-weight regressions for juvenile steelhead (*n* = 142) captured in the Salmon River watershed, September 2015.



3.1.2.4. Fish Abundance

The geometric mean depth-velocity-adjusted-abundance in 2015 was 10.5 fry per 100 m^2 (fry per unit/FPU), which is below the target of 60 FPU set by provincial biologists. It is also the lowest FPU calculated between 1998 and 2015, which is the duration of the juvenile steelhead monitoring program. The target of 60 FPU was based on a predicted juvenile Rainbow Trout/steelhead capacity of 162 g/100 m^2 (Lill 2002) and assumes a mean fry weight of 2.7 g (Pellett 2014). The average abundance across all years is 53 FPU; slightly below the 60 FPU target (Figure 16).

Figure 16. Geometric mean depth-velocity-adjusted-abundance of steelhead fry (fry per unit, FPU) sampled in the Salmon River watershed in 1998-2015.



*2011 data represent sites upstream of the diversion only.

The density of steelhead fry in the Salmon River and tributaries was variable among sites in 2015 (Figure 17). The highest density of fish was observed at SAM-EF01 (208 FPU), and the lowest density at SAM-EF05 where no fry were caught. There were six juvenile steelhead captured at SAM-EF05, although they were all classified as age 1+. The smallest of those fish were 82 mm and 83 mm, and it is possible that they were large age 0+ fish. The average standardized fry abundance was much higher downstream of the diversion (62.1 FPU) than upstream of the diversion (8.9 FPU) (Table 25). The geometric mean FPU for all sites combined in 2015 is 10.5 (Figure 16), lower than the arithmetic mean of 35.5 FPU for all sites (Table 25). This difference is because fish abundance in 2015 was unevenly distributed between sites, with 90 out of 208 total fish caught at SAM-EF01. The geometric mean indicates the central tendency and is less sensitive to the influence of particularly low or high values (such as those at SAM-EF01) than the arithmetic mean.

In 2013 and 2014, geometric mean densities above and below the diversion were similar (95.8 FPU above the diversion, and 102.3 FPU below the diversion in 2013; 77.6 FPU above the diversion, and 77.4 FPU below the diversion in 2014) (Pellet 2014, Abell *et al.* 2015b). The 2013 and 2014 results indicated that adult steelhead successfully spawned both upstream and downstream of the diversion dam, with comparable incubation success observed in both areas. By contrast, the 2015 results show that spawning success was spatially variable, with fry densities generally lower upstream of the diversion dam than downstream. The depth-velocity-adjusted FPU metric is deliberately used to standardize for depth and velocity differences between sites, and the calculation of a geometric (not arithmetic) mean moderates the influence of particularly high or low measurements. Nonetheless, there remains uncertainty about whether the large difference in abundance between sites upstream and downstream of the diversion dam reflects general differences between these two areas of the watershed, or is an artefact of the high abundance measured at SAM-EF01. In addition, four of the upstream sites were sampled during relatively higher flows (Table 20), which potentially confounded the results as high flows may have caused local redistribution of fish, reducing fish density in the sites. However, it is notable that the lowest abundance measured upstream of the diversion (0 FPU at SAM-EF05) was recorded during lower flow conditions on the same day that most of the downstream sites were sampled (Table 20), indicating that differences in flow do not completely account for the differences.

Figure 17. Depth-velocity-adjusted steelhead fry abundance (fish per unit area; FPU) sampled at each site in the Salmon River watershed in 2015.

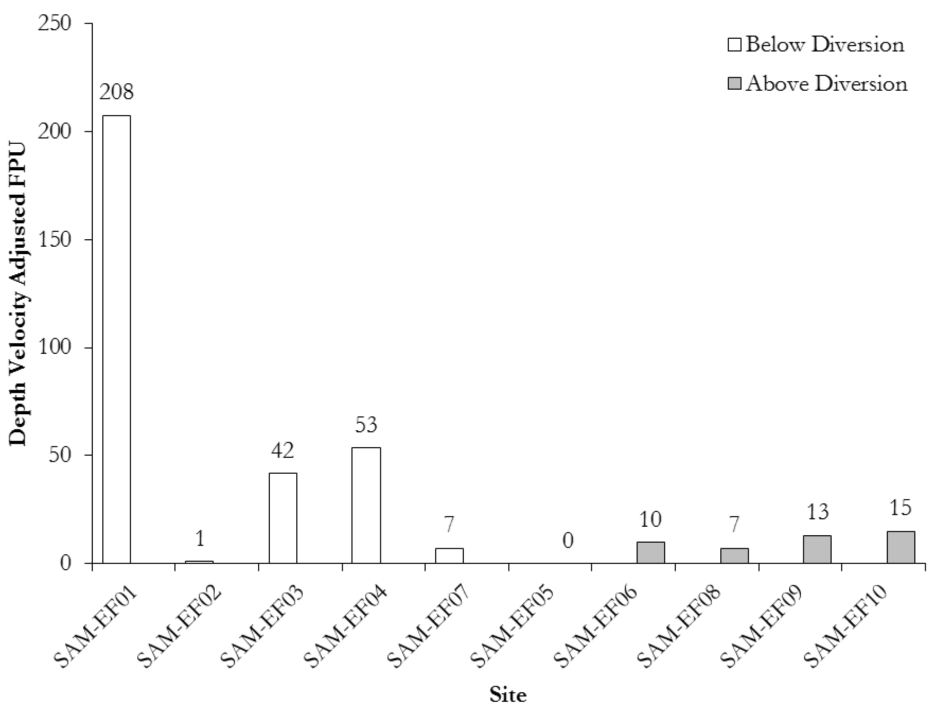


Table 25. Steelhead fry abundance and biomass results from electrofishing sites located upstream and downstream of the Salmon River Diversion, September 2015.

Location	Site	Usability (%)	Observed Densities[1,2]		Adjusted Densities[3,4]		Maximum Densities[5,6]	
			FPU_{obs} (#/100 m^2)	BPU_{obs} (g/100 m^2)	FPU_{adj} (#/100 m^2)	BPU_{adj} (g/100 m^2)	FPU_{max} (#/100 m^2)	BPU_{max} (g/100 m^2)
Below Diversion	SAM-EF01	42%	87.3	163.8	207.5	389.6	120	224.9
	SAM-EF02	94%	0.9	2.4	1.0	2.6	86	224.9
	SAM-EF03	92%	38.3	77.3	41.7	84.2	111	224.9
	SAM-EF04	58%	30.9	98.4	53.4	170.4	70	224.9
	SAM-EF07	66%	4.5	18.1	6.9	27.5	56	224.9
	Mean	**70%**	**32.4**	**72.0**	**62.1**	**134.9**	**88.8**	**224.9**
Above Diversion	SAM-EF05	74%	0.0	0.0	0.0	0.0	n/a	224.9
	SAM-EF06	59%	5.7	18.2	9.7	30.9	71	224.9
	SAM-EF08	47%	3.2	5.6	6.9	12.0	130	224.9
	SAM-EF09	70%	9.0	26.0	12.8	37.0	78	224.9
	SAM-EF10	66%	9.8	25.3	14.9	38.3	87	224.9
	Mean	**63%**	**5.6**	**15.0**	**8.9**	**23.6**	**91.5**	**224.9**
All Sites Combined	**Mean**	**67%**	**19.0**	**43.5**	**35.5**	**79.3**	**90.0**	**224.9**

[1] FPU_{obs} = Observed fish per unit (100 m^2) based on population estimates computed using MicroFish V3.0

[2] BPU_{obs} = Biomass of fish per unit (100 m^2) based on population estimates computed using MicroFish V3.0

[3] FPU_{adj} = FPU_{obs}/Usability (%)

[4] BPU_{adj} = BPU_{obs}/Usability (%)

[5] FPU_{max} = Theoretical maximum biomass/mean weight (g) of the age class (by site)

[6] BPU_{max} = Theoretical maximum biomass based on mean growing season alkalinity measured at SAM-WQ in Year 1 and 2 (19.7 mg/L as $CaCO_3$) and a model provided by R. Ptolemy (Rivers Biologist, Ministry of Environment) ((alkalinity^0.62)×36). Note that this is extremely similar to the value that has been historically reported (224.5 g/100 m^2) based on an older, slightly different model and historic alkalinity measurements (e.g., see BCCF 2013).

In 2015, the geometric mean fish density was lower than in any previously measured years (1998-2014). The geometric mean fish density above and below the diversion has been variable since 2006, with an apparent increase in fry abundance in sites upstream of the diversion in 2011–2013 (Figure 18). Between 2006 and 2010, relative abundance was greater downstream of the diversion. In 2014, fry density was similar between sites above and below the diversion, and was more consistent with results collected between 1998 and 2006. In 2015, fry density was again greater downstream of the diversion.

Figure 19 shows the average unadjusted densities of steelhead fry compared with the peak adult steelhead count from the 11.5 km Lower Index reach on the Salmon River (Kay Creek to Pallans). The 2015 datum indicates low steelhead fry density, even relative to the low adult returns in 2014. Results are similar to low fry density from low adult returns in 2000, 2003, 2004, and 2005.

Figure 18. Geometric mean depth-velocity-adjusted juvenile steelhead (all age classes) fish per unit area (FPU) at sites upstream and downstream of the Salmon River Diversion, 1998–2015.

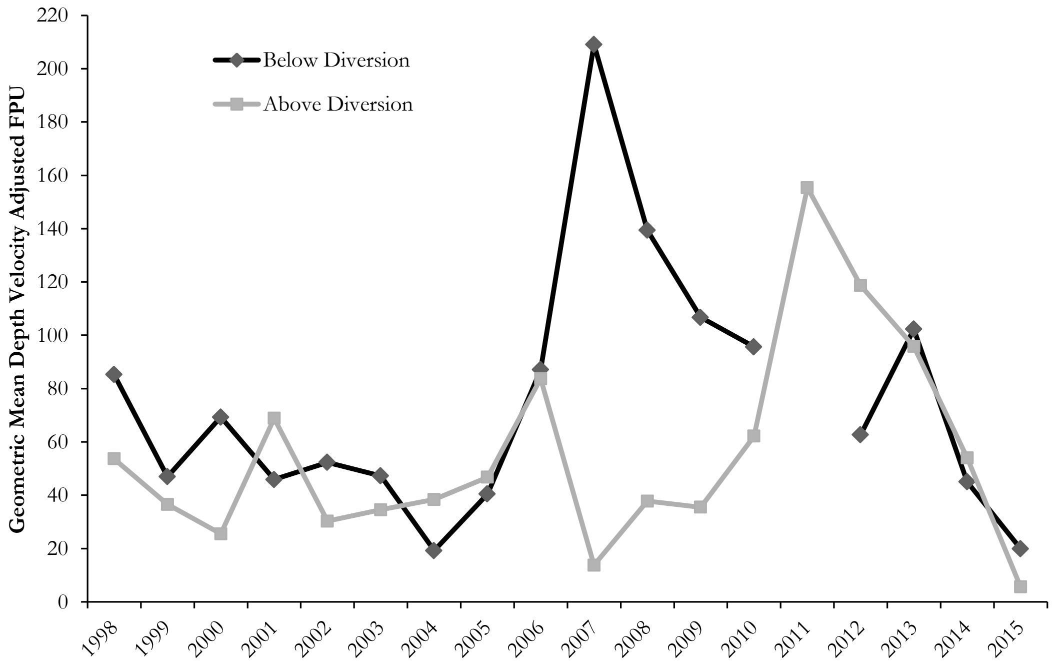
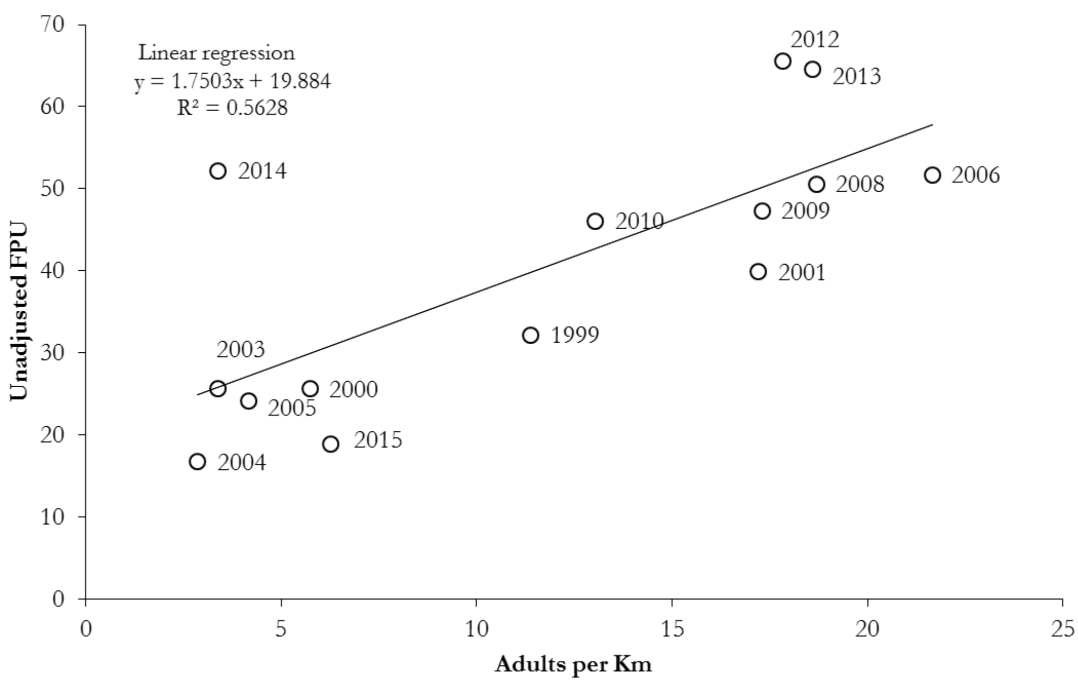


Figure 19. Juvenile steelhead fish per unit (FPU; non-depth-velocity-adjusted) vs. adult steelhead counts in the Lower Index reach during the previous year.



3.1.3. Salmon River Juvenile Coho Salmon Abundance

3.1.3.1. Flow and habitat

Juvenile Coho Salmon sampling site characteristics are summarized in Table 26. Sampling has historically been undertaken in mid to late September. In Year 2, sampling was conducted on September 23 and 24, and October 01. As was the case for juvenile steelhead sampling (Section 3.1.2.1), sampling was scheduled on dates when discharge was predicted to be at, or as close as possible to, base flow conditions. Rain events during the second half of September meant that sampling had to be scheduled for a relatively short period when flow had receded following rain events; however, flow conditions were nonetheless relatively high compared with base flows earlier in the summer (e.g., see Figure 2).

Total site area ranged from 153.1 m^2 to 196.0 m^2, with 96% to 98% of the area of the sites > 0.1 m deep. Water temperatures ranged from 10.0°C to 14.5°C. The warmest temperature was measured at SAM-BS04 (Paterson Creek), which is downstream of the diversion (Map 2).

Table 26. Salmon River watershed juvenile Coho Salmon sampling site characteristics, 2015. Discharge data from WSC (2016).

Location	Site	Sampling date	Total area (m^2)	Area > 0.1 m deep (m^2)	Water temp. (°C)	Habitat type	Discharge (at 12:00; m^3/s)	
							Salmon R. above Campbell Lake Diversion (08HD015)	Salmon R. above Memekay R. (08HD007)
Upstream of diversion	SAM-BS01	2015-09-23	196.0	189.7	10.7	Pool	11.09	12.79
	SAM-BS02	2015-09-23	159.3	155.3	10.0	Pool	11.09	12.79
	SAM-BS03	2015-09-23	185.0	180.9	12.9	Pool	11.09	12.79
Downstream of diversion	SAM-BS04	2015-10-01	183.8	179.1	14.5	Pool	3.13	4.94
	SAM-BS05	2015-10-01	183.8	179.1	10.8	Pool	3.13	4.94
	SAM-BS06	2015-09-24	153.1	146.4	12.9	Pool	40.13	27.38

3.1.3.2. Catch Results

Catch results for individual sites are summarized in Table 27. Fork length-frequency data for sites upstream and downstream of the Salmon River Diversion are summarized in Figure 20. No fish were caught at SAM-BS01 and only three fish were caught at SAM-BS03, both of which are upstream of the diversion (Table 27). A total of 111 to 149 fry were caught at each of the remaining sites; estimated fry density ranged from 0 to 1.06 fish/m^2 (Table 27).

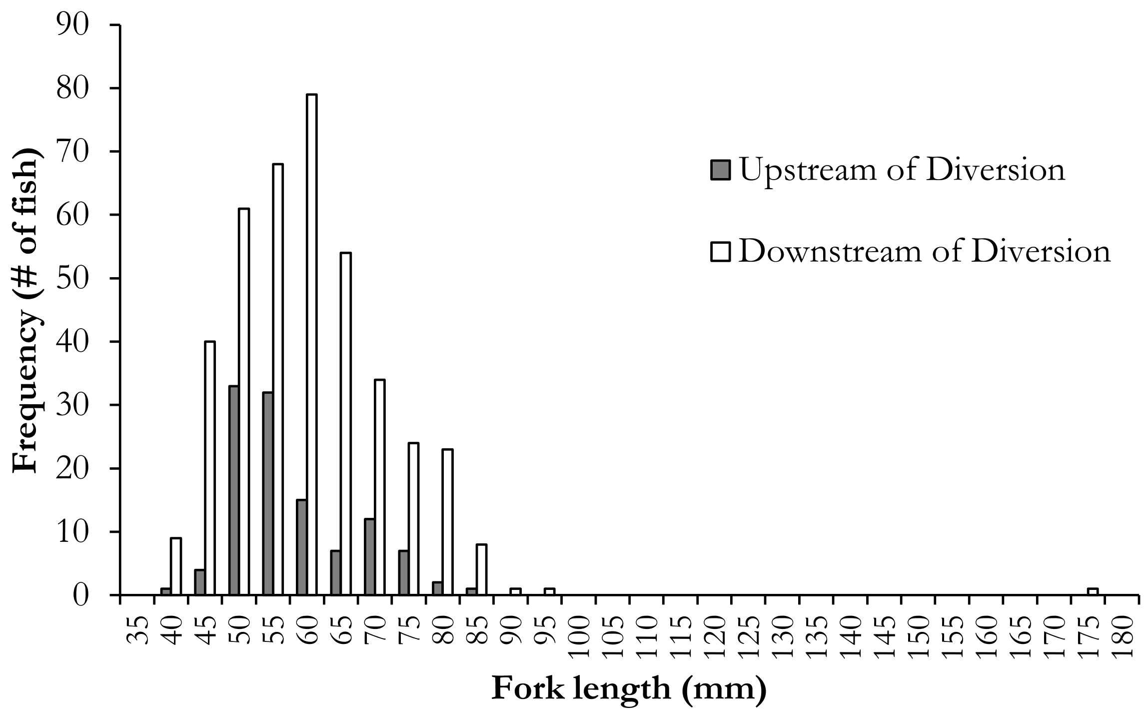
With one exception, juvenile Coho Salmon fork length ranged from 38 mm to 95 mm (Figure 20). One unusually large fish with fork length of 175 mm was recorded at SAM-BS04; scale analysis confirmed that this fish was aged 1+. Upstream of the diversion, the modal fork-length category was 46–50 mm (29% of fish), whereas the modal fork length category was 56–60 mm downstream of the diversion (20% of fish; Figure 20).

Based on the results of scale analysis, the majority (99%) of juvenile Coho Salmon caught were aged 0+, i.e., they emerged in 2015. Only three fish aged 1+ were caught, with one fish caught at each of the three sites downstream of the diversion. No fish aged 2+ were caught (Table 27). Age 2+ fish were also absent in Year 1 catch data, although the relative abundance of 1+ fish was higher in Year 1 when this age class comprised 6–28% of catches at each of the five sites where fish were caught (Abell *et al*. 2015b).

Table 27. Salmon River watershed juvenile Coho Salmon catch results, 2015.

Location	Site	Catch results				# of	Mean	Estimated	Estimated
		# of fry	0+ (#)	1+ (#)	2+ (#)	passes	mass (g)	total # of fry	density (#/m^2)
Upstream of diversion	SAM-BS01	0	0	0	0	2	-	0	0
	SAM-BS02	111	111	0	0	3	2.15	116	0.74
	SAM-BS03	3	3	0	0	3	2.77	3	0.02
Downstream of diversion	SAM-BS04	111	110	1	0	3	3.36	122	0.88
	SAM-BS05	145	144	1	0	4	1.56	151	0.84
	SAM-BS06	149	148	1	0	4	2.84	155	1.06

Figure 20. Fork length-frequency histogram of juvenile Coho Salmon captured in the Salmon River watershed, 2015.



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3.1.3.3. Biomass Estimates

Fish aged 0+ accounted for all or the majority of total estimated biomass of juvenile of Coho Salmon at the five sites where fish were caught (Figure 21). Estimated total biomass ranged from 0–3.0 g/m^2 with the highest biomass at sites SAM-BS04 and SAM-BS06, both of which are downstream of the diversion.

Comparison of estimated total biomass between Year 1 and Year 2 indicates that there was a relative decline in estimated total biomass during Year 2 at sites upstream of the diversion where fish were caught, whereas total biomass was more consistent between the two years at sites downstream of the diversion (Figure 22). Upstream of the diversion, no fish were caught at SAM-BS01 during both years, while there were marked relative declines in estimated total biomass during Year 2 at SAM-BS02 and SAM-BS03, where total biomass estimates were 59% and 99% lower, respectively, in Year 2 compared with Year 1. Downstream of the diversion, estimated total biomass declined by 16% in Year 2 at one site (SAM-BS04), while it increased by 17% and 44% at the two remaining sites (Figure 22).

Figure 21. Measured Juvenile Coho Salmon biomass by age class, 2015.

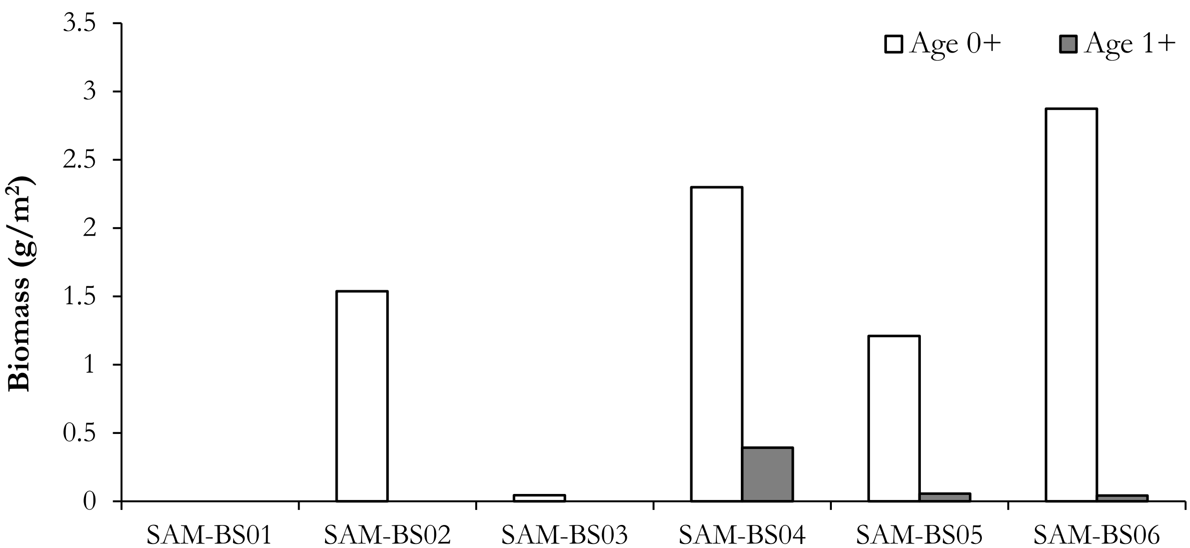
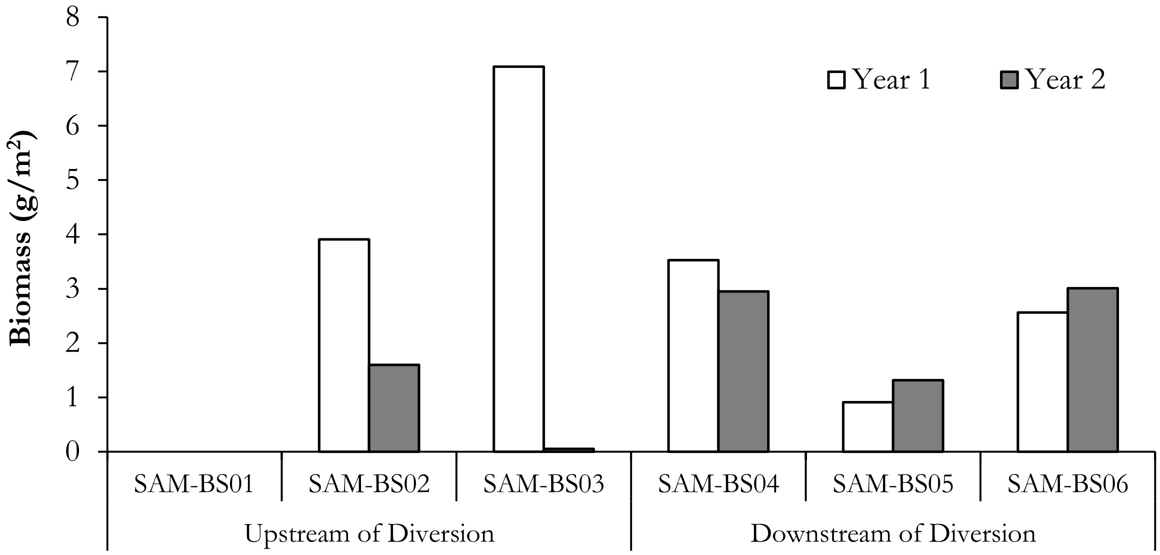


Figure 22. Total estimated Juvenile Coho Salmon biomass by site during Year 1 (2014) and Year 2 (2015).



3.1.4. Salmon and Quinsam River Salmon Escapement, 2014

Salmon escapement data for 2014 (Year 1) for the Salmon and Quinsam rivers are presented in Table 28. Summary statistics for the period of record are also provided in this table to provide points of reference. Figure 23 and Figure 24 present salmon escapement data for the periods of record for the Salmon River and Quinsam River respectively.

Table 28. 2014 salmon escapement data for the Salmon and Quinsam rivers (DFO 2016).

River	Statistic	Chinook	Chum	Coho	Pink	Sockeye
Salmon	2014 count	440	Not inspected	3,304	87,619	Not inspected
	Mean (1953-2014)	868	969	3,363	31,365	31
	Median(1953-2014)	711	400	2,000	7,554	0
	10th percentile (1953-2014)	136	0	320	1,290	0
	90th percentile (1953-2014)	1,500	3,500	7,500	86,438	100
	Percent of years sampled (1953-2014)[1]	100	94	98	100	56
Quinsam	2014 count	2,366	91	14,883	1,421,213	7
	Mean (1957-2014)	4,075	507	12,461	126,287	56
	Median(1957-2014)	3,208	300	9,357	30,000	25
	10th percentile (1957-2014)	25	82	1,500	1,350	6
	90th percentile (1957-2014)	10,126	1,500	33,307	358,209	140
	Percent of years sampled (1957-2014)[1]	79	95	98	98	74

1. Note that this is approximate; uncertainty in data recording means that a count of zero is not always distinguished from a record of 'not measured'.

Figure 23. Salmon escapement for the Salmon River (1953-2014; DFO 2016).

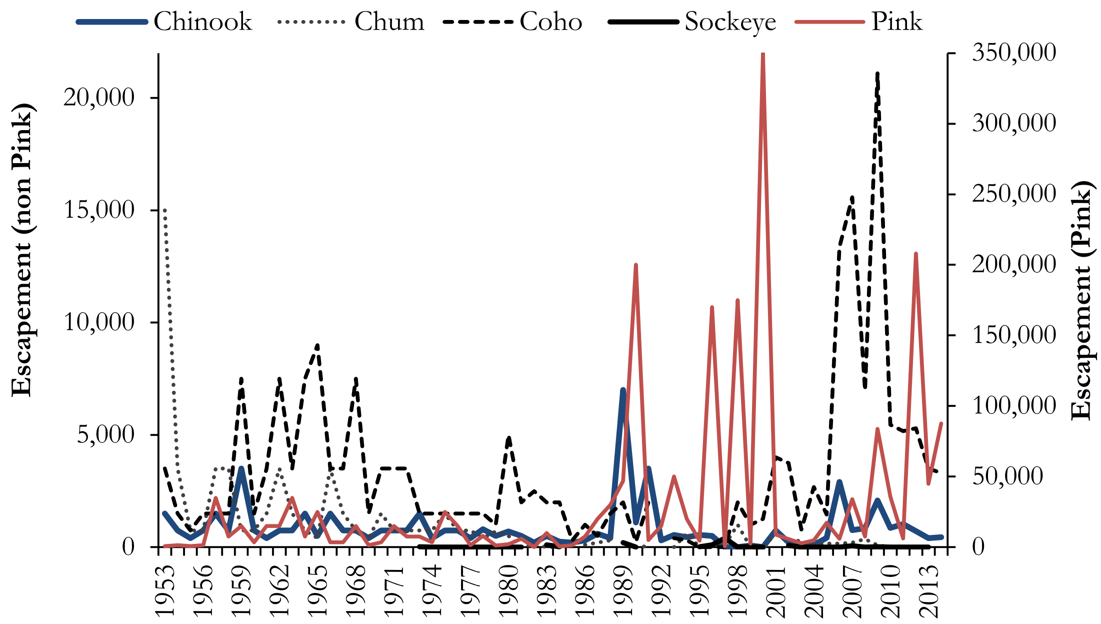
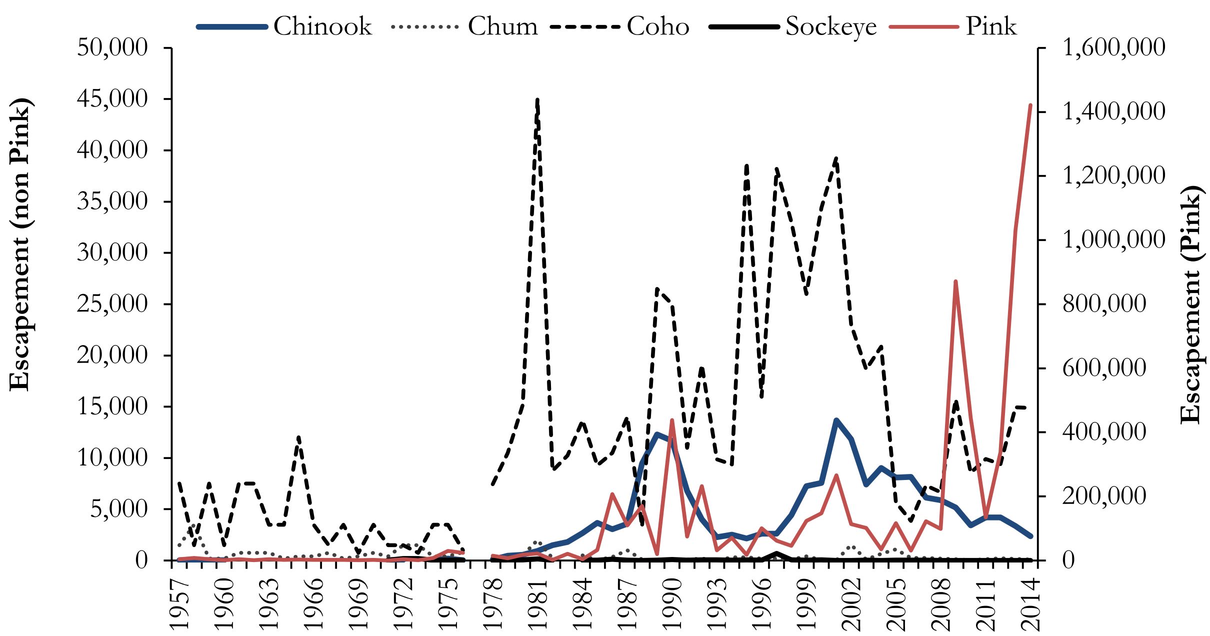


Figure 24. Salmon escapement for the Quinsam River (1957-2014; DFO 2016).



Pink, Coho and Chinook salmon were the dominant returning species in 2014, with escapement of each of these three species highest in the Quinsam River (Table 28). Pink Salmon escapement was particularly high in 2014, especially in the Quinsam River where Pink Salmon escapement (1.42 million) was the highest on record, surpassing the previous highest count that was recorded in 2013 (1.03 million). Coho Salmon escapement exceeded the median historical counts on both rivers, while Chinook Salmon escapement was lower than historical mean and median counts on both rivers.

3.1.5. Quinsam River Salmon Counting Fence Operation to Enumerate Downstream Juvenile Migration

Conditions for the trapping operations were good throughout the sampling period, yielding high quality downstream migration data. Data collected at the salmon counting fence are summarized in Table 29.

Total estimated migration of Pink Salmon fry was 2.7 million (Table 29). This is approximately eight times less than the count in Year 1 (22.0 million), which was notable as the largest estimate recorded since trapping operations began in 1974 (Ewart and Kerr 2014). However, the difference is surprising considering that Pink Salmon escapement in 2014 exceeded escapement in 2013 (1.4 million compared with 1.0 million; Figure 24). Thus, Pink Salmon fry outmigration estimates in Year 2 were substantially lower than those in Year 1, despite ~40% greater spawner abundance during the prior year.

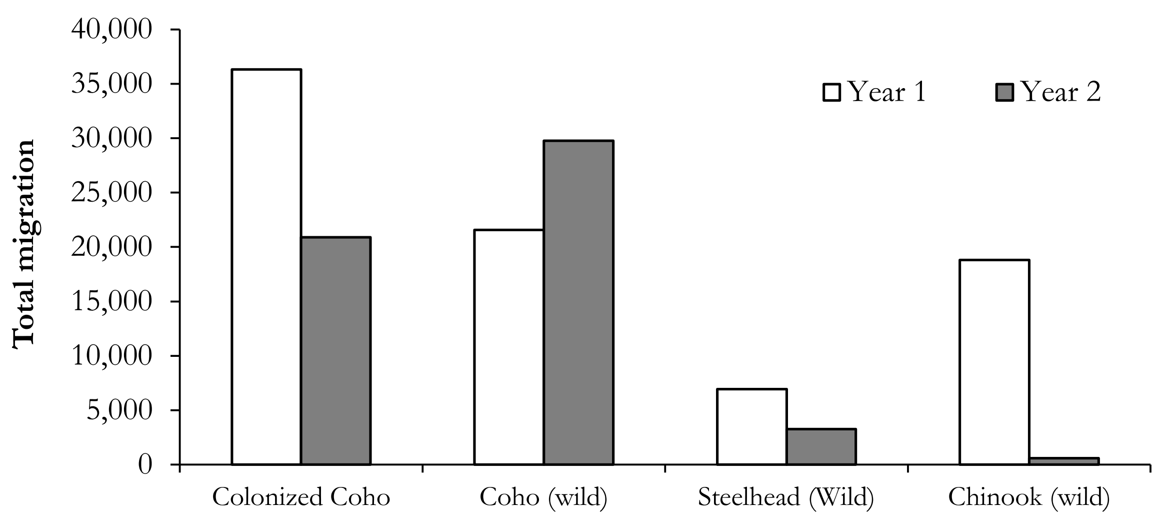
Figure 25 shows total migration estimates for the three JHTMON-8 priority species in the Quinsam River (Chinook Salmon, Coho Salmon and steelhead). Total Coho Salmon smolt abundance was slightly lower in Year 2 than Year 1 (50,679 compared with 57,903), although the number of fish assumed to be wild was ~40% higher. The abundance of steelhead smolts in Year 2 was ~50% that of Year 1 (3,264 compared with 6,930; Figure 25). Wild Chinook Salmon fry abundance was estimated to be ~97% lower in Year 2 than Year 1 (588 compared with 18,881; Figure 25), although hatchery-incubated Chinook Salmon were released in the watershed for the first time in approximately 10 years (see below; Fortkamp, pers. comm. 2015).

In 2015, 'Colonized' Coho Salmon and Chinook Salmon fry were released in the Quinsam River watershed by hatchery staff. During June 9–13, 157,661 Coho Salmon fry were transported from the hatchery to the upper Quinsam River. On May 11 and 12, 217,603 Chinook Salmon fry were transported from the hatchery and released into Lower Quinsam Lake.

Table 29. Summary of downstream migration data collected at the Quinsam River Hatchery salmon counting fence, March 12 to June 22, 2015.

Species	Life stage	Total estimated migration	Peak migration	Migration period	Comments
Colonized Coho	Smolt	20,905	12/05/2015	Apr 24 - Jun 20	
Wild Coho	Smolt	29,774	12/05/2015	Apr 24 - Jun 20	
2 Year old Coho	Smolt	11	-	May 1	
Coho	Fry	38,776	22/05/2015	Mar 13 - Jun 18	
Steelhead	Smolt	3,264	11/05/2015	Apr 20 - May 31	
Steelhead	Fingerling	18	-	May 26	Started counting May 19
Steelhead	Kelts	57	25/04/2015	Apr 25 - May 8	
Cutthroat	Fingerling	72	-	Apr 26 -May 25	Started counting May 19
Cutthroat	Smolt	622	15/05/2015	Apr 25 - Jun 22	
Cutthroat	Kelts	246	01/05/2015	Mar 20 - May 14	
Trout fry	Fry	648	08/06/2015	May 26 - Jun 20	
Chinook	Fry	588	25/05/2015	Mar 31 - May 29	
Colonized Chinook	Fry	142,610	22/05/2015	May 18 - Last day	
Chum	Fry	433	19/04/2015	Apr 18 - Apr 20	
Sockeye	Fry	108	31/03/2015	Mar 31 - Apr 8	
Pink	Fry	2,736,848	27/03/2015	Start - May 19	
Dolly Varden	Smolt	47	26/04/2015	Apr 26 - May 15	
Lamprey (2 species)	All	2,245	22/04/2015	Start - end	
Sculpin	All	1,881	21/03/2015	Start - Jun 16	

Figure 25. Total estimated outmigration of Priority Species on the Quinsam River during Year 1 and 2. Data relate to smolt or fry (Chinook Salmon) life stages.



3.2. Water Quality

3.2.1. Review of Historical Water Quality Data

A background review of water quality data was undertaken during Year 2 to compile and review existing water quality data previously identified for the Salmon River watershed, and to review the status and key findings of existing and historical water quality monitoring in the Quinsam River. The aims were to identify and collate available data that could support the JHTMON-8 study objectives, and to identify opportunities to incorporate data from other monitoring programs into future JHTMON-8 data analysis.

The review indicated that water quality monitoring has been conducted, or is ongoing, in the Salmon River watershed by BCCF and Environment Canada. Water quality monitoring has been conducted, or is ongoing, in the Quinsam River watershed by the Quinsam River Hatchery, Environment Canada, and Quinsam Coal Corporation.

The review is presented in Appendix A. This includes discussion of proposals for how data collected as part of other monitoring programs can be used support the JHTMON-8 study objectives. Proposed ways to improve the study are also summarized in Section 5 of this report.

3.2.2. Water Chemistry

3.2.2.1. Salmon River

The in situ and lab water chemistry results for the Salmon River at SAM-WQ are summarized in Table 30 (general variables measured in situ), Table 31 (dissolved gases), Table 32 (general variables measured at ALS labs), and Table 33 (low level nutrients measured at ALS labs). Laboratory reports are presented in Appendix C. Results for Year 2 are presented alongside those for Year 1 for comparison. Data collected in Year 2 did not differ substantially from Year 1.

The following water quality variable concentration ranges were measured over the course of the monthly sampling during Years 1 and 2 in the Salmon River. Only those values that exceed the provincial or federal guidelines for the protection of aquatic life, or are not within the normal ranges of BC rivers, are discussed in additional detail (see Appendix E for applicable guidelines and typical ranges).

Alkalinity

Alkalinity (as $CaCO_3$) measured at ALS labs ranged from 12.3 mg/L (May 2014) to 23.9 mg/L (September 2014) during the two years of monitoring (Table 30). Alkalinity concentrations less than 10 mg/L in streams indicate sensitivity to acidic inputs, or poor buffering capacity. Alkalinity in the range of 10 mg/L to 20 mg/L indicates that the watercourse is moderately sensitive to acidic inputs, whereas values greater than 20 mg/L suggest a low sensitivity (Nagpal *et al.* 2006). Thus, the Salmon River is moderately sensitive to acidic inputs during the growing season.

Specific Conductivity and Total Dissolved Solids

Specific conductivity (conductivity normalized to 25°C) measured in situ ranged from 28.2 µS/cm (May 2014 sampling) to 54.7 µS/cm (September 2014) (Table 30). Similarly, lab values for specific conductivity ranged from 27.2 µS/cm to 59.9 µS/cm, with the lowest value occurring in May 2014, and the highest in July 2015. Coastal British Columbia streams generally have a specific conductivity of ~100 µS/cm (RISC 1998).

Total dissolved solids measured in the lab for the Salmon River ranged from 25 mg/L (May 2015) to 53 mg/L (November 2014) (Table 32).

pH

pH values measured in the laboratory ranged from 7.38 (May 2014) to 7.85 (August 2015), whereas in situ pH ranged from 6.83 to 7.88 (Table 30 and Table 32 respectively). Natural fresh waters have a pH range from 4 to 10; British Columbia lakes tend to have a pH ≥ 7.0, and coastal streams commonly have pH values of 5.5 to 6.5 (RISC 1998).

Turbidity and Total Suspended Solids (TSS)

Turbidity in the Salmon River at SAM-WQ was low during both years, indicating high water clarity (values ranged from 0.11 NTU to 0.92 NTU) (Table 30). Similarly, low TSS concentrations were measured throughout the sampling period, with concentrations that were predominantly non-detectable (<1.0 mg/L; Table 32). An exception was a concentration of 8.1 mg/L measured in one duplicate in August 2014. This result was presumed anomalous as the associated duplicate had a concentration of <1.0 mg/L.

Dissolved Oxygen

Dissolved oxygen concentrations in the Salmon River were generally high over the course of the two years of monitoring, but were lower in 2015 than in 2014. In British Columbia, surface waters generally exhibit dissolved oxygen concentrations greater than 10 mg/L, and are close to equilibrium with the atmosphere (i.e., ~ 100%; RISC 1998). However, dissolved oxygen concentrations in the summer of 2015 were less than 10 mg/L. This likely reflects the drought conditions experienced in summer 2015.

Dissolved oxygen concentrations did not meet the more conservative provincial guideline (DO instantaneous minimum of 9 mg/L) for the protection of buried embryo/alevin (Table 31) (MoE 1997a and MoE 1997b, Appendix E) on one sampling date during each year. On September 23, 2014 average DO concentration was 8.80 mg/L (88.2% saturation) and on June 16, 2015 the DO concentration was 8.31 mg/L (81.5% saturation). With regards to species of primary interest, the September date overlaps with the Chinook Salmon incubation period, while the June date overlaps with the steelhead incubation period (see Table 41 for periodicity information).

Total Gas Pressure

Total Gas Pressure (TGP) was not measured in Year 2. In Year 1, ΔP (TGP in mm Hg minus barometric pressure in mm Hg) ranged from -11 mm Hg to 13 mm Hg, which is well within the normal range for natural waters (Fidler and Miller 1994). Based on Year 1 results, and the low potential of the Salmon River diversion to cause elevated TGP concentrations, this variable was not measured in Year 2.

Nitrogen

Ammonia concentrations in the Salmon River at SAMWQ were less than the MDL of 5.0 μg N/L. (Table 33) in 2014 and 2015. Ammonia is usually present at low concentrations (<100 μg N/L) in waters not affected by wastewater discharges (Nordin and Pommen 1986).

Nitrite concentrations were below the MDL of 1.0 μg N/L for all the monthly sampling dates (Table 33) in 2014 and 2015. Nitrite is an unstable intermediate ion which serves as an indicator of recent contamination from sewage and/or agricultural runoff; levels are typically <1.0 μg N/L (RISC 1998).

Nitrate concentrations ranged from 8.5 μg N/L to 96.6 μg N/L over the course of the sampling, with the highest concentrations measured in August 2015. These concentrations are typical of oligotrophic lakes and streams, which typically have nitrate concentrations lower than 100 μg N/L (Nordin and Pommen 1986).

Phosphorus

Orthophosphate was below the detection limit of 1.0 μg P/L or very close to the detection limit in both years (Table 33). Very low orthophosphate concentrations are expected as it is a readily biologically available form of phosphorus and would be quickly taken up by primary producers in nutrient limited streams. Coastal British Columbia streams typically have orthophosphate concentrations <1.0 μg P/L (Slaney and Ward 1993; Ashley and Slaney 1997).

Total phosphorus concentrations over the Year 1 sampling period were low ranging from <2.0 μg P/L to 5.6 μg P/L in 2014. In Year 2, all samples had total phosphorus concentrations of <2.0 μg P/L (Table 33).

Table 30. Salmon River (SAM-WQ) general water quality variables measured in situ during Years 1 and 2, 2014 and 2015.

Year	Date	Specific Conductivity µS/cm				pH pH units				Air Temperature °C				Water Temperature °C			
		Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2014	21-May	28.2	28.2	28.2	0.0	6.91	6.91	6.91	0.00	-	-	-	-	9.1	9.1	9.1	0.0
	17-Jun	37.1	37.1	37.1	0.0	7.21	7.17	7.23	0.03	12	12	12	0	12.2	12.1	12.2	0.1
	23-Jul	46.7	46.7	46.7	0.0	7.03	7.03	7.03	0.00	14	14	14	0	15.5	15.5	15.5	0.0
	18-Aug	54.1	54.1	54.1	0.0	7.14	7.12	7.16	0.02	16	16	16	0	17.2	17.2	17.2	0.0
	23-Sep	54.7	54.7	54.8	0.1	7.22	7.21	7.23	0.01	17	17	17	0	14.6	14.6	14.6	0.0
	03-Nov	35.5	35.5	35.6	0.1	6.85	6.83	6.87	0.02	8	-	-	-	8.2	8.2	8.2	0.0
2015	13-May	41.5	41.5	41.5	0.0	7.36	7.34	7.39	0.03	11	11	11	0	10.8	10.8	10.8	0.0
	16-Jun	41.1	41.1	41.2	0.1	7.87	7.86	7.88	0.01	17	17	17	0	14.5	14.5	14.6	0.1
	22-Jul	52.6	52.6	52.6	0.0	7.60	7.58	7.62	0.02	16	16	16	0	16.5	16.5	16.5	0.0
	12-Aug	47.8	47.7	47.8	0.1	7.32	7.32	7.32	0.00	15	15	15	0	16.3	16.3	16.3	0.0
	17-Sep	47.4	47.4	47.4	0.0	7.09	7.08	7.09	0.01	11	11	11	0	11.2	11.2	11.2	0.0
	15-Oct	41.5	41.5	41.6	0.1	7.38	7.37	7.40	0.02	9	9	9	0	9.0	9.0	9.0	0.0

[1] Average of three replicates (n=3) on each date unless otherwise indicated.

Table 31. Salmon River (SAM-WQ) dissolved gases measured in situ during Years 1 and 2, 2014 and 2015.

Year	Quarter	Dissolved Oxygen %				Dissolved Oxygen mg/L				Barometric Pressure mm Hg				TGP %				TGP mm Hg				ΔP mm Hg			
		Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2014	21-May	102.6	102.6	102.6	0.0	11.68	11.67	11.68	0.01	748	748	748	0	102	102	102	0	761	761	761	0	13	13	13	0
	17-Jun	99.3	99.1	99.7	0.3	10.73	10.68	10.76	0.04	749	749	749	0	101	101	102	1	758	755	761	3	9	6	12	3
	23-Jul	101.8	101.8	101.9	0.1	10.20	10.20	10.20	0.00	747	747	747	0	101	101	101	0	755	755	755	0	8	8	8	0
	18-Aug	98.9	98.0	100.6	1.4	9.56	9.43	9.73	0.15	750	750	750	0	101	101	102	1	761	757	764	4	11	7	14	4
	23-Sep	88.2	87.1	88.8	0.9	8.80	8.71	8.86	0.08	760	760	760	0	98	98	99	1	749	748	751	2	-11	-12	-9	2
	03-Nov	95.7	95.1	96.5	0.7	11.08	11.02	11.18	0.09	763	762	763	1	100	100	100	0	763	761	764	2	0	-2	1	2
2015	13-May	93.7	93.7	93.8	0.1	10.38	10.37	10.39	0.01	742	742	742	0	-	-	-	-	-	-	-	-	-	-	-	-
	16-Jun	81.5	81.3	81.8	0.3	8.31	8.27	8.34	0.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	22-Jul	96.1	96.1	96.2	0.1	9.40	9.38	9.42	0.02	744	744	744	0	-	-	-	-	-	-	-	-	-	-	-	-
	12-Aug	92.0	91.9	92.1	0.1	9.02	8.98	9.06	0.04	747	747	747	0	-	-	-	-	-	-	-	-	-	-	-	-
	17-Sep	82.8	82.4	83.3	0.5	9.08	9.04	9.14	0.05	746	746	746	0	-	-	-	-	-	-	-	-	-	-	-	-
	15-Oct	99.1	98.9	99.3	0.2	11.46	11.44	11.48	0.02	750	750	750	0	-	-	-	-	-	-	-	-	-	-	-	-

[1] Average of three replicates (n=3) on each date unless otherwise indicated. A single data listed under Avg. indicates n=1.

Blue shading indicates that the more conservative provincial guideline (DO instantaneous minimum of 9 mg/L) for the protection of buried embryo/alevin has not been achieved. Note that the guideline for life stages other than buried embryo/alevin is met (DO instantaneous minimum of 5 mg/L).

Table 32. Salmon River (SAM-WQ) general water quality variables measured at ALS labs during Years 1 and 2, 2014 and 2015.

Year	Date	Date	Alkalinity, Total (as CaCO3) mg/L				Specific Conductivity µS/cm				Total Dissolved Solids mg/L				Total Suspended Solids mg/L				Turbidity NTU				pH pH units			
			Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2014	21-May	SAM-WQ	12.3	12.2	12.3	0.1	27.2	27.0	27.3	0.2	32	31	32	1	<1.0	<1.0	<1.0	0.0	0.30	0.22	0.38	0.11	7.38	7.35	7.40	0.04
		SAM-field blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.60	-	-	-
		SAM-travel blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.54	-	-	-
	17-Jun	SAM-WQ	17.6	17.3	17.8	0.4	40.5	37.5	43.5	4.2	33	31	34	2	<1.0	<1.0	<1.0	0.0	0.22	0.17	0.26	0.06	7.57	7.55	7.59	0.03
		SAM-field blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.44	-	-	-
		SAM-travel blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.48	-	-	-
	23-Jul	SAM-WQ	21.0	20.7	21.2	0.4	46.5	46.4	46.6	0.1	38	38	38	0	<1.0	<1.0	<1.0	0.0	0.92	0.71	1.12	0.29	7.58	7.53	7.62	0.06
		SAM-field blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.50	-	-	-
		SAM-travel blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.47	-	-	-
	18-Aug	SAM-WQ	23.8	23.6	23.9	0.2	56.3	55.3	57.3	1.4	49	43	55	8	<4.6	<1.0	8.1	5.0	0.22	0.20	0.23	0.02	7.79	7.76	7.82	0.04
		SAM-field blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	6.50	-	-	-
		SAM-travel blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	6.05	-	-	-
	23-Sep	SAM-WQ	23.9	23.8	23.9	0.1	53.1	52.8	53.4	0.4	46	41	51	7	<1.0	<1.0	<1.0	0.0	0.26	0.23	0.28	0.04	7.65	7.48	7.82	0.24
		SAM-field blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.28	-	-	-
		SAM-travel blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	6.03	-	-	-
	03-Nov	SAM-WQ	16.6	16.5	16.6	0.1	37.2	36.7	37.7	0.7	53	37	69	23	<1.0	<1.0	<1.0	0.0	0.33	0.32	0.34	0.01	7.61	7.56	7.65	0.06
		SAM-field blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.75	-	-	-
		SAM-travel blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.73	-	-	-
2015	13-May	SAM-WQ	15.8	15.3	16.2	0.6	33.5	33.3	33.6	0.2	25	23	27	3	<1.0	<1.0	<1.0	0.0	0.16	0.14	0.17	0.02	7.38	7.33	7.42	0.06
		SAM-field blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.50	-	-	-
		SAM-travel blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	6.77	-	-	-
	16-Jun	SAM-WQ	21.6	20.8	22.4	1.1	47.8	47.7	47.8	0.1	32	31	33	1	<1.0	<1.0	<1.0	0.0	0.11	0.11	0.11	0.00	7.66	7.65	7.66	0.01
		SAM-field blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	6.32	-	-	-
		SAM-travel blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	6.22	-	-	-
	22-Jul	SAM-WQ	23.1	22.6	23.5	0.6	59.9	55.0	64.8	6.9	32	31	32	1	<1.0	<1.0	<1.0	0.0	0.13	0.12	0.13	0.01	7.69	7.68	7.70	0.01
	12-Aug	SAM-WQ	22.6	21.7	23.4	1.2	51.4	51.2	51.6	0.3	47	45	48	2	<1.0	<1.0	<1.0	0.0	0.16	0.14	0.18	0.03	7.85	7.81	7.88	0.05
	17-Sep	SAM-WQ	20.4	20.4	20.4	0.0	47.2	47.1	47.3	0.1	32	32	32	0	<1.0	<1.0	<1.0	0.0	0.18	0.16	0.19	0.02	7.72	7.70	7.74	0.03
	15-Oct	SAM-WQ	18.2	18.1	18.2	0.1	40.7	40.6	40.8	0.1	37	36	37	1	<1.0	<1.0	<1.0	0.0	0.36	0.24	0.48	0.17	7.43	7.43	7.43	0.00

[1] Average of two replicates (n=2) on each date unless otherwise indicated. For field and travel blanks n=1.
Parameters that have a concentration below the detection limit are assumed to have a concentration equal to the detection limit for calculation purposes.

Table 33. Salmon River (SAM-WQ) low level nutrients measured at ALS labs during Years 1 and 2, 2014 and 2015.

Year	Date	Site	Ammonia, Total (as N) µg/L				Dissolved Orthophosphate (as P) µg/L				Nitrate (as N) µg/L				Nitrite (as N) µg/L				Total Phosphorus (P) µg/L			
			Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2014	21-May	SAM-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	8.8	8.4	9.1	0.5	<1.0	<1.0	<1.0	0.0	3.2	3.1	3.2	0.1
		SAM-field blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
		SAM-travel blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
	17-Jun	SAM-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	15.5	15.2	15.7	0.4	<1.0	<1.0	<1.0	0.0	<2.1	<2.0	2.1	0.1
		SAM-field blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
		SAM-travel blank	60.8	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
	23-Jul	SAM-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	8.5	8.5	8.5	0.0	<1.0	<1.0	<1.0	0.0	2.4	2.2	2.5	0.2
		SAM-field blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
		SAM-travel blank	50.2	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
	18-Aug	SAM-WQ	5.8	5.5	6.0	0.4	<1.1	<1.0	1.1	0.1	27.6	27.4	27.7	0.2	<1.0	<1.0	<1.0	0.0	<3.8	<2.0	5.6	2.5
		SAM-field blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
		SAM-travel blank	88.5	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
	23-Sep	SAM-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	71.6	70.8	72.4	1.1	<1.0	<1.0	<1.0	0.0	<2.3	<2.0	2.5	0.4
		SAM-field blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
		SAM-travel blank	81.6	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
	03-Nov	SAM-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	26.1	25.6	26.5	0.6	<1.0	<1.0	<1.0	0.0	<2.0	<2.0	<2.0	0.0
		SAM-field blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
		SAM-travel blank	87.7	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
2015	13-May	SAM-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	12.2	12.1	12.3	0.1	<1.0	<1.0	<1.0	0.0	<2.0	<2.0	<2.0	0.0
		SAM-field blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
		SAM-travel blank	18.8	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
	16-Jun	SAM-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	52.8	52.8	52.8	0.0	<1.0	<1.0	<1.0	0.0	<2.0	<2.0	<2.0	0.0
		SAM-field blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
		SAM-travel blank	43.6	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
	22-Jul	SAM-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	25.0	24.6	25.4	0.6	<1.0	<1.0	<1.0	0.0	<2.0	<2.0	<2.0	0.0
	12-Aug	SAM-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	96.6	95.9	97.3	1.0	<1.0	<1.0	<1.0	0.0	<2.0	<2.0	<2.0	0.0
	17-Sep	SAM-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	40.0	39.9	40.0	0.1	<1.0	<1.0	<1.0	0.0	<2.0	<2.0	<2.0	0.0
	15-Oct	SAM-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	20.1	20.0	20.1	0.1	<1.0	<1.0	<1.0	0.0	<2.0	<2.0	<2.0	0.0

[1] Average of two replicates (n=2) on each date unless otherwise indicated. For field and travel blanks n=1.

Parameters that have a concentration below the detection limit are assumed to have a concentration equal to the detection limit for calculation purposes.

3.2.2.1. Quinsam River

The in situ and lab water chemistry results for the Quinsam River at QUN-WQ are summarized in Table 34 (general variables measured in situ), Table 35 (dissolved gases measured in situ), Table 36 (general variables measured at ALS labs), and Table 37 (low level nutrients measured at ALS labs). Laboratory reports are presented in Appendix D. Results for Year 2 are presented alongside those for Year 1 for comparison. Data collected in Year 2 did not differ substantially from Year 1.

The following water quality variable concentration ranges were measured over the course of the monthly sampling during Year 1 and Year 2 in the Quinsam River. Only those values that exceed the provincial or federal guidelines for the protection of aquatic life, or are not within the normal ranges of BC rivers, are discussed in additional detail (see Appendix E for applicable guidelines and typical ranges).

Alkalinity

Alkalinity (as $CaCO_3$) measured at ALS labs ranged from 23.5 mg/L (Nov 2014) to 54.0 mg/L (July, 2015; Table 34) over the two years of sampling. Alkalinity concentrations were in all cases greater than 20 mg/L suggesting that the Quinsam River has a low sensitivity to acidic inputs (Nagpal *et al.* 2006).

Specific Conductivity and Total Dissolved Solids

In-situ specific conductivity (conductivity normalized to 25°C) ranged from 69.4 µS/cm (Nov sampling) to 197.7 µS/cm (August sampling) (Table 34). Similarly, lab values for specific conductivity ranged from 70.7 µS/cm (November 2014 sampling) to 206.0 µS/cm (August 2015 sampling). Coastal British Columbia streams generally have a specific conductivity of ~100 µS/cm (RISC 1998). Most specific conductivity values in the Quinsam River were higher than typical levels in coastal streams. This potentially reflects the influence of primary productivity in the two lakes upstream of the monitoring site. Alternatively, high values of specific conductivity measured in the past have previously been linked with coal mining activities in the watershed (Redenbach 1990 cited in Burt 2003).

Total dissolved solids measured in the lab for the Quinsam River ranged from 53 mg/L (Nov 2014) to 173 mg/L (September 2015) (Table 32).

pH

pH values measured in the laboratory ranged from 7.52 to 8.05 while in situ pH ranged from 7.01 to 7.71 (Table 36 and Table 34, respectively). Natural fresh waters have a pH range from 4 to 10, British Columbia lakes tend to have a pH ≥ 7.0, and coastal streams commonly have pH values of 5.5 to 6.5 (RISC 1998).

Turbidity and Total Suspended Solids (TSS)

Turbidity in the Quinsam River at QUN-WQ was low, indicating high water clarity (values ranged from 0.37 NTU to 0.93 NTU) (Table 36). Similarly, low TSS concentrations were measured during the monthly Year 1 and Year 2 sampling periods with non-detectable (<1.0 mg/L) concentrations in all cases.

Dissolved Oxygen

Dissolved oxygen concentrations and % saturation in the Quinsam River were high for streams in general over the course of the monthly monitoring; however, during the June, August and September sampling in 2014, and the June, July, August, and September sampling in 2015, the average DO concentration did not meet the more conservative provincial guideline (DO instantaneous minimum of 9 mg/L) for the protection of buried embryos/alevins (Table 35) (MoE 1997a and MoE 1997b, Appendix E). The September sampling dates were during the early stages of the Pink Salmon incubation period (see Table 46 for periodicity information).

All samples met the guideline for life stages other than buried embryo/alevin (DO instantaneous minimum of 5 mg/L). In British Columbia, surface waters generally exhibit DO concentrations greater than 10 mg/L, and are close to equilibrium with the atmosphere (i.e., ~100%; RISC 1998).

Total Gas Pressure

In Year 1, ΔP (TGP in mm Hg minus barometric pressure in mm Hg) ranged from -14 mm Hg to 7 mm Hg (Table 35), which is well within the normal range for natural waters (Fidler and Miller 1994).

Based on the Year 1 results, and the low potential for the Quinsam River diversion to cause elevated TGP concentrations, this variable was not measured in Year 2.

Nitrogen

Ammonia concentrations in the Quinsam River at QUN-WQ were less than, or close to, the detection limit of 5.0 µg N/L (Table 35) during 2014 and 2015. Ammonia is usually present at low concentrations (<100 µg N/L) in waters not affected by waste discharges (Nordin and Pommen 1986).

Nitrite concentrations were below the detection limit of 1.0 µg N/L for all the monthly sampling dates in 2014 and 2015 (Table 33). Nitrite is an unstable intermediate ion serving as an indicator of recent contamination from sewage and/or agricultural runoff; levels are typically <1.0 µg N/L (RISC 1998).

Nitrate concentrations were low and ranged from 13.5 µg N/L (May 2014) to 41.3 µg N/L (August 2015) over the course of the sampling in 2014 and 2015 (Table 37). In oligotrophic lakes and streams, nitrate concentrations are usually lower than 100 µg N/L (Nordin and Pommen 1986).

Phosphorus

Orthophosphate was below the detection limit of 1.0 µg P/L or very close to the detection limit in 2014 and 2015 (Table 37). Very low orthophosphate concentrations are expected as it is a readily biologically available form of phosphorus and would be quickly taken up in nutrient limited streams.

Coastal British Columbia streams typically have orthophosphate concentrations <1.0 μg P/L (Slaney and Ward 1993; Ashley and Slaney 1997).

Total phosphorus concentrations over the Year 1 sampling period were low ranging from <2.0 μg P/L to 5.0 μg P/L (Table 37).

Table 34. Quinsam River (QUN-WQ) general water quality variables measured in situ during Years 1 and 2, 2014 and 2015.

Year	Date	Specific Conductivity µS/cm				pH pH units				Air Temperature °C				Water Temperature °C			
		Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2014	23-May	95.6	95.6	95.6	0.0	7.38	7.38	7.39	0.01	-	-	-	-	12.8	12.8	12.8	0.0
	18-Jun	143.1	143.1	143.1	0.0	7.58	7.57	7.58	0.01	14	14	14	0	17.1	17.1	17.1	0.0
	22-Jul	148.1	148.1	148.1	0.0	7.36	7.36	7.36	0.00	16	16	16	0	17.7	17.7	17.7	0.0
	19-Aug	152.3	152.2	152.4	0.1	7.38	7.36	7.43	0.04	19	19	19	0	20.2	20.2	20.2	0.0
	24-Sep	109.9	109.9	109.9	0.0	7.30	7.23	7.36	0.07	14	14	14	0	16.1	16.1	16.1	0.0
	04-Nov	69.4	69.4	69.4	0.0	7.01	7.01	7.02	0.01	7	7	7	0	9.6	9.6	9.6	0.0
2015	12-May	144.4	144.4	144.5	0.1	7.68	7.68	7.68	0.00	14	14	14	0	14.2	14.2	14.2	0.0
	17-Jun	98.1	14.0	140.2	72.8	7.71	7.71	7.71	0.00	15	15	15	0	18.2	18.2	18.2	0.0
	23-Jul	190.7	190.7	190.7	0.0	7.49	7.49	7.49	0.00	17	17	17	0	17.0	17.0	17.0	0.0
	13-Aug	197.7	197.6	197.7	0.1	7.41	7.40	7.41	0.01	17	17	17	0	18.5	18.5	18.5	0.0
	16-Sep	185.7	185.7	185.7	0.0	7.50	7.50	7.50	0.00	12	12	12	0	14.1	14.1	14.1	0.0
	14-Oct	131.9	131.8	131.9	0.1	7.52	7.50	7.54	0.02	11	11	11	0	9.5	9.5	9.6	0.1

[1] Average of three replicates (n=3) on each date unless otherwise indicated.

Table 35. Quinsam River (QUN-WQ) dissolved gases measured in situ during Years 1 and 2, 2014 and 2015.

Year	Date	Oxygen Dissolved (In Situ) %				Oxygen Dissolved (In Situ) mg/L				Barometric Pressure mm Hg				TGP %				TGP mm Hg				ΔP mm Hg			
		Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2014	23-May	101.8	101.4	102.6	0.7	10.74	10.69	10.82	0.07	744	743	745	1	100	100	100	0	744	744	745	1	0	0	1	1
	18-Jun	91.3	90.9	91.9	0.5	8.84	8.80	8.87	0.04	748	748	749	1	101	101	101	0	755	753	757	2	7	5	8	2
	22-Jul	95.8	95.8	95.9	0.1	9.13	9.12	9.13	0.01	747	747	748	1	101	101	101	0	753	753	753	0	6	5	6	1
	19-Aug	77.9	77.7	78.3	0.3	7.01	6.99	7.03	0.02	745	744	745	1	99	99	99	0	735	735	735	0	-10	-10	-9	1
	24-Sep	91.7	90.1	92.7	1.4	8.78	8.53	8.91	0.21	753	752	753	1	98	98	98	0	739	739	740	1	-13	-14	-13	1
	04-Nov	88.5	88.4	88.5	0.1	9.95	9.94	9.96	0.01	761	761	762	1	99	99	99	0	755	755	755	0	-6	-7	-6	1
2015	12-May	96.2	96.2	96.3	0.1	9.89	9.88	9.89	0.01	741	741	741	0	-	-	-	-	-	-	-	-	-	-	-	-
	17-Jun	83.7	83.6	83.9	0.2	7.90	7.89	7.91	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	23-Jul	84.2	84.1	84.4	0.2	8.14	8.13	8.14	0.01	744	744	744	0	-	-	-	-	-	-	-	-	-	-	-	-
	13-Aug	84.2	84.1	84.4	0.2	7.89	7.88	7.91	0.02	746	746	746	0	-	-	-	-	-	-	-	-	-	-	-	-
	16-Sep	78.1	77.8	78.5	0.4	8.03	8.00	8.05	0.03	743	743	743	0	-	-	-	-	-	-	-	-	-	-	-	-
	14-Oct	87.0	86.8	87.3	0.3	9.88	9.87	9.89	0.01	754	754	754	0	-	-	-	-	-	-	-	-	-	-	-	-

[1] Average of three replicates (n=3) on each date unless otherwise indicated.

Blue shading indicates that the more conservative provincial guideline (DO instantaneous minimum of 9 mg/L) for the protection of buried embryo/alevin has not been achieved. Note that the guideline for life stages other than buried embryo/alevin is met (DO instantaneous minimum of 5 mg/L).

Table 36. Quinsam River (QUN-WQ) general water quality variables measured at ALS labs during Years 1 and 2, 2014 and 2015.

Year	Date	Site	Alkalinity, Total (as $CaCO_3$) mg/L				Specific Conductivity µS/cm				Total Dissolved Solids mg/L				Total Suspended Solids mg/L				Turbidity NTU				pH pH units			
			Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2014	23-May	QUN-WQ	31.7	31.5	31.8	0.2	94.8	94.1	95.4	0.9	69	68	70	1	<1.0	<1.0	<1.0	0.0	0.59	0.52	0.65	0.09	7.77	7.77	7.77	0.00
		QUN-field blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.60	-	-	-
		QUN-travel blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.64	-	-	-
	18-Jun	QUN-WQ	41.0	40.8	41.1	0.2	139.5	139.0	140.0	0.7	96	96	96	0	<1.0	<1.0	<1.0	0.0	0.42	0.40	0.44	0.03	7.87	7.87	7.87	0.00
		QUN-field blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.47	-	-	-
		QUN-travel blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.45	-	-	-
	22-Jul	QUN-WQ	42.4	42.4	42.4	0.0	140.0	139.0	141.0	1.4	103	101	105	3	<1.0	<1.0	<1.0	0.0	0.46	0.44	0.47	0.02	7.73	7.65	7.81	0.11
		QUN-field blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.69	-	-	-
		QUN-travel blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.76	-	-	-
	19-Aug	QUN-WQ	42.1	41.9	42.3	0.3	156.0	146.0	166.0	14.1	96	95	96	1	<1.0	<1.0	<1.0	0.0	0.70	0.47	0.93	0.33	7.81	7.57	8.05	0.34
		QUN-field blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.91	-	-	-
		QUN-travel blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	6.17	-	-	-
	24-Sep	QUN-WQ	35.0	35.0	35.0	0.0	109.0	109.0	109.0	0.0	71	67	74	5	<1.0	<1.0	<1.0	0.0	0.56	0.50	0.62	0.08	7.55	7.52	7.58	0.04
		QUN-field blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.45	-	-	-
		QUN-travel blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.41	-	-	-
	04-Nov	QUN-WQ	23.7	23.5	23.8	0.2	71.3	70.7	71.8	0.8	59	53	64	8	<1.0	<1.0	<1.0	0.0	0.74	0.71	0.77	0.04	7.61	7.59	7.63	0.03
		QUN-field blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.70	-	-	-
		QUN-travel blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.75	-	-	-
2015	12-May	QUN-WQ	40.8	40.6	41.0	0.3	143.0	143.0	143.0	0.0	91	89	93	3	<1.0	<1.0	<1.0	0.0	0.38	0.37	0.39	0.01	7.79	7.78	7.80	0.01
		QUN-field blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.84	-	-	-
		QUN-travel blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.80	-	-	-
	17-Jun	QUN-WQ	43.9	43.8	43.9	0.1	157.0	157.0	157.0	0.0	97	94	100	4	<1.0	<1.0	<1.0	0.0	0.41	0.40	0.42	0.01	7.91	7.90	7.92	0.01
		QUN-field blank	<2.0	-	-	-	3.2	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	6.22	-	-	-
		QUN-travel blank	<2.0	-	-	-	<2.0	-	-	-	<10	-	-	-	<1.0	-	-	-	<0.10	-	-	-	5.91	-	-	-
	23-Jul	QUN-WQ	52.9	51.7	54.0	1.6	206.0	206.0	206.0	0.0	120	120	120	0	<1.0	<1.0	<1.0	0.0	0.49	0.49	0.49	0.00	8.00	7.99	8.01	0.01
	13-Aug	QUN-WQ	48.8	48.0	49.6	1.1	175.0	173.0	177.0	2.8	124	120	127	5	<1.0	<1.0	<1.0	0.0	0.36	0.30	0.42	0.08	7.78	7.70	7.85	0.11
	16-Sep	QUN-WQ	46.2	46.0	46.3	0.2	178.0	177.0	179.0	1.4	145	116	173	40	<1.0	<1.0	<1.0	0.0	0.40	0.38	0.42	0.03	7.94	7.94	7.94	0.00
	14-Oct	QUN-WQ	34.0	33.9	34.1	0.1	130.0	129.0	131.0	1.4	94	92	96	3	<1.3	<1.0	1.6	0.4	0.47	0.40	0.53	0.09	7.55	7.52	7.58	0.04

[1] Average of two replicates (n=2) on each date unless otherwise indicated. For field and travel blanks n=1.

Parameters that have a concentration below the detection limit are assumed to have a concentration equal to the detection limit for calculation purposes.

Table 37. Quinsam River (QUN-WQ) low level nutrients measured at ALS labs during Years 1 and 2, 2014 and 2015.

Year	Date	Site	Ammonia, Total (as N) µg/L				Dissolved Orthophosphate (as P) µg/L				Nitrate (as N) µg/L				Nitrite (as N) µg/L				Total Phosphorus (P) µg/L			
			Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD	Avg[1]	Min	Max	SD
2014	23-May	QUN-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	13.8	13.5	14.0	0.4	<1.0	<1.0	<1.0	0.0	3.9	3.8	3.9	0.1
		QUN-field blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
		QUN-travel blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
	18-Jun	QUN-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	29.7	29.2	30.1	0.6	<1.0	<1.0	<1.0	0.0	2.8	2.7	2.9	0.1
		QUN-field blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
		QUN-travel blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
	22-Jul	QUN-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	31.6	31.3	31.9	0.4	<1.0	<1.0	<1.0	0.0	2.9	2.6	3.2	0.4
		QUN-field blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
		QUN-travel blank	27.1	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
	19-Aug	QUN-WQ	<5.2	<5.0	5.3	0.2	<1.0	<1.0	<1.0	0.0	17.1	17.0	17.1	0.1	<1.0	<1.0	<1.0	0.0	4.8	4.6	5.0	0.3
		QUN-field blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
		QUN-travel blank	38.7	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
	24-Sep	QUN-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	21.2	20.7	21.6	0.6	<1.0	<1.0	<1.0	0.0	4.3	3.9	4.6	0.5
		QUN-field blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
		QUN-travel blank	55.1	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
	04-Nov	QUN-WQ	5.1	5.1	5.1	0.0	<1.0	<1.0	<1.0	0.0	24.6	24.0	25.1	0.8	<1.0	<1.0	<1.0	0.0	3.7	2.9	4.4	1.1
		QUN-field blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
		QUN-travel blank	99.5	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
2015	12-May	QUN-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	23.0	22.9	23.1	0.1	<1.0	<1.0	<1.0	0.0	2.9	2.5	3.3	0.6
		QUN-field blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
		QUN-travel blank	11.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
	17-Jun	QUN-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	23.8	23.6	23.9	0.2	<1.0	<1.0	<1.0	0.0	<2.0	<2.0	<2.0	0.0
		QUN-field blank	<5.0	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
		QUN-travel blank	58.5	-	-	-	<1.0	-	-	-	<5.0	-	-	-	<1.0	-	-	-	<2.0	-	-	-
	23-Jul	QUN-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	29.9	29.3	30.5	0.8	<1.0	<1.0	<1.0	0.0	<2.1	<2.0	2.1	0.1
	13-Aug	QUN-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	41.0	40.6	41.3	0.5	<1.0	<1.0	<1.0	0.0	<2.0	<2.0	<2.0	0.0
	16-Sep	QUN-WQ	<5.0	<5.0	<5.0	0.0	<1.0	<1.0	<1.0	0.0	14.0	13.9	14.1	0.1	<1.0	<1.0	<1.0	0.0	<2.2	<2.0	2.3	0.2
	14-Oct	QUN-WQ	9.0	8.8	9.2	0.3	<1.0	<1.0	<1.0	0.0	36.0	35.6	36.3	0.5	<1.0	<1.0	<1.0	0.0	4.6	4.4	4.8	0.3

[1] Average of two replicates (n=2) on each date unless otherwise indicated. For field and travel blanks n=1.

Parameters that have a concentration below the detection limit are assumed to have a concentration equal to the detection limit for calculation purposes.

ECOFISH RESEARCH

3.2.3. Water and Air Temperature Monitoring

3.2.3.1. Salmon River

Summary

Baseline water temperature data were examined to characterize the thermal regime of the Salmon River at SAM-WQ. High flow events in the fall of 2014 led to the loss of both temperature data loggers, and replacements were not installed until spring 2015. Therefore, there are no temperature data available from October 21, 2014 to May 15, 2015 and, therefore, complete monthly records are available for June through September in both years. Minimum water temperatures in the Salmon River could not be calculated for SAM-WQ as there is no coverage of the winter months. However, water temperature is measured by Environment Canada at two hydrometric gauges in the Salmon River, one upstream and one downstream of SAM-WQ (see Appendix A for analysis of Environment Canada data). The water temperature measurements for both years at SAM-WQ are shown in Figure 26, and the mean, minimum, and maximum water temperatures for each month of the record are summarized in Table 38.

In 2015, mean monthly water temperatures in June (16.9°C) and July (19.1°C) were higher than those in 2014, reflecting high air temperatures and low rainfall associated with the drought that occurred in Vancouver Island at that time. However, mean monthly temperatures in 2015 for August (17.6°C) and September (11.7°C) were lower than those for 2014 (Table 38). Based on the available data for 2015, the coolest temperature measurement was 8.7°C in September and the warmest temperature measurement was 24.5°C in July (Table 38).

From a fisheries biology perspective, the water temperature records for the Salmon River indicate occurrences of warm water temperatures. Over the period of record (154 days in 2015), there were 41 days (27%) with daily-mean temperatures above 18°C, as well as nine days (6%) with daily-mean temperatures above 20°C (Table 39).

Figure 26. Water temperature in the Salmon River (SAM-WQ) for 2014 and 2015 on days with available data (May to October).

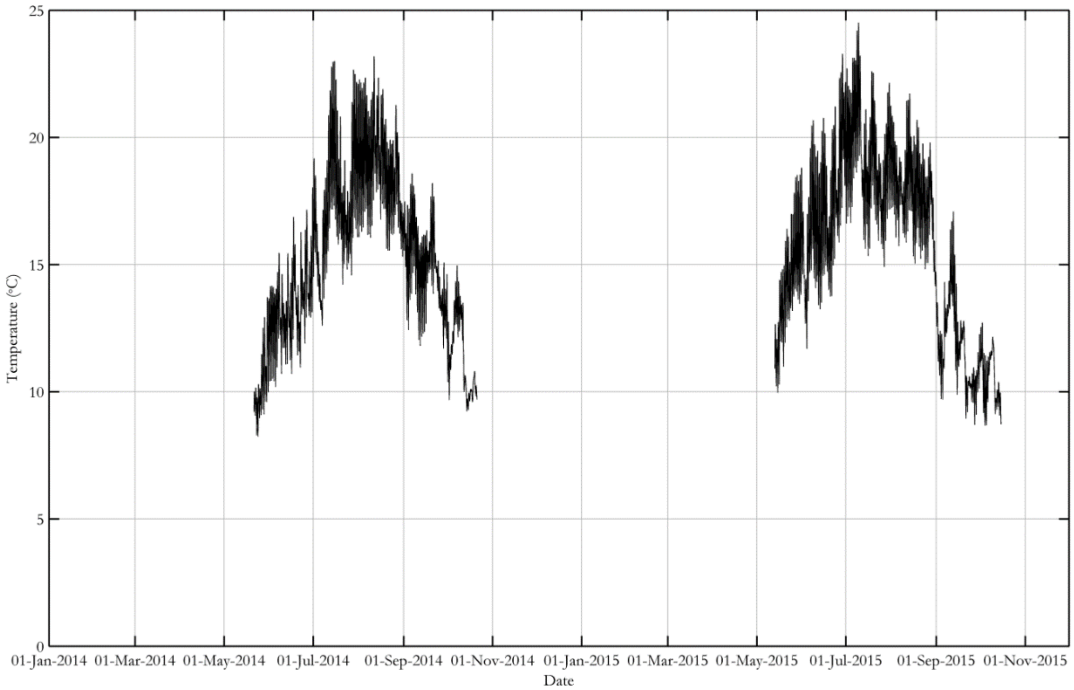


Table 38. Monthly water temperature statistics in the Salmon River (SAM-WQ).

Year	Month	SAM-WQ[1,2]			
		Avg	Min	Max	SD
2014	May	-	-	-	-
	Jun	13.3	10.2	18.0	1.4
	Jul	17.2	12.6	23.0	2.3
	Aug	18.7	15.3	23.2	1.7
	Sep	14.9	11.7	18.6	1.5
	Oct	-	-	-	-
	Nov	-	-	-	-
	Dec	-	-	-	-
2015	Jan	-	-	-	-
	Feb	-	-	-	-
	Mar	-	-	-	-
	Apr	-	-	-	-
	May	-	-	-	-
	Jun	16.9	11.7	23.3	2.4
	Jul	19.1	14.9	24.5	2.0
	Aug	17.6	13.6	21.7	1.5
	Sep	11.7	8.7	17.1	1.6
	Oct	-	-	-	-

[1]Data collection gap from October 2014 to May 2015 is due to lost Tidbits.

[2]Months with less than three weeks of data were not included.

Rates of Change

Large, rapid temperature changes can affect fish growth and survival (Oliver and Fidler 2001). Rates of change in water temperature at SAM-WQ were therefore examined; these are summarized in Table 40 and presented in Figure 27. Hourly rates of temperature change were between -0.4°C/hr and +0.8°C/hr for at least 90% of the time (based on the 5th and 95th percentiles), and were between -0.6°C/hr and +1.0°C/hr for at least 98% of the time (based on the 1st and 99th percentiles).

The maximum positive rate of water temperature change varied from 0.8°C/hr to 1.3°C/hr and the negative rate of water temperature change varied from -0.4°C/hr to -0.8°C/hr. The majority of rates of hourly temperature change were within ± 1°C/hr (Table 40). Based on our experience on other streams in British Columbia, it is normal for a small percentage of data points to have hourly rates of water temperature change that exceed ±1°C. When water temperature decreases faster than 1°C/hr it is usually associated with a rainfall event.

Table 39. Summary of the number of days with mean daily water temperatures >18°C and >20°C in the Salmon River (SAM-WQ) in 2014 and 2015.

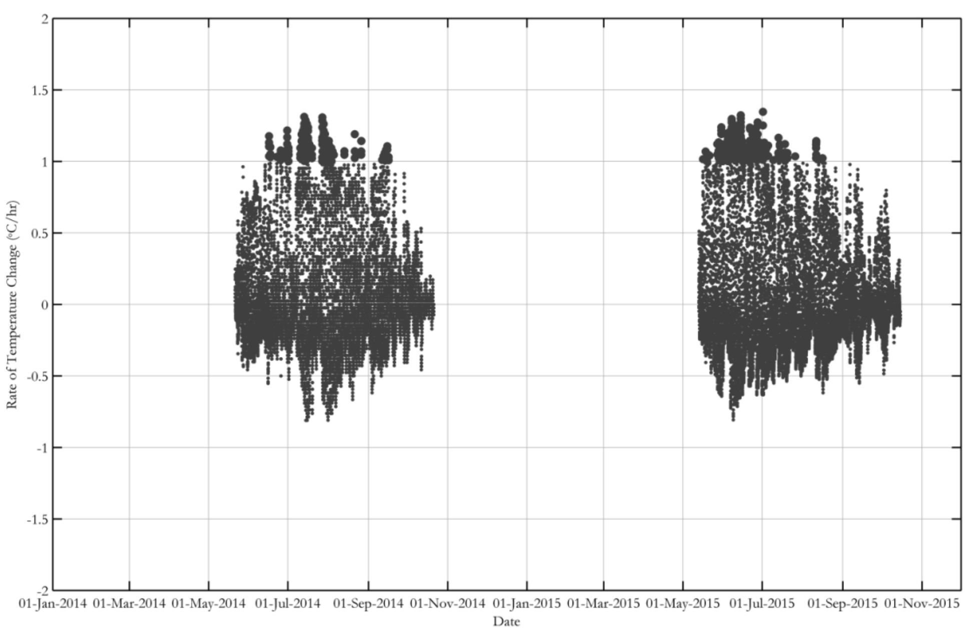
Site	Year	Record Length (days)	Days T_{water}> 20°C	Days T_{water}> 18°C	Days T_{water} < 1°C
SAM-WQ[1]	2014	152	2	35	unknown
	2015	154	9	41	unknown

[1] Data records at SAM-WQ do not cover the winter period due to lost Tidbits

Table 40. Statistics for the hourly rates of change in water temperature at SAM-WQ in the Salmon River in 2014 and 2015. Shown is the frequency of rates of change exceeding a magnitude of 1°C/hr. The record is incomplete (see Figure 27).

Station	Start of record	End of record	Number of Datapoints	Occurrence of rates >1°C/hr		Max -ve	Percentile				Max+ve
				Number	% of record		1th	5th	95th	99th	
SAM-WQ	21-May-2014	15-Oct-2015	29,557	392	1.3	-0.8	-0.6	-0.4	0.8	1.0	1.3

Figure 27. Rate of change in hourly water temperature in the Salmon River (SAM-WQ) in 2014 (a) and 2015 (b) for days with available data.



Mean Weekly Maximum Water Temperatures

The mean weekly maximum water temperature (MWMxT) is an important indicator of the exposure of fish to prolonged periods of warm water temperatures. The guidelines for the protection of aquatic life state "Where fish distribution information is available, then mean weekly maximum water temperatures should only vary + or - 1 degrees C beyond the optimum temperature range of each life history phase (incubation, rearing, migration and spawning) for the most sensitive salmonid species present" (Oliver and Fidler 2001). Temperature data for 2014 were not compared with guideline values in the Year 1 report (Abell *et al.* 2015b) and, therefore, comparisons using data collected during both years are presented here.

Fish species of primary interest for JHTMON-8 in the Salmon River are steelhead, Coho Salmon and Chinook Salmon. Steelhead and Coho Salmon are present both upstream and downstream of SAM-WQ, while the range for Chinook Salmon extends to the Memekay River confluence, approximately 15 km downstream of SAM-WQ (based on distributions presented in Burt 2010). The MWMxT data are compared to optimum temperature ranges for different fish species in Table 41. For each life stage, Table 41 also shows the percentage of MWMxT data that are above, within, and below the optimum ranges for fish life stages during baseline monitoring. The percentages of MWMxT data that are above and below the optimum ranges by more than 1°C are also presented.

If the water temperature data record is less than 50% complete for a particular species/life stage, comparisons to the provincial guidelines must be interpreted with caution. As data were only available for May 15 to October 15, the comparison of MWMxT with guideline values provides an incomplete assessment of the suitability of water temperatures for fish. Nonetheless, the analysis provides useful information about whether the upper limits were exceeded during the summer. In particular, the analysis provides useful information about whether water temperatures were excessively warm at times for juvenile steelhead and Coho Salmon during the rearing life stage.

For Chinook Salmon, MWMxT were above upper limits by > 1°C at times for all four relevant life stages during both years. Note though that incubation and rearing life stages are poorly represented by the data, and data were only available for 72–82% of the spawning periods. Data were available for the full duration of the migration period in both years; MWMxT exceeded the upper limit of the optimum range (19°C) by > 1°C for 38.5% of the time in 2014 and 25.6% of the time in 2015 (Table 41).

For Coho Salmon, MWMxT were above upper limits by > 1°C at times for the migration and spawning periods in 2014, although these life stages are poorly represented by the data. For the rearing life stage, MWMxT were above the upper optimum limit (16°C) for 42.8% of the time in 2014 and 62.3% of the time in 2015 (Table 41).

For steelhead, MWMxT were above upper limits by > 1°C for ≥ 50% of the time for spawning and incubation periods in both years, although these life stages are poorly represented by the data. For the rearing life stage, MWMxT were outside of the optimum temperature range (16–18°C) for the majority of the monitoring periods. At times, MWMxT was either below or above the optimum range for rearing in both years, with MWMxT within the optimum range for 23.7% of the time in 2014 and 10.4% of the time in 2015 (Table 41).

Table 41. Mean weekly maximum temperatures (MWMxT) in the Salmon River in 2014 and 2015 compared to optimum temperature ranges for fish species present. Periodicity information is from Burt (2010).

Species	Life Stage			Year	Percent Complete	MWMxT (°C)		% of MWMxT				
	Periodicity	Optimum Temperature Range (°C)	Duration (days)			Min.	Max.	Below Lower Bound by >1°C	Below Lower Bound	Between Bounds	Above Upper Bound	Above Upper Bound by >1°C
Chinook Salmon	Migration (Jul. 15 to Sep. 30)	3.3-19.0	78	2014	100	13.4	22.2	0.0	0.0	50.0	50.0	38.5
				2015	100	10.6	21.0	0.0	0.0	48.7	51.3	25.6
	Spawning (Sep. 01 to Oct. 31)	5.6-13.9	61	2014	82	10.2	17.7	0.0	0.0	42.0	58.0	48.0
				2015	72.1	10.1	15.4	0.0	0.0	81.8	18.2	11.4
	Incubation (Sep. 01 to Apr. 23)	5.0-14.0	235	2014	21.3	10.2	17.7	0.0	0.0	44.0	56.0	48.0
				2015	18.7	10.1	15.4	0.0	0.0	81.8	18.2	9.1
	Rearing (Mar. 07 to Jul. 23)	10.0-15.5	139	2014	45.3	10.1	22.1	0.0	0.0	54.0	46.0	36.5
				2015	51.1	12.9	23.3	0.0	0.0	9.9	90.1	85.9
Coho Salmon	Migration (Sep. 01 to Nov. 30)	7.2-15.6	91	2014	54.9	10.2	17.7	0.0	0.0	54.0	46.0	26.0
				2015	48.4	10.1	15.4	0.0	0.0	100.0	0.0	0.0
	Spawning (Oct. 01 to Dec. 15)	4.4-12.8	76	2014	26.3	10.2	14.0	0.0	0.0	50.0	50.0	10.0
				2015	18.4	10.1	11.9	0.0	0.0	100.0	0.0	0.0
	Incubation (Oct. 01 to Apr. 15)	4.0-13.0	197	2014	10.2	10.2	14.0	0.0	0.0	60.0	40.0	0.0
				2015	7.1	10.1	11.9	0.0	0.0	100.0	0.0	0.0
	Rearing (Jan. 01 to Dec. 31)	9.0-16.0	365	2014	41.6	10.1	22.2	0.0	0.0	42.8	57.2	42.8
				2015	42.2	10.1	23.3	0.0	0.0	34.4	65.6	62.3
Rainbow Trout/ Steelhead	Spawning (Mar. 01 to May. 31)	10.0-15.5	92	2014	10.9	10.1	13.4	0.0	0.0	20.0	80.0	50.0
				2015	19.6	12.9	18.2	0.0	0.0	0.0	100.0	100.0
	Incubation (Mar. 01 to Jun. 30)	10.0-12.0	122	2014	32.8	10.1	17.0	0.0	0.0	15.0	85.0	80.0
				2015	39.3	12.9	22.4	0.0	0.0	0.0	100.0	97.9
	Rearing (Jan. 01 to Dec. 31)	16.0-18.0	365	2014	41.6	10.1	22.2	38.2	42.8	23.7	33.6	28.9
				2015	42.2	10.1	23.3	29.2	34.4	10.4	55.2	46.8

Blue shading indicates provincial guideline exceedance of the lower bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001).
Red shading indicates provincial guideline exceedance of the upper bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001).
Gray shading indicates the percent complete is less than 50%, comparisons to the provincial guidelines are not included for <50% of data.

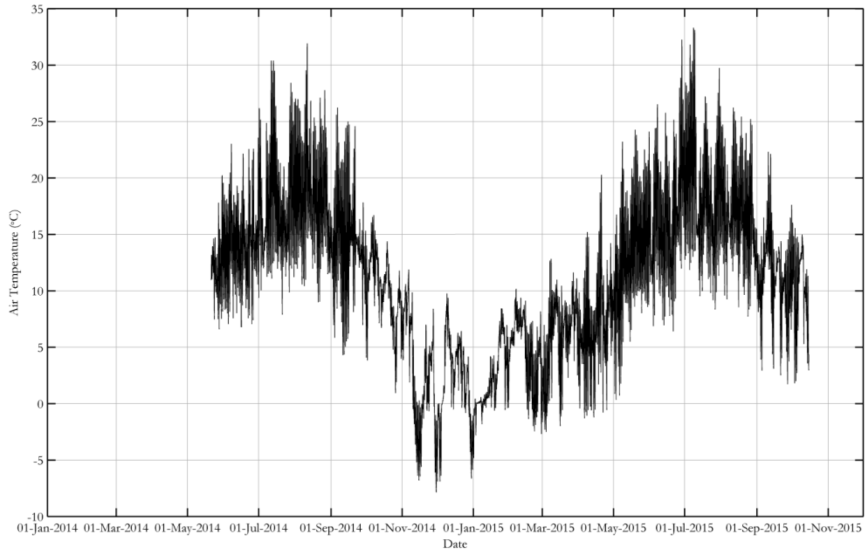
Air Temperature

Air temperature data are summarized in Table 42 and Figure 28. The lowest air temperature measured during the monitoring period was -7.9ºC measured in November, 2014, while the highest air temperature was 33.3°C in July, 2015. The maximum monthly mean air temperature (18.1°C) was in July, 2015.

Table 42. Monthly air temperature at the Salmon River (SAM-AT) in 2014 and 2015.

Year	Month	SAM-AT			
		Avg	Min	Max	SD
2014	May	-	-	-	-
	Jun	13.7	6.8	23.6	3.4
	Jul	16.9	7.9	30.4	4.4
	Aug	17.8	9.0	31.9	4.4
	Sep	13.7	4.3	26.2	4.2
	Oct	9.9	0.9	16.7	2.9
	Nov	2.2	-7.9	11.9	4.7
	Dec	1.9	-6.9	9.8	3.7
2015	Jan	1.9	-4.8	8.4	2.6
	Feb	4.5	-2.7	10.2	3.1
	Mar	5.6	-2.5	12.8	3.3
	Apr	6.4	-1.3	20.3	3.9
	May	12.6	0.4	24.3	4.9
	Jun	15.9	6.4	32.3	4.8
	Jul	18.1	8.3	33.3	5.1
	Aug	16.2	7.7	26.2	3.7
	Sep	10.9	1.7	22.3	3.5
	Oct	-	-	-	-

Figure 28. Air temperature at the Salmon River (SAM-AT) in 2014 and 2015.



3.2.3.2. Quinsam River

Summary

Water temperature data were examined to characterize the thermal regime of the Quinsam River at QUN-WQ for the monitoring period. The water temperature records are shown in Figure 29 and the mean, minimum, and maximum water temperatures for each month of the record are summarized in Table 43.

To date, the highest monthly-mean water temperature of 19.8°C occurred in August, 2014 and the lowest monthly-mean water temperature of 3.8°C occurred in January, 2015. The coolest temperature recorded was 2.0°C measured in January, 2015 and the warmest temperature was 23.0°C, measured in both June and July, 2015 (Table 43).

From a fisheries biology perspective, the water temperature records for the Quinsam River indicate occurrences of warm water temperatures. Over the period of record in 2015 (286 days), there were 69 days (24%) with daily-mean temperatures above 18°C, and 16 days (6%) with daily mean temperature above 20°C (Table 44).

Figure 29. Water temperature in the Quinsam River (QUN-WQ) in 2014 and 2015.

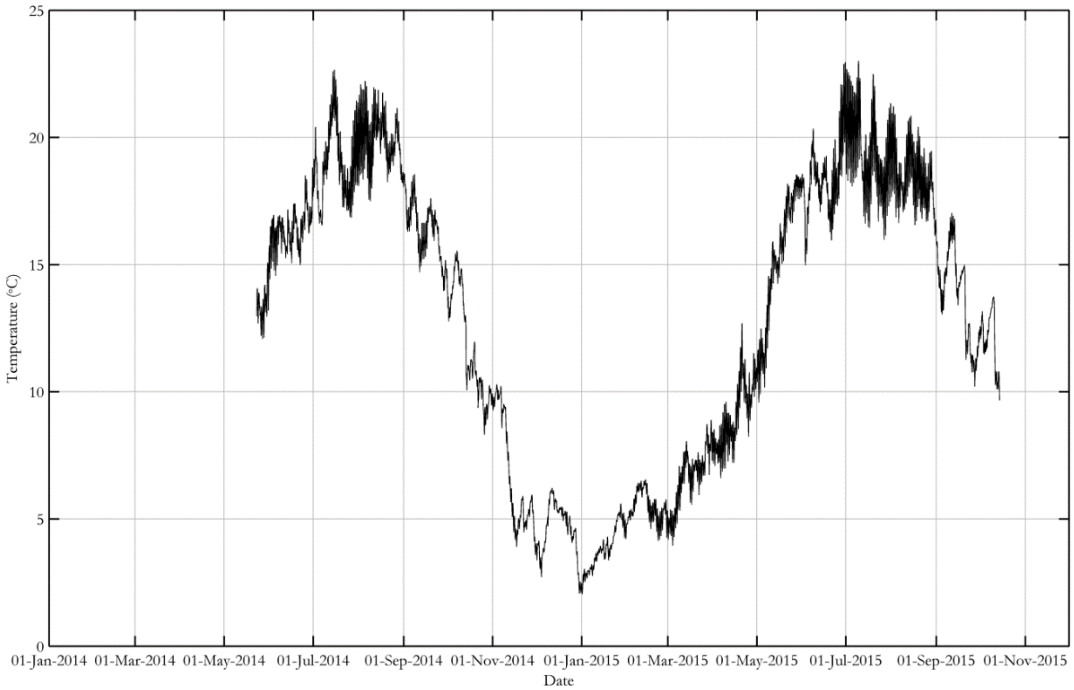


Table 43. Monthly water temperature in the Quinsam River (QUN-WQ) in 2014 and 2015.

Year	Month	QUN-WQ[1]			
		Avg	Min	Max	SD
2014	May	-	-	-	-
	Jun	16.3	14.4	18.8	0.7
	Jul	18.9	16.5	22.7	1.4
	Aug	19.8	17.5	22.2	1.0
	Sep	16.3	13.9	18.6	1.1
	Oct	11.8	8.3	15.5	2.1
	Nov	6.6	3.6	10.3	2.2
	Dec	4.5	2.1	6.2	1.0
2015	Jan	3.8	2.0	5.6	0.8
	Feb	5.5	4.1	6.5	0.6
	Mar	6.6	4.0	8.9	1.1
	Apr	9.0	6.6	12.7	1.3
	May	15.1	9.6	18.5	2.5
	Jun	18.3	15.0	23.0	1.4
	Jul	19.2	16.0	23.0	1.6
	Aug	18.3	15.9	21.2	1.1
	Sep	13.7	10.2	17.0	1.8
	Oct	-	-	-	-

[1] Months with less than three weeks of data were not included.

Rates of Change

Rates of change in water temperature at QUN-WQ are summarized Table 45 and presented in Figure 30. The hourly rates of temperature change at the monitoring stations were between -0.2°C/hr and +0.3°C/hr for at least 90% of the time (based on the 5th and 95th percentiles) and were between -0.4°C/hr and +0.6°C/hr for at least 98% of the time (based on the 1st and 99th percentiles).

The maximum positive rate of water temperature change varied from 0.3°C/hr to 1.1°C/hr, and the negative rate of water temperature change varied from -0.2°C/hr to -1.3°C/hr. The majority of rates of hourly temperature change were within ± 0.6°C/hr (Table 45). Based on our experience on other streams in British Columbia, it is normal for a small percentage of data points to have hourly rates of water temperature change that exceed ±1°C.

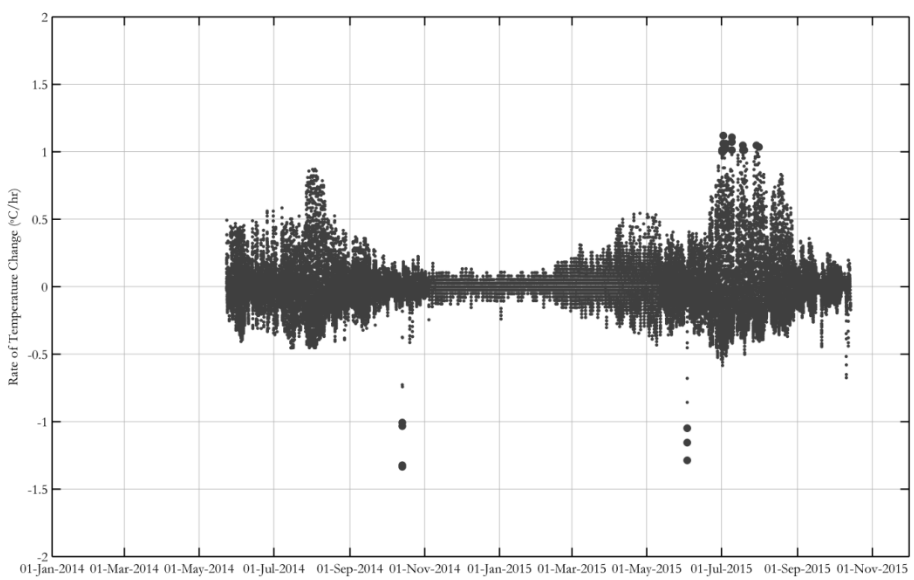
Table 44. Summary of the number of days with mean daily water temperatures >18°C and >20°C in the Quinsam River at QUN-WQ.

Site	Year	Record Length (days)	Days T_{water}> 20°C	Days T_{water}> 18°C	Days T_{water} < 1°C
QUN-WQ	2014	222	21	54	0
	2015	286	16	69	0

Table 45. Statistics for the hourly rates of change in water temperature at QUN-WQ in the Quinsam River. Shown is the frequency of rates of change exceeding a magnitude of 1°C/hr.

Station	Start of record	End of record	Number of Datapoints	Occurrence of rates >1°C/hr		Max -ve	Percentile				Max+ve
				Number	% of record		1th	5th	95th	99th	
QUN-WQ	23-May-2014	14-Oct-2015	48,861	24	0.0	-1.3	-0.4	-0.2	0.3	0.6	1.1

Figure 30. Rate of change in hourly water temperature in the Quinsam River (QUN-WQ) in 2014 and 2015.



Mean Weekly Maximum Water Temperatures

Fish species of primary interest for JHTMON-8 in the Quinsam River are steelhead, Coho Salmon and Chinook Salmon, although Pink Salmon is also of considerable significance to fishery managers. steelhead and Coho Salmon are present both upstream and downstream of QUN-WQ, although falls and cascades downstream of Lower Quinsam Lake are complete barriers to Chinook Salmon and Pink Salmon (Burt 2003). Thus, results for these two latter species should be interpreted with caution. An analysis of water temperature data collected over multiple years at the Quinsam River Hatchery is presented in the separate review of historical water quality data (Appendix A).

The MWMxT data for both 2014 and 2015 are compared to optimum temperature ranges for fish species in Table 46. For each life stage, Table 46 also shows the percentage of MWMxT data that are above, within, and below the optimum ranges for fish life stages during baseline monitoring. The percentages of MWMxT data above and below the optimum ranges by more than 1°C are also shown. If the water temperature data record is less than 50% complete for a particular species/life stage, comparisons to the provincial guidelines must be interpreted with caution.

Considering both years and all species/life stages, MWMxT in the Quinsam River exceeded optimum ranges by more than 1°C an average of 27% of the time, and were below optimum ranges an average of 16% of the time (Table 46).

For Chinook Salmon, temperatures were typically within optimum ranges with the exception of the rearing period, when MWMxT exceeded the upper limit (15.5°C) by > 1°C for 48.2% of the time in 2015 (the one year with full data coverage) (Table 46).

For Coho Salmon, temperatures were typically within the optimum ranges during the spawning and incubation periods. For the migration period, full data coverage is available for 2014 when water temperatures were within the optimum range for 44.4% of the time and > 1°C below the range for 44.4% of the time. For the rearing stage, MWMxT (incomplete coverage for both years) were within the optimum range for 23.9% (2014) to 26.9% (2015) of the time (Table 46).

For Pink Salmon, the analysis indicates the presence of high water temperatures during migration and spawning, particularly during 2014 when temperatures exceeded the upper bound of the optimum range by > 1°C for most of the time.

For steelhead, MWMxT were rarely (0–22.1% of the time) within the optimum ranges for any life stage. Most notably, water temperatures during the spawning stage in 2015 (the only year with appropriate data) were below the optimum range for 100% of the time, and > 1°C below the lower bound for 86.7% of the time. Note that the guideline temperature ranges for steelhead life stages are based on those for 'Rainbow Trout' (Oliver and Fidler 2001) and are not specific to fish with an anadromous life history (i.e., steelhead). Data specific to steelhead (Carter 2005 and references therein) indicate that steelhead are adapted to tolerate MWMxT considerably lower than the optimum ranges presented in (Table 46) during spawning and incubation, although survival is likely to be affected by temperatures that exceed these ranges. Thus, the occurrence of MWMxT in the

Quinsam River that are below the optimum ranges for Rainbow Trout spawning and incubation do not necessarily indicate poor conditions for these steelhead life stages.

Table 46. Mean weekly maximum temperatures (MWMxT) in the Quinsam River in 2014 and 2015 compared to optimum temperature ranges for fish species present. Periodicity information is from Burt (2003).

Species	Life Stage			Year	Percent Complete	MWMxT (°C)		% of MWMxT				
	Periodicity	Optimum Temperature Range (°C)	Duration (days)			Min.	Max.	Below Lower Bound by >1°C	Below Lower Bound	Between Bounds	Above Upper Bound	Above Upper Bound by >1°C
Chinook Salmon	Migration (Sep. 23 to Nov. 23)	3.3-19.0	62	2014	100	5.2	16.5	0.0	0.0	100.0	0.0	0.0
				2015	33.9	11.6	12.9	0.0	0.0	100.0	0.0	0.0
	Spawning (Oct. 01 to Nov. 30)	5.6-13.9	61	2014	100	4.7	15.0	0.0	26.2	57.4	16.4	3.3
				2015	21.3	11.6	12.9	0.0	0.0	100.0	0.0	0.0
	Incubation (Oct. 15 to Apr. 30)	5.0-14.0	198	2014	100	2.8	11.8	9.6	21.2	78.8	0.0	0.0
				2015	-	-	-	-	-	-	-	-
	Rearing (Mar. 07 to Jul. 23)	10.0-15.5	139	2014	43.9	13.7	21.8	0.0	0.0	11.5	88.5	83.6
				2015	100	6.3	22.5	23.0	29.5	18.7	51.8	48.2
Coho Salmon	Migration (Sep. 15 to Dec. 31)	7.2-15.6	108	2014	100	3.1	17.1	44.4	45.4	44.4	10.2	7.4
				2015	26.9	11.6	15.2	0.0	0.0	100.0	0.0	0.0
	Spawning (Oct. 15 to Jan. 15)	4.4-12.8	93	2014	100	2.8	11.8	10.8	28.0	72.0	0.0	0.0
				2015	-	-	-	-	-	-	-	-
	Incubation (Oct. 15 to Dec. 31)	4.0-13.0	78	2014	100	3.1	11.8	0.0	6.4	93.6	0.0	0.0
				2015	-	-	-	-	-	-	-	-
	Rearing (Jan. 01 to Dec. 31)	9.0-16.0	365	2014	60.8	3.1	21.8	23.0	23.9	23.9	52.3	38.3
				2015	78.4	2.8	22.5	29.7	33.9	26.9	39.2	36.4
Pink Salmon	Migration (Aug. 01 to Oct. 15)	7.2-15.6	76	2014	100	11.8	21.8	0.0	0.0	26.3	73.7	67.1
				2015	97.4	11.6	20.9	0.0	0.0	50.0	50.0	41.9
	Spawning (Sep. 15 to Oct. 15)	7.2-12.8	31	2014	100	11.8	17.1	0.0	0.0	9.7	90.3	83.9
				2015	93.5	11.6	15.2	0.0	0.0	65.5	34.5	20.7
	Incubation (Sep. 15 to Apr. 07)	4.0-13.0	205	2014	100	2.8	17.1	1.5	9.3	77.1	13.7	12.7
				2015	14.1	11.6	15.2	0.0	0.0	75.9	24.1	17.2
Rainbow Trout/ Steelhead	Spawning (Feb. 15 to Apr. 15)	10.0-15.5	60	2014	-	-	-	-	-	-	-	-
				2015	100	5.3	9.4	86.7	100.0	0.0	0.0	0.0
	Incubation (Feb. 15 to Jun. 15)	10.0-12.0	121	2014	19	13.7	16.8	0.0	0.0	0.0	100.0	100.0
				2015	100	5.3	19.3	43.0	50.4	14.0	35.5	33.9
	Rearing (Jan. 01 to Dec. 31)	16.0-18.0	365	2014	60.8	3.1	21.8	45.5	47.7	22.1	30.2	22.5
				2015	78.4	2.8	22.5	56.6	60.8	5.6	33.6	22.7

Blue shading indicates provincial guideline exceedance of the lower bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001).
Red shading indicates provincial guideline exceedance of the upper bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001).
Gray shading indicates the percent complete is less than 50%, comparisons to the provincial guidelines are not included for <50% of data.

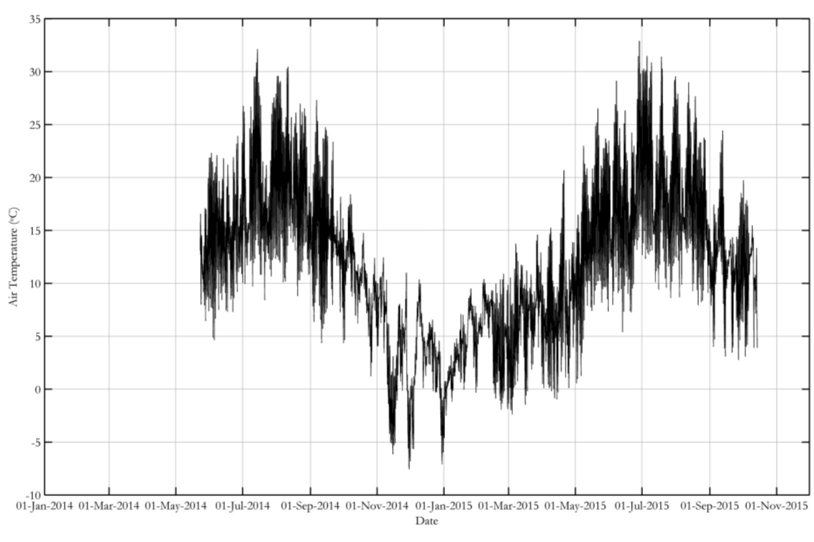
Air temperature

Air temperature data are summarized in Table 47 and Figure 31. The maximum monthly mean air temperature (18.7°C) was in July, 2015. The lowest air temperature measured during the monitoring period was -7.6°C measured in November, 2015, while the highest air temperature of 32.9°C occurred in July, 2015.

Table 47. Monthly air temperature statistics at the Quinsam River (QUN-AT) in 2014 and 2015.

Year	Month	QUN-AT			
		Avg	Min	Max	SD
2014	May	-	-	-	-
	Jun	14.3	4.6	23.9	3.8
	Jul	17.8	8.4	32.1	4.9
	Aug	18.5	8.8	30.5	4.7
	Sep	14.1	4.4	27.3	4.4
	Oct	10.1	1.2	18.4	2.9
	Nov	3.1	-7.6	12.4	4.7
	Dec	2.4	-7.1	10.4	3.7
2015	Jan	3.1	-4.6	9.5	2.7
	Feb	5.2	-1.9	10.9	3.1
	Mar	6.1	-2.4	14.6	3.5
	Apr	7.0	-1.0	20.7	4.1
	May	13.7	0.6	26.5	5.1
	Jun	16.9	5.4	32.9	5.2
	Jul	18.7	8.6	31.5	5.3
	Aug	16.8	7.9	29.0	4.4
	Sep	11.5	2.8	24.4	3.8
	Oct	-	-	-	-

Figure 31. Air temperature at the Quinsam River (QUN-AT) in 2014 and 2015.



3.3. Invertebrate Drift

3.3.1. Salmon River Invertebrate Drift

The invertebrate drift density (individuals/m^3), biomass (mg/m^3), Simpson's family-level diversity index (1-λ), richness (# families), and CEFI index at each site on each sample date are provided in Table 48. Means, standard deviations and coefficients of variation are shown for 2014 data only, when samples from all five drift nets were analyzed separately. Biomass results are also plotted in Figure 32. In all cases other than the CEFI index (where only aquatic taxa are considered), the results are for all taxa (aquatic, semi-aquatic, and terrestrial).

3.3.1.1. Density

The invertebrate drift density in Salmon River was variable across sampling dates, increasing from spring through mid-summer, and then declining into late summer and fall. Mean density values were generally lowest during spring (1.12 individuals/m^3 on May 13) and fall (1.19 and 1.20 individuals/m^3 on September 17 and October 15, respectively), and peaked in mid-summer (3.66 individuals/m^3 on July 22, 2015) (Table 48). The lowest density was measured on August 12, 2015. Density values during the weekly sampling period in July, ranged from 1.77 individuals/m^3 to 3.66 individuals/m^3 (Table 48). Overall, invertebrate drift density in the Salmon River was higher during 2015 sampling than during 2014 sampling (Abell *et al.* 2015b).

3.3.1.2. Biomass

The invertebrate drift biomass in Salmon River was variable across sampling dates (Figure 32), and did not show a spring peak such as was observed in 2014 (Figure 32). Mean biomass values ranged from 0.03 mg/m^3 on July 22, to 0.09 mg/m^3 on September 17 (Table 48). There was no clear relationship between biomass and abundance, e.g., the lowest biomass measurements were on dates with the highest and lowest corresponding density measurements (Table 48). Biomass measurements were similar in 2015 and 2014 (Figure 32).

3.3.1.3. Simpson's Family Level Diversity (1- λ)

Mean Simpson's family level diversity values were highest in the spring (0.92 and 0.84 on May 13 and June 16) and fall (0.82 on September 17 and October 15) (Table 48), similar to 2014 trends (Abell *et al.* 2015b). There was a positive correlation between diversity and biomass ($R = 0.75$, $p = 0.02$), and between diversity and richness ($R = 0.82$, $p < 0.01$).

3.3.1.4. Richness (# of Families)

Mean family richness ranged from 26 families (July 22) to 47 families (May 13), with no clear seasonal trend (Table 48).

3.3.1.5. Canadian Ecological Flow Index

CEFI results showed no apparent seasonal trend (Table 48). Low CEFI values are described as <0.25 (Armanini *et al.* 2011) and all CEFI values in the Salmon River were greater than this threshold. CEFI values ranged from 0.32 on three of four July sampling dates to 0.37 on October 15. The consistent CEFI values throughout the sampling period suggest that any effects of flow on the invertebrate ecosystem are not seasonally influenced.

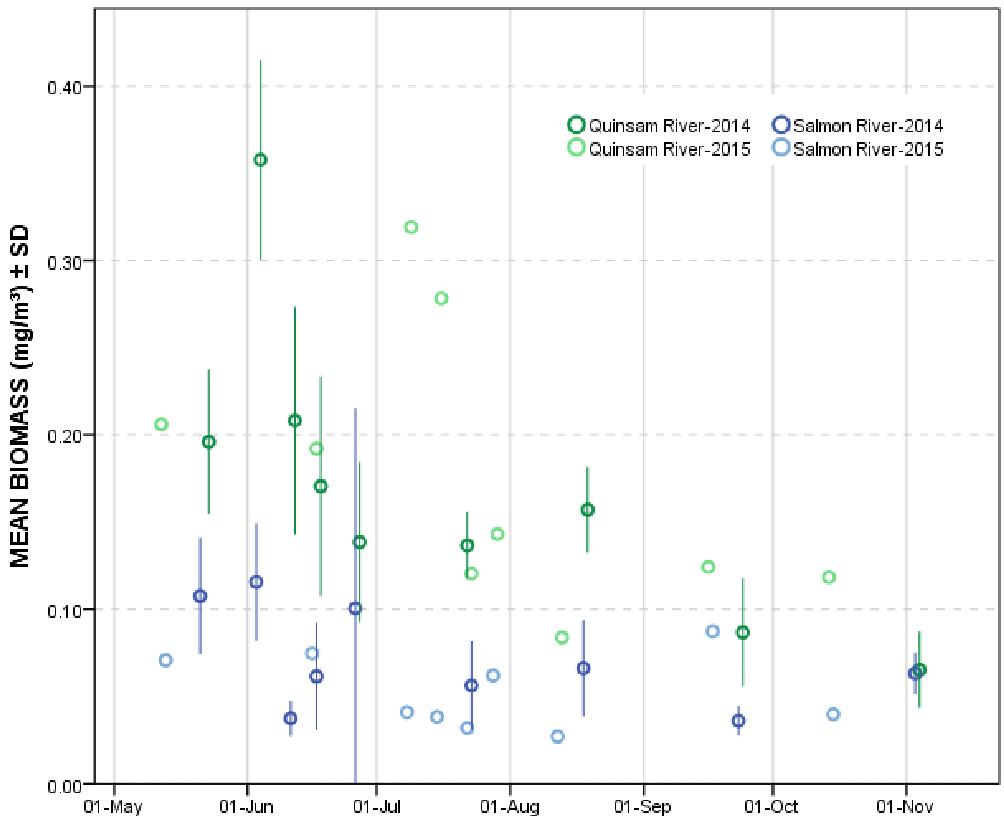
Table 48. Salmon River invertebrate drift mean density (individuals/m^3), biomass (mg/m^3), Simpson's diversity index (1-λ, family level), richness (# of families) and CEFI index. Note that in 2014 each drift net was analyzed separately, while in 2015 all five nets per site were combined into one sample.

All Taxa (Aquatic, Semi-Aquatic, and Terrestrial)														
Year	Sample Date	Number of Replicates	Density (#/m^3)			Biomass (mg/m^3)			CEFI Index†			Richness (# of Families)‡	Simpson's Diversity Index (1-λ)‡
			Mean	S.D.	C.V.	Mean	S.D.	C.V.	Mean	S.D.	C.V.		
2014	21-May	5	0.85	0.26	30.06	0.11	0.03	31.09	0.37	0.01	1.86	74	0.86
	03-Jun	5	0.92	0.24	25.77	0.12	0.03	29.09	0.34	0.01	2.80	80	0.91
	11-Jun	5	0.72	0.29	40.33	0.04	0.01	27.14	0.34	0.01	2.19	48	0.89
	17-Jun	5	1.10	0.37	34.00	0.06	0.03	49.98	0.37	0.01	2.28	59	0.85
	26-Jun	5	0.86	0.33	38.49	0.10	0.11	113.95	0.35	0.01	2.91	55	0.89
	23-Jul	5	1.48	0.52	35.28	0.06	0.03	45.09	0.33	0.01	3.91	38	0.82
	18-Aug	5	3.11	1.43	46.04	0.07	0.03	41.65	0.34	0.01	1.92	37	0.75
	23-Sep	5	1.28	0.21	16.20	0.04	0.01	23.50	0.34	0.01	1.52	37	0.91
	03-Nov	5	0.89	0.21	23.50	0.06	0.01	18.80	0.37	0.01	2.97	76	0.89
2015	13-May	1	1.12	-	-	0.07	-	-	0.34	-	-	47	0.92
	16-Jun	1	3.32	-	-	0.07	-	-	0.35	-	-	44	0.84
	08-Jul	1	2.27	-	-	0.04	-	-	0.32	-	-	29	0.77
	15-Jul	1	2.03	-	-	0.04	-	-	0.32	-	-	30	0.67
	22-Jul	1	3.66	-	-	0.03	-	-	0.33	-	-	26	0.65
	28-Jul	1	1.77	-	-	0.06	-	-	0.32	-	-	32	0.78
	12-Aug	1	0.91	-	-	0.03	-	-	0.33	-	-	35	0.74
	17-Sep	1	1.19	-	-	0.09	-	-	0.34	-	-	30	0.82
	15-Oct	1	1.20	-	-	0.04	-	-	0.37	-	-	40	0.82

† Calculation considers only aquatic taxa

‡ Replicates were averaged where applicable prior to calculating metric

Figure 32. Salmon River and Quinsam River mean invertebrate drift biomass (mg/m³) ± 1 standard deviation (SD). SD was only calculated for 2014, when five drift nets were analyzed separately per site.



3.3.1.6. Top Five Families Contributing to Biomass

A summary of the top five families contributing to biomass in the invertebrate drift community on each sample date is provided in Table 49. Note that in some instances, a taxonomic level higher than family is listed (e.g., Ephemeroptera), as this was the lowest taxonomic level enumerated. The invertebrate community was dominated (in terms of biomass) by mayflies (Baetidae, Ephemeroptera, Ameletidae, and Heptageniidae), true flies (Chironomidae, Simuliidae, Ceratopogonidae, and Chironomidae), and mites (Hygrobatidae, Torrenticolidae, and Sperchontidae). Caddisflies (Limnephilidae, Lepidostomatidae, Glossosomatidae, and Hydropsychidae), and beetles (Elmidae and Dystiscidae), and were also occasionally within the top five families during sampling.

Considering all samples, Baetidae (mayflies) was among the top contributors to biomass on every sample date, and was the top contributor on October 15 (with a contribution of 15.5%). Baetidae was the second greatest contributor to biomass on four of the nine sample dates, with contributions ranging from 12.1% to 18.1%. Baetidae was also one of the top contributors in 2014.

Chironomidae (true flies) was a top five contributor to biomass on eight of the nine sample dates. This taxon was the top contributor to biomass on five dates (with contributions of 22.3% to 41.4%).

Torrenticolidae (mites) was among the top contributor to biomass on five of the nine sample dates. This taxon was the top contributor on June 16, contributing 12.8% of the total biomass.

Simuliidae (true flies) was among the top contributors to biomass on three sample dates. This taxon was the top contributor to biomass on September 17 (38.6%).

Limnephilidae (caddisflies) was the top contributor to biomass on May 13 (26.9%) but was not among the top five contributors on any other sampling dates.

Table 49. Salmon River: top five families contributing to invertebrate drift biomass.

Salmon River	13-May-15	Salmon River	16-Jun-15	Salmon River	8-Jul-15	Salmon River	15-Jul-15	Salmon River	22-Jul-15
Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass
Limnephilidae	26.9	Torrenticolidae	12.8	Chironomidae	27.0	Chironomidae	41.4	Chironomidae	39.4
Lepidostomatidae	8.4	Baetidae	12.1	Baetidae	13.3	Baetidae	12.3	Glossosomatidae	17.3
Baetidae	7.9	Dytiscidae	9.9	(Ephemeroptera)	8.6	Elmidae	8.0	Torrenticolidae	9.4
Chironomidae	7.8	Hydropsychidae	9.1	Torrenticolidae	7.7	Torrenticolidae	7.5	Baetidae	8.4
Elmidae	6.7	Simuliidae	8.1	Sperchontidae	7.0	Lepidostomatidae	4.1	Ameletidae	4.1
Sum	57.71	Sum	51.98	Sum	63.76	Sum	73.29	Sum	78.66

Salmon River	28-Jul-15	Salmon River	12-Aug-15	Salmon River	17-Sep-15	Salmon River	15-Oct-15
Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass
Chironomidae	22.3	Chironomidae	30.8	Simuliidae	38.6	Baetidae	15.5
Baetidae	18.1	Simuliidae	11.3	Chironomidae	25.5	Simuliidae	11.1
Ameletidae	9.8	Torrenticolidae	8.6	Baetidae	4.6	Heptageniidae	9.9
Hygrobatidae	8.3	Ameletidae	5.8	Ceratopogonidae	3.8	Chironomidae	9.0
(Ephemeroptera)	6.6	Baetidae	5.4	Aphididae	3.1	Elmidae	6.8
Sum	65.06	Sum	61.75	Sum	75.54	Sum	52.27

Key
Mayflies
Caddisflies
True Flies
Mites
Beetles
True Bugs

3.3.1.7. Multivariate Analysis

The results of the cluster analysis performed on the Bray-Curtis similarity matrices (generated from density data) are provided in the dendrogram in Figure 33. Data from the highest available taxonomic resolution were analyzed using density on each sample date. Black lines indicate branching of groups with a dissimilar community composition at a 5% significance level (SIMPROF test); red lines denote groups that are not significantly different in their community composition at a 5% significance level (Simprof test). The analyses suggest a seasonal trend in community composition. Samples collected in the fall (November 3, 2014 and October 15, 2015) are similar to each other and dissimilar to invertebrate drift community compositions on other sample dates. Spring samples in 2015 (May 13 and June 16, 2015) are not similar to samples collected other times of year, or to each other. Weekly samples collected in June 2014 and July 2015 are similar to each other, indicating that community composition of invertebrates remains relatively constant throughout those months.

The multi-dimensional scaling (MDS) on the Bray Curtis similarity matrices (generated from density data at the highest taxonomic resolution available in the dataset) is shown in an ordination plot in Figure 34. Points that are close together represent samples that are very similar in community composition, while points that are far apart correspond to samples with very different community composition. MDS plots were generated using density data from each sample date. The MDS generated has a stress value of 0.15. Stress values ≤0.1 correspond to a good ordination with negligible possibility of a misleading interpretation with respect to differences in community composition among samples (Clarke and Warwick 2001). Stress values between 0.1 and 0.2 provide a useful 2-dimensional MDS representation as long as there is agreement in groupings between dendrograms (i.e., Figure 33) and the MDS plot (i.e., Figure 34) (Clark and Warwick 2001). The similarities displayed by the MDS plot agree with those seen in the dendogram. Conclusions drawn regarding seasonal trends in community similarities are therefore the same.

Figure 33. Salmon River cluster analysis results on the Bray-Curtis similarity matrix, by date.

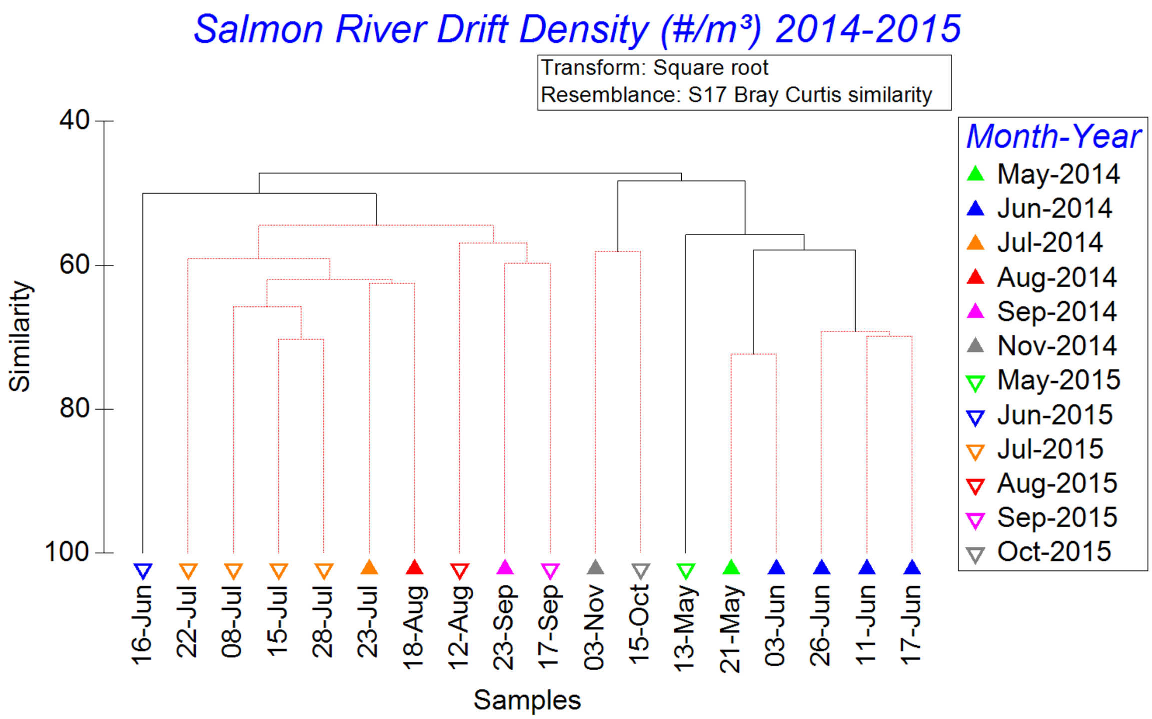
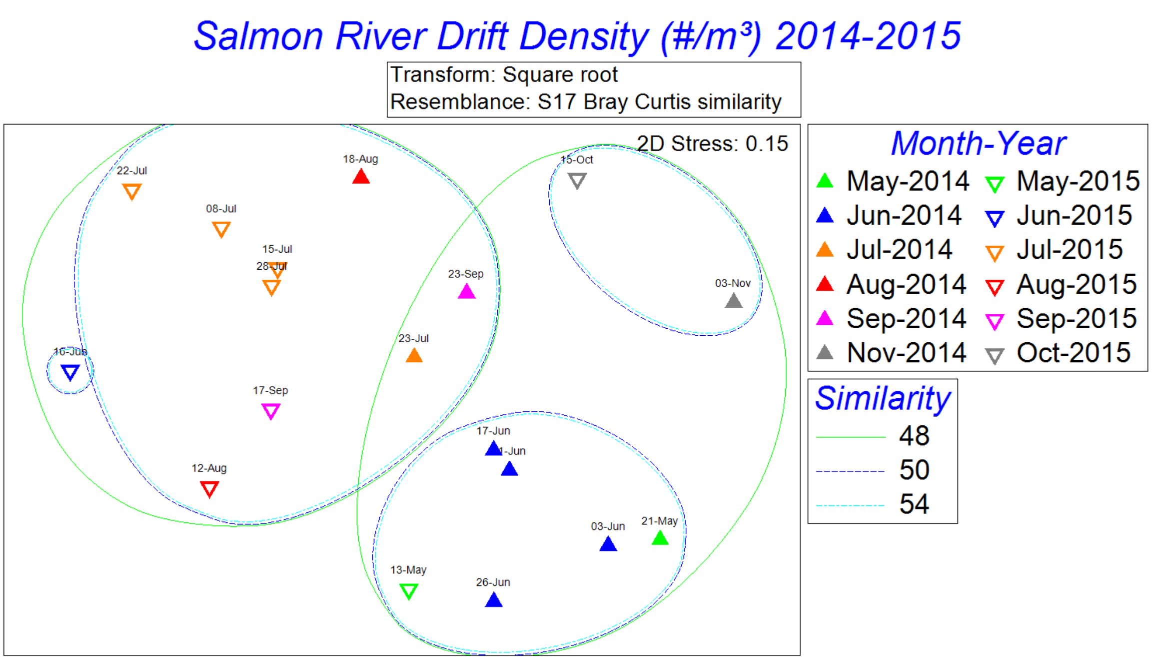


Figure 34. Salmon River non-metric, multi-dimensional scaling ordination plot by date.



3.3.2. Quinsam River Invertebrate Drift

The invertebrate drift density (individuals/m^3), biomass (mg/m^3), Simpson's family-level diversity index (1-λ), richness (# families), and CEFI index at each site on each sample date are provided in Table 50. Means, standard deviations and coefficients of variation are shown for 2014 data only, when samples from all five drift nets were analyzed separately. Biomass results are also plotted in Figure 32. In all cases other than the CEFI index (where only aquatic taxa are considered), the results are for all taxa (aquatic, semi-aquatic, and terrestrial).

3.3.2.1. Density

The invertebrate drift density in the Quinsam River was variable across sampling dates, but was generally lower in the spring and fall than in the summer months. The lowest values occurred on May 12 (1.38 individuals/m^3) and September 16 (1.71 individuals/m^3). The highest density was observed from June to August, when density ranged from 2.52 to 6.38 individuals/m^3 (Table 50).

3.3.2.2. Biomass

The invertebrate drift biomass in the Quinsam River was highest during the spring and early summer, and then decreased in late summer and fall. The lowest biomass was observed on August 13 (0.08 mg/m^3) and the highest on July 9 (0.32 mg/m^3). Biomass was not consistent during the weekly July samples, varying from 0.12 to 0.32 mg/m^3). Biomass was generally similar to 2014 (Figure 32).

3.3.2.3. Simpson's Family Level Diversity (1- λ)

Mean Simpson's family level diversity values varied throughout the season, with no clear trend (Table 50). Diversity ranged from 0.64 on July 29 to 0.87 on October 14. Diversity and density were negatively correlated (R= -0.80, p=0.01), indicating that low diversity values tended to be associated with high density (Table 50). This suggests that the high density values observed in summer are a result of high invertebrate abundance for a subset of taxa, rather than an overall increase in invertebrate population abundance across a wide range of taxa.

3.3.2.4. Richness (# of Families)

Mean family richness results show no apparent seasonal trend, with 33 to 73 families recorded in each sample.

3.3.2.5. Canadian Ecological Flow Index

Mean CEFI values were consistent throughout the sampling season, ranging from 0.33 to 0.35, except on August 13 when the CEFI value was 0.31. Low CEFI values are described as <0.25 (Armanini *et al.* 2011) and therefore all CEFI values in the Quinsam River were greater than this threshold. The consistent CEFI values throughout the sampling period suggest that any effects of flow on the invertebrate ecosystem are not seasonally influenced.

Table 50. Quinsam River invertebrate drift mean density (individuals/m^3), biomass (mg/m^3), Simpson's diversity index (1-λ, family level), richness (# of families) and CEFI index. Note that in 2014 each drift net was analyzed separately, while in 2015 all five nets per site were combined into one sample.

All Taxa (Aquatic, Semi-Aquatic, and Terrestrial)														
Year	Sample Date	Number of Replicates	Density (#/m^3)			Biomass (mg/m^3)			CEFI Index†			Richness (# of Families)‡	Simpson's Diversity Index (1-λ)‡
			Mean	S.D.	C.V.	Mean	S.D.	C.V.	Mean	S.D.	C.V.		
2014	23-May	5	0.96	0.12	12.52	0.20	0.04	21.16	0.37	0.01	2.83	66	0.84
	04-Jun	5	2.74	0.22	8.06	0.36	0.06	15.97	0.36	0.02	4.50	66	0.80
	12-Jun	5	2.58	0.30	11.72	0.21	0.07	31.35	0.36	0.01	2.36	65	0.74
	18-Jun	5	3.12	0.64	20.61	0.17	0.06	36.87	0.36	0.01	1.62	63	0.76
	27-Jun	5	2.47	0.45	18.36	0.14	0.05	33.23	0.35	0.01	2.09	70	0.81
	22-Jul	5	4.19	0.73	17.47	0.14	0.02	14.07	0.36	0.00	0.64	60	0.82
	19-Aug	5	6.88	3.26	47.47	0.16	0.02	15.66	0.35	0.01	1.85	59	0.66
	24-Sep	5	2.36	0.85	35.86	0.09	0.03	35.64	0.32	0.01	3.35	52	0.81
	04-Nov	5	0.65	0.22	33.38	0.07	0.02	33.45	0.33	0.01	1.57	80	0.93
2015	12-May	1	1.38	-	-	0.21	-	-	0.35	-	-	52	0.78
	17-Jun	1	4.41	-	-	0.19	-	-	0.33	-	-	50	0.65
	09-Jul	1	6.38	-	-	0.32	-	-	0.34	-	-	61	0.74
	16-Jul	1	2.52	-	-	0.28	-	-	0.35	-	-	73	0.81
	23-Jul	1	4.38	-	-	0.12	-	-	0.33	-	-	53	0.76
	29-Jul	1	4.58	-	-	0.14	-	-	0.34	-	-	39	0.64
	13-Aug	1	4.34	-	-	0.08	-	-	0.31	-	-	42	0.78
	16-Sep	1	1.71	-	-	0.12	-	-	0.35	-	-	33	0.79
	14-Oct	1	2.07	-	-	0.12	-	-	0.34	-	-	50	0.87

† Calculation considers only aquatic taxa

‡ Replicates were averaged where applicable prior to calculating metric

3.3.2.6. Top Five Families Contributing to Biomass

A summary of the top five families contributing to biomass in the invertebrate drift community on each sample date is provided in Table 51. Note that in some instances, a taxonomic level higher than family is listed (e.g., Ephemeroptera, Trichoptera, Lepidoptera), as this was the lowest taxonomic level enumerated. The invertebrate community was dominated (in terms of biomass) by true flies (Chironomidae and Simuliidae) and mayflies (Baetidae, Ephemeroptera, and Leptophlebiidae, and Ameletidae). Caddisflies (Limnephilidae, Hydropsychidae, and Trichoptera), stoneflies (Plecoptera and Capniidae), mites (Sperchontidae), beetles (Chrysomelidae, Latridiidae, and Chrysomeloidea), true bugs (Aphididae, Pentatomidae, and Cercopidae), wasp (Vespidae) and butterfly (Lepidoptera) were also occasionally within the top five families during sampling.

Considering all sample dates, Baetidae (mayflies) was among the top contributor to biomass on seven of the nine sample dates, with the contribution ranging from 7.9% to 25.2%. Baetidae was the top contributor on June 17, contributing 25.2% to the total biomass.

Chironomidae (true flies) was among the top contributors to biomass on all nine sample dates. Chironomidae was the top contributor for three dates in mid-summer (July 23 to August 13) contributing 17.1% to 24.4% of the biomass.

Chrysomelidae (beetles) was among the top contributors on three dates in summer (July 9 to July 23), and was the top contributor on July 16, contributing 34.1% of the biomass.

Simuliidae was among the top contributors to biomass on eight of the nine sampling days, and was the top contributor in the spring (May 12) and late summer (August 13 and September 16), with contributions ranging from 13.7% to 39.0%.

Plecoptera (stoneflies) was the top contributor to biomass on July 9 (20.7%), but was not among the top contributors on any other sampling dates.

Table 51. Quinsam River: top five families contributing to invertebrate drift biomass.

Quinsam River	12-May-15	Quinsam River	17-Jun-15	Quinsam River	9-Jul-15	Quinsam River	16-Jul-15	Quinsam River	23-Jul-15
Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass
Simuliidae	25.9	Baetidae	25.2	(Plecoptera)	20.7	Chrysomeloidea	34.1	Chironomidae	19.3
Limnephilidae	19.6	Chironomidae	24.0	Chironomidae	13.1	Baetidae	11.4	Baetidae	12.8
Baetidae	9.9	(Lepidoptera)	17.9	Chrysomelidae	11.1	Vespidae	10.5	Chrysomeloidea	9.4
Chironomidae	7.5	Simuliidae	9.2	Baetidae	7.4	Chironomidae	6.7	Simuliidae	7.4
(Ephemeroptera)	7.4	Aphididae	3.6	Latridiidae	6.3	Simuliidae	6.1	(Trichoptera)	7.0
Sum	70.33	Sum	79.83	Sum	58.62	Sum	68.74	Sum	55.82

Key
Mayflies
Stoneflies
Caddisflies
True Flies
Mites
Beetles
True Bugs
Wasp
Butterfly

Quinsam River	29-Jul-15	Quinsam River	13-Aug-15	Quinsam River	16-Sep-15	Quinsam River	14-Oct-15
Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass	Family	% of Total Biomass
Chironomidae	24.4	Chironomidae	17.1	Simuliidae	39.0	Simuliidae	13.7
Baetidae	18.3	Simuliidae	14.6	Chironomidae	15.5	Chironomidae	12.9
Simuliidae	15.9	Pentatomidae	9.3	(Ephemeroptera)	13.7	Capniidae	8.4
Limnephilidae	5.5	Baetidae	9.3	Ameletidae	6.3	Cercopidae	8.2
Leptophlebiidae	4.4	Hydropsychidae	7.9	Sperchontidae	4.7	(Ephemeroptera)	7.2
Sum	68.54	Sum	58.17	Sum	79.20	Sum	50.47

3.3.2.7. Multivariate Analysis

The results of the cluster analysis performed on the Bray-Curtis similarity matrices (generated from density data) are provided in the dendrograms in Figure 35. Data from the highest available taxonomic resolution were analyzed using density data from sample date. Black lines indicate branching of groups with a dissimilar community composition (taxa present and densities at which they are present) at a 5% significance level (SIMPROF test); red lines denote groups that are not significantly different in their community composition at a 5% significance level (SIMPROF test). The analyses indicate that there is a seasonal trend in the invertebrate drift community composition. Samples collected in fall (October 14, 2015 and November 4, 2014) have the least similar community composition compared to the other sample dates, followed by samples collected in spring (May 12, 2015, May 23, 2014, and June 4, 2014) and early fall (September 16, 2015). Samples collected in the summer (June 12 to August 19, 2014 and June 17 to August 13, 2015) are not significantly different from each other.

The multi-dimensional scaling (MDS) on the Bray Curtis similarity matrices (generated from density data at the highest taxonomic resolution available in the dataset) is shown in an ordination plot in Figure 36, where points that are close together represent samples that are very similar in community composition and points that are far apart correspond to samples with very different community composition. MDS plots were generated using density data from each sample date. The MDS generated has a stress value of 0.12. Stress values ≤0.1 correspond to a good ordination with negligible possibility of a misleading interpretation with respect to differences in community composition among samples (Clarke and Warwick 2001). Stress values between 0.1 and 0.2 provide a useful 2-dimensional MDS representation as long as there is agreement in groupings between dendrograms (Figure 35) and the MDS plot (Figure 36) (Clark and Warwick 2001). The similarities displayed in Figure 36 are supported by those in the dendogram (Figure 35). Conclusions drawn regarding seasonal trends in community similarities are therefore the same.

Figure 35. Quinsam River cluster analysis result on the Bray-Curtis similarity matrix by date.

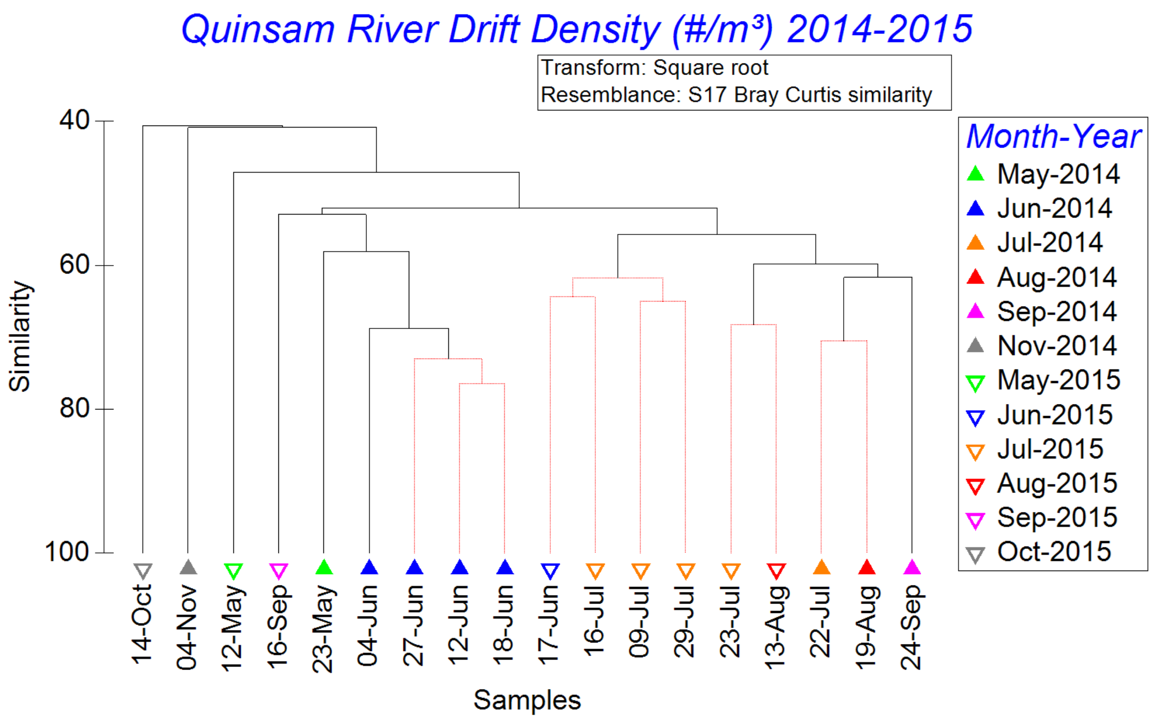
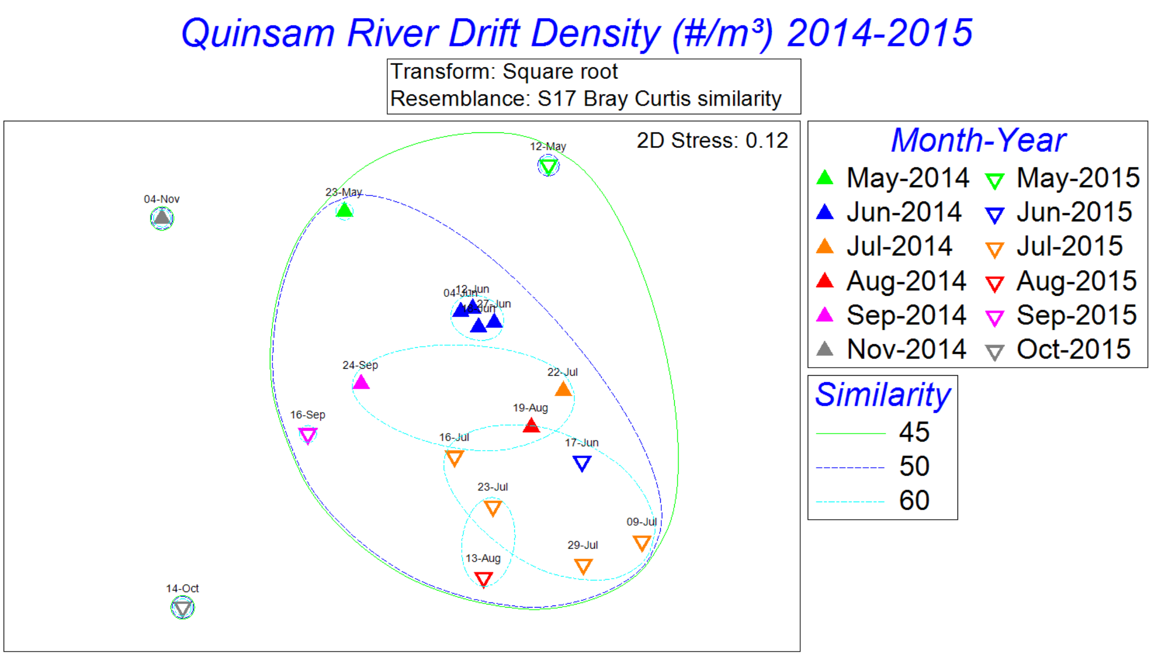


Figure 36. Quinsam River non-metric multi-dimensional scaling ordination plot by date.



3.3.3. Comparison of kick net and drift net sampling methods

Invertebrates collected using kick net sampling consisted almost exclusively of aquatic taxa (99.61% and 100.00% in the Salmon River and Quinsam River, respectively; Table 52). The kick net method involves holding the collection net completely under the stream surface for three minutes, so the dominance of aquatic taxa is to be expected. Invertebrates collected using drift net sampling were still dominated by aquatic taxa, but to a lesser extent (85.74% and 74.97% in the Salmon River and Quinsam River, respectively; Table 52). Drift nets are installed with the top of the net above the stream surface, so that invertebrates carried on the surface are collected. These invertebrates are more likely to have entered the stream from terrestrial or semi-aquatic (riparian) habitats.

Table 52. Contribution of invertebrate taxa to total biomass by habitat type.

Habitat	Relative Contribution to Total Biomass			
	SAM-Drift	SAM-Kicknet	QUN-Drift	QUN-Kicknet
Aquatic	85.74	99.61	74.97	100.00
Semi-Aquatic	5.43	0.22	19.25	0.00
Terrestrial	8.83	0.17	5.78	0.00

The contribution of individual families to invertebrate biomass differed between the two sampling methods. In the Salmon River, Baetidae (mayflies) and Chironomidae (true flies) were top contributors using both methods, but all other taxa differed (Table 53a). In the Quinsam River, Chironomidae (true flies) accounted for the majority of the biomass based on drift net sampling, while Hydropsychidae (caddisflies) was the dominant taxon based on kick sampling (Table 53b).

Table 53. Top five families contributing to invertebrate biomass collected from a drift net and kick net in a) Salmon River, and b) Quinsam River.

a)

Salmon River	Drift net	Salmon River	Kick net
Family	% of Total Biomass	Family	% of Total Biomass
Simuliidae	38.6	Chironomidae	16.4
Chironomidae	25.5	Heptageniidae	14.8
Baetidae	4.6	Baetidae	11.9
Ceratopogonidae	3.8	Ameletidae	8.6
Aphididae	3.1	Hydropsychidae	7.8

b)

QUN	Drift	QUN	Kicknet
Family	% of Total Biomass	Family	% of Total Biomass
Simuliidae	39.0	Hydropsychidae	16.5
Chironomidae	15.5	Tipulidae	14.5
(Ephemeroptera)	13.7	(Trichoptera)	13.7
Ameletidae	6.3	Chironomidae	7.3
Sperchontidae	4.7	Lumbriculidae	5.9
Mayflies	True Flies	Caddisflies	Mites
True Bugs	Aquatic worms		

4. DISCUSSION

A summary of the current status of each of the six hypotheses is provided below, including brief details of analyses that should be undertaken to formally test each hypothesis when data for more years are available. Such analysis should be trialled approximately mid-way through the study. Further details of the proposed data analysis methods are outlined in Section 1.4 and in Abell *et al.* (2015a).

$H_0$1: Annual population abundance does not vary with time (i.e., years) over the course of the Monitor

Although this study is at an early stage, JHTMON-8 results and historical data compiled so far show considerable inter-annual variability in juvenile fish abundance. Key results from Year 2 monitoring related to this hypothesis include:

- Adult steelhead counts were generally higher than in 2014, although counts were low relative to historical counts. The total count for the primary index reach (Lower Index; 72 fish) was substantially higher than in 2014 (39 fish; the lowest recorded count), yet it was still approximately equal to only the 25th percentile of historical counts (see Section 3.1.1);
- Juvenile steelhead fry abundance in the Salmon River (10.5 fry per 100 m^2 (FPU)) was the lowest yet recorded (1998–2015), and considerably lower than the target of 60 FPU set by provincial biologists. This low abundance at least partly reflects the relatively low adult returns, as indicated by the low adult counts in spring 2015 (Figure 10). However, the ratio of FPU to the peak corresponding adult count was also below average (Figure 19), suggesting that recruitment per spawner was relatively low and, therefore, below average environmental conditions may have also contributed to low fry density. Abundance was substantially lower upstream of the diversion (8.9 FPU) compared with downstream of the diversion (62.1 FPU), although the higher value largely reflects a particularly high count at a single site (see Section 3.1.2);
- Estimated juvenile Coho Salmon biomass in the Salmon River in 2015 was comparable to estimates in 2014 at sites downstream of the diversion, although biomass estimates at sites upstream of the diversion were lower in 2015. Juvenile Coho Salmon sampled in 2015 were predominantly (> 99%) aged 0+ (see Section 3.1.3);
- Salmonid escapement data for 2014 (i.e., Year 1) show that Pink Salmon escapement was particularly high, especially in the Quinsam River where Pink Salmon escapement (1.42 million) was the highest on record. Coho Salmon escapement exceeded the median historical counts on both rivers, while Chinook Salmon escapement was lower than historical mean and median counts on both rivers (see Section 3.1.4); and
- Despite the record high Pink Salmon escapement in 2014, estimates of out-migrating Pink Salmon fry in 2015 were approximately eight times lower than the previous year, suggesting poor spawning and/or incubation success (see Section 3.1.5). Coho Salmon smolt abundance in 2015 was comparable to 2014 although wild Chinook Salmon fry abundance was estimated to be ~97% lower in 2015 than in 2014.

Proposed analysis methods to examine trends in juvenile fish abundance are described in Abell *et al.* (2015a, b). Analysis should commence approximately mid-way through the monitor. This will include analysis to attempt to derive satisfactory spawner-recruitment relationships for priority species. Such analysis will help to examine whether inter-annual variability in abundance is related to factors that can be influenced by BC Hydro operations, or whether variability is due to factors such as harvest and marine productivity that are unrelated to the freshwater environment. It is currently unknown whether it will be possible to derive satisfactory relationships; if not, the potential influence of variability in escapement should still be considered qualitatively, as failure to do so can lead to misleading inferences about the role of environmental factors in driving population fluctuations (Walters and Ludwig 1981).

Historical data have now been provided for the Quinsam River Hatchery salmon counting fence for 1996–2013, which is the period for which digital records are available (Fortkamp, pers. comm. 2016). We plan to include these historical data when presenting data in all future JHTMON-8 monitoring reports to provide greater context for variability in juvenile fish abundance. Counts were also made prior to this since the 1970s, although data are currently only available in hard copy (Fortkamp, pers. comm. 2016). Given that adult escapement has been estimated annually since 1957 for the Quinsam River (Figure 24), we suggest that these older data are compiled and stored in digital format to support analysis of variability in smolt to spawner ratios that will help to test H_06. We anticipate that this task can be completed within the scope of the JHTMON-8 program by an LKT technician although we plan to first discuss this task further with hatchery staff to clarify the resources required.

Data have yet to be compiled by DFO for historical Salmon River juvenile Coho Salmon sampling; however, this is an ongoing priority for DFO and we expect that these data will be available to support JHTMON-8 analysis at a later stage of the program (Anderson, pers. comm. 2015).

Juvenile fish sampling on the Salmon River was scheduled to target periods with base flow conditions, with sampling dates adjusted in response to changes in flow. However, rainfall events during mid to late September meant that relatively high flow conditions occurred at some sites during juvenile Coho Salmon and steelhead sampling in Year 2 (Figure 2; Table 20; Table 26). Sampling during elevated flows has potential to bias results. Specifically, sampling during higher flows is expected to potentially depress fish density due to fish moving from a site into new habitats (i.e., the abundance of fish at a site declines), or due to increased wetted width (i.e., the abundance at a site is unchanged but fish are dispersed over a wider area). We expect that high flow conditions had some influence on catch data during Year 2, although inspection of the data does not show clear differences in results associated with variability in flows. For example, the highest density of juvenile Coho Salmon (at SAM-BS06; Table 27) was observed on the date with highest discharge (Table 26). Similarly, the lowest abundance of juvenile steelhead measured upstream of the diversion (0 FPU at SAM-EF05) was recorded on a date with lower discharge than on the days when the remaining upstream sites were sampled. This likely reflects that specific site boundaries (i.e., where the stop nets are placed) are modified each year to ensure that the most representative habitats are sampled, based on the flow conditions and channel morphometry present on the day. Nonetheless, it is important that crews continue to undertake sampling during the most appropriate flow conditions possible. Final analysis after Year 10 should also examine potential effects due to flow conditions and account for any bias accordingly.

H_02: Annual population abundance is not correlated with annual habitat availability as measured by Weighted Usable Area (WUA)

Weighted Usable Area (in m^2) provides an index of habitat availability that is calculated using relationships developed between flow and the area of different habitats (Lewis *et al.* 2004). The metric is weighted based on Habitat Suitability Index scores; these provide a relative measure (between 0 and 1) of the suitability of a particular habitat for the species and life stage of interest.

To test this hypothesis, it will be necessary to analyze fish abundance data collected during this study, in concert with WUA determined as part of separate studies to derive relationships between habitat and flow for sites on the Salmon and Quinsam rivers. Specifically, JHTMON-6 will involve deriving flow-habitat relationships for the Salmon River, whereas results of work already undertaken during the WUP process can be used to provide information about flow-habitat relationships in the Quinsam River mainstem downstream of the diversion (BC Hydro 2013). A study plan for JHTMON-6 is currently being finalized, with field work expected to commence in 2016.

Analysis to test this hypothesis should be undertaken separately for individual species and watersheds. Initially, analysis should focus on the ten-year period of the monitor. It will subsequently be valuable to also consider historical data, although this will depend on whether it is deemed appropriate to hindcast the flow-habitat relationship using historical flow data.

$H_0$3: Annual population abundance is not correlated with water quality

Year 2 water quality results were generally consistent with Year 1 data. These show that measurements of some water quality variables were, at times, outside of the preferred ranges for fish species present in the watersheds. Specifically, water temperatures that exceeded guideline temperatures for suitable salmonid rearing conditions were recorded on both rivers, while dissolved oxygen concentrations less than the provincial guideline for the protection of buried embryo/alevin were recorded at times during the growing season. The low dissolved oxygen measurements were during periods when there was potential for adverse effects on Pink Salmon, Chinook Salmon and steelhead incubation.

The historical review of water quality data undertaken during Year 2 provided valuable information that will help to test this hypothesis (Dinn *et al.* 2016). Readers are referred to the review in Appendix A for full details; however, key tasks and findings were:

- As part of the review, water quality data relating to nutrient enrichment monitoring in the Salmon River watershed (1989–2015) were collated and provided by BCCF. These data can be used to support analysis to test $H_0$3 and $H_0$5 (related to food availability);
- Temperature data collected in the Salmon River (Water Survey of Canada, BCCF) and the Quinsam River (Quinsam River Hatchery) were analyzed. This provided information on how water temperature varies spatially within the watersheds, which had been identified as an uncertainty (Abell *et al.* 2015a, b). Historical data (1999–2014) collected at two sites on the Quinsam River downstream of the JHTMON-8 index site were analyzed and compared with optimum temperature ranges for different life stages. A key result was the occurrence of undesirably warm water temperatures during the rearing life stage of numerous species, most

notably Chinook Salmon. Also, undesirably warm water temperatures were found to occur frequently during the migration and spawning life stages of Pink Salmon; and

- The scope and key findings of ongoing biweekly monitoring conducted by Environment Canada at the mouth of the Quinsam River were reviewed. This showed that results of this monitoring program have potential to support JHTMON-8 objectives by providing information about the potential for adverse water quality effects associated with industrial activities, and providing information to evaluate longitudinal trends in water quality of the river.

The three proposals to improve the study from the review are presented in Section 5.2 below. In addition, we also propose that analysis is undertaken in future years to characterize the relationships between air and water temperature measurements for each stream. Specifically, we propose that, each year, the correlation between air and water temperatures is quantified separately for each stream. For the five-year and ten year reports, we then propose that the analysis is updated with all JHTMON-8 monitoring data to date, with inferences then drawn about the relative sensitivity of water temperatures in each stream to changes in air temperature. Where applicable, this will be supported by reference to other studies where applicable (e.g., Moore 2006). This analysis will provide insight into the relative importance of a key variable (air temperature) for controlling water temperature. This can be used to assess whether additional analysis should be undertaken to further examine other potential controls on water temperature. This could help to understand how diversion flows influence water temperatures and, potentially, how diversion operations could be managed to mitigate any adverse temperature effects.

$H_0$4: Annual population abundance is not correlated with the occurrence of flood events

Hydrologic data to test this hypothesis will be obtained from the Water Survey of Canada for the discharge gauges in both watersheds (see Map 2 and Map 3). We propose to use discharge records to quantify a range of hydrologic metrics (e.g., see indicators in Table 54) that can be analyzed in conjunction with fish abundance data to test this hypothesis. We propose that the main component of this analysis will be undertaken at the end of the monitor when a complete dataset is available. However, it will be beneficial to start compiling data and identifying appropriate metrics at an earlier stage. The Salmon River Desktop Review (Abell et al. 2015a) outlined ten data analysis tasks to be completed during the course of JHTMON-8, with the expectation that one task will be completed each year. The task identified for Year 3 was: "Collate historical discharge data and quantify a range of Indicators of Hydrologic Alteration". We propose that this preliminary analysis to support *$H_0$4* testing is conducted for both the Salmon River and Quinsam River watersheds in Year 3.

Although quantitative analysis has therefore not yet been undertaken to examine the effects of floods, qualitative observations during 2015 indicate that major flood events may have significant negative effects on fish abundance in the study watersheds. In the second week of December 2014, major flooding occurred throughout central eastern Vancouver Island. Instantaneous discharge peaked in the middle reaches of the Salmon River[2] at 380 m^3/s. This discharge has only been exceeded during one year in the period 1960–2014 (WSC 2016). Similarly, instantaneous discharge peaked at 111 m^3/s near the mouth of the Quinsam River[3], where maximum annual discharge ≥ 110 m^3/s has only been recorded during four years in the period 1957–2014 (WSC 2016).

As discussed in Section 3.1.5, Pink Salmon fry abundance in the Quinsam River was low in 2015 relative to a record high estimate of adult abundance in 2014. Therefore, it is possible that high water velocities associated with the major high flow event caused scouring and loss of eggs during the incubation stage; this hypothesis is strongly supported by Quinsam River Hatchery staff, based on their personal observations of erosion during the high flow periods (Fortkamp, pers. comm. 2016). It can also be speculated (but with less certainty) that the high flows in December 2014 affected juvenile fish abundance measured in the Salmon River during 2015. Specifically, it is plausible that high flows impeded the upstream migration of adult Coho Salmon during 2014, possibly accounting for the low abundance of Coho Salmon fry upstream (but not downstream) of the diversion, relative to the previous year (see Section 3.1.3). The proposed analysis to test $H_0 4$ should help to clarify the potential for such effects, and we recognize that alternative factors could account for the suspected low incubation success, e.g., superimposition of redds due to high density of spawning fish.

Table 54. Characteristics of hydrologic variability quantified by Indicators of Hydrologic Alteration (Richter *et al.* 1996).

Characteristic	Example indicator
Magnitude	Maximum annual daily mean discharge
Timing	Date of annual maximum discharge
Duration	Annual mean duration of flood pulses
Frequency	# of flood pulses per year
Rate of change	Mean of absolute differences between daily mean discharge measurements

$H_0 5$: Annual population abundance is not correlated with food availability as measured by aquatic invertebrate sampling

So far, only two years of invertebrate drift data have been collected in either watershed and, therefore, data for further years are required before relationships between aquatic invertebrate drift and fish abundance can be examined. However, analysis undertaken by BCCF summarized in the

[2] At Water Survey of Canada gauge 'Salmon River Above Memekay River' 08HD007 (WSC 2016). Shown on Map 2.

[3] At Water Survey of Canada gauge 'Quinsam River Near Campbell River' 08HD005 (WSC 2016). Shown on Map 3.

background water quality review (Dinn *et al.* 2016; Appendix A) indicates that this null hypothesis can be rejected with regards to juvenile steelhead in the Salmon River watershed. Although, aquatic invertebrate sampling has not been previously undertaken in the Salmon River watershed, analysis of data collected during nutrient enrichment monitoring shows that fertilization rate was positively correlated with fry mass, smolt length and smolt abundance (Pellett 2011). Research elsewhere has shown significant increases in macroinvertebrate biomass following stimulation of primary productivity by stream nutrient enrichment (Johnston *et al.* 1990, Kohler *et al.* 2008).

Future analysis should focus on using metrics of invertebrate biomass and density as independent variables. Analysis should be completed once ten years of data have been collected. Analysis should initially be undertaken to test whether there are relationships between annual metrics of invertebrate biomass/density during the growing season, and juvenile recruitment (normalized to spawner abundance if applicable) for priority species that rear in the streams during the growing season (e.g., Coho Salmon and steelhead). Appropriate statistical techniques include regression and correlation analysis. Invertebrate community composition should also be considered as it relates to food quality; further discussion of planned analysis is presented in Abell *et al.* 2015a. As with water quality, the study is currently premised on the assumption that invertebrate drift measured at a single index site is representative of conditions experienced by fish in the wider watershed.

$H_0$6: Annual smolt abundance is not correlated with the number of adult returns (Quinsam River)

No analysis has been undertaken to test this hypothesis at this time; this hypothesis will be tested during later analysis to determine whether robust spawner-recruitment relationships can be derived (see discussion of $H_0$1 above). Initial analyses could commence approximately midway through the 10-year study and should incorporate historical data to maximize the sample sizes available. As discussed above, historical data from the Quinsam River salmon counting fence were obtained during Year 2 and we intend to include these in future JHTMON-8 monitoring reports.

5. PROPOSALS TO IMPROVE THE STUDY IN FUTURE YEARS

5.1. Status of Proposals in the Year 1 Monitoring Report

Table 55 summarizes the current status of proposals[4] made in the Year 1 Monitoring Report to improve the study in future years (Abell *et al.* 2015b). Only two of the ten proposals remain underway. The first of these (#1) relates to the need to obtain historical data and DFO has confirmed that the outstanding data are being compiled (Anderson, pers. comm. 2015). The second outstanding proposal (#2) relates to the inclusion of historical water quality data collected by BCCF

[4] These were termed "recommendations" in the Year 1 Report; however, we now use the term "proposals" as we recognize that "recommendations" can have a specific meaning in the context of WUP monitoring that is different to our intended meaning. Specifically, these proposals relate to relatively minor methodological changes that we will adopt within the scope of the current project to improve the existing study.

in JHTMON-8 analysis. These data were compiled and provided to LKT this year (see Dinn *et al*. 2016; Appendix A) and are therefore available to be incorporated into JHTMON-8 analysis at a later stage.

Three proposals relating to options to increase the spatial resolution of water quality sampling have been deferred (Table 55). There remain benefits to increasing the number of sites in each watershed that are sampled; however, without additional resources, this would require reducing the current scope in other ways, e.g., by sampling fewer variables. Given that the scope of JHTMON-8 reflects the outcomes of consultation and technical reviews during the Water Use Plan development process, any such changes require careful consideration. We note that the background water quality review undertaken in Year 2 identified a number of opportunities to use existing datasets within the current scope of JHTMON-8 to partly address the issue of limited spatial coverage (see Dinn *et al*. 2016; Appendix A).

Table 55. Current status of proposals made in the Year 1 Monitoring Report to improve the study in future years (Abell *et al.* 2015b).

Number	Environmental component	Proposal to improve the study[1]	Implementation status
1	Fisheries	Historical data should be compiled for the Quinsam River Salmon Counting Fence operations and the Salmon River juvenile Coho Salmon sampling to maximize the extent of data available to test $H_0 1$.	Underway. Historical data from the Quinsam River salmon counting fence have been provided for the period 1996-2013. Older data in hard copy could provided if resources are provided to assist with digitizing. Historical juvenile Coho data have been requested from DFO and this is currently being processed.
2	Water quality	Data (predominantly nutrient and benthic chlorophyll *a* concentrations) collected by BCCF as part of the ongoing nutrient enrichment monitoring program in the Salmon River watershed should be explicitly considered when testing $H_0 3$. These data could also provide information to test $H_0 5$ that relates to food abundance.	Underway. Data were compiled and reviewed during Year 2 as part of the review of historic data. This included developing a plan to analyze data to test JHTMON-8 hypotheses.
3		A brief desktop review should be undertaken for the Quinsam River watershed; the review should describe data sources and compile and summarize available water quality monitoring data.	Completed in Year 2
4		Increase the spatial resolution of water quality sampling - option 1: Establish more sites to monitor water temperature near-continuously using in situ probes (e.g., a further three sites in each watershed).	Deferred
5		Increase the spatial resolution of water quality sampling - option 2: Add a single control site in the upper watershed of both rivers, upstream of the diversion infrastructure.	Deferred
6		Increase the spatial resolution of water quality sampling - option 3: Also undertake water quality sampling at individual (although not necessarily all) fish sampling sites in the Salmon River watershed, e.g. add two further sites upstream of the diversion.	Deferred
7		Modify the suite of water quality parameters by omitting TGP.	Completed in Year 2
8		Use annual temperature records to analyze mean weekly maximum temperatures in the context of optimal ranges for individual species and life stages.	Completed in Year 2
9	Invertebrate drift	The month that is sampled weekly should be rotated in Year 2 to July, with the remainder of the months sampled monthly.	Completed in Year 2
10		Develop a method to avoid bias in biomass measurements due to large bodied individuals.	Completed. Biomass to be calculated with and without large bodied individuals as necessary. Issue not encountered in Year 2.

1. Termed "recommendation" in the Year 1 Report.

5.2. Updated JHTMON-8 Proposals to Improve the Study

An updated list of proposals to improve the study is presented in Table 56. This reflects the progress made regarding proposals from Year 1 (discussed above), and proposals based on Year 2 results that are discussed in Section 4, or presented in the background water quality review (Appendix A). Proposals made in the background water quality review relate to work proposed for the end of the monitor, although they will be tracked in future monitoring reports to ensure that they are carried through to Year 10.

Table 56. Proposals to improve future JHTMON-8 data collection and analysis. See Table 55 for status of outstanding proposals from Year 1.

Number	Environmental component	Proposal to improve the study	Added in Year 1 or 2?
1	Fisheries	Historical data (1996–2013) from Quinsam River Salmon Counting Fence operations that were provided in Year 2 should be presented alongside data collected during the JHTMON-8 program.	2
2		Outstanding historical data (1970s-1995) from the Quinsam River Salmon Counting Fence operations should be collated and digitized (currently only available in hard copy).	2
3		Historical Salmon River juvenile Coho Salmon abundance data collected by DFO should be quality assured and compiled.	1
4	Water quality (based on background review; Dinn *et al*. 2016)	Future JHTMON-8 analysis should incorporate water quality data collected by BCCF to reflect the influence of fertilization in the Salmon River watershed.	1
5		Ongoing analysis of Quinsam River water quality data undertaken by Environment Canada should be reviewed at the end of the JHTMON-8 program.	2
6		Analysis of water temperature data collected by the Quinsam River Hatchery should be undertaken as part of JHTMON–8.	2
7	Water quality (other)	Analyze relationships between air and water temperatures for each watershed.	2
8	Invertebrate drift	The month that is sampled weekly should be rotated in Year 3 to August, with the remainder of the growing season sampled monthly.	2
9	Hydrology	Historical discharge records for gauges maintained by Water Service of Canada should be compiled. Appropriate metrics to use in analysis to test $H_0 4$ (regarding floods) should be identified.	2

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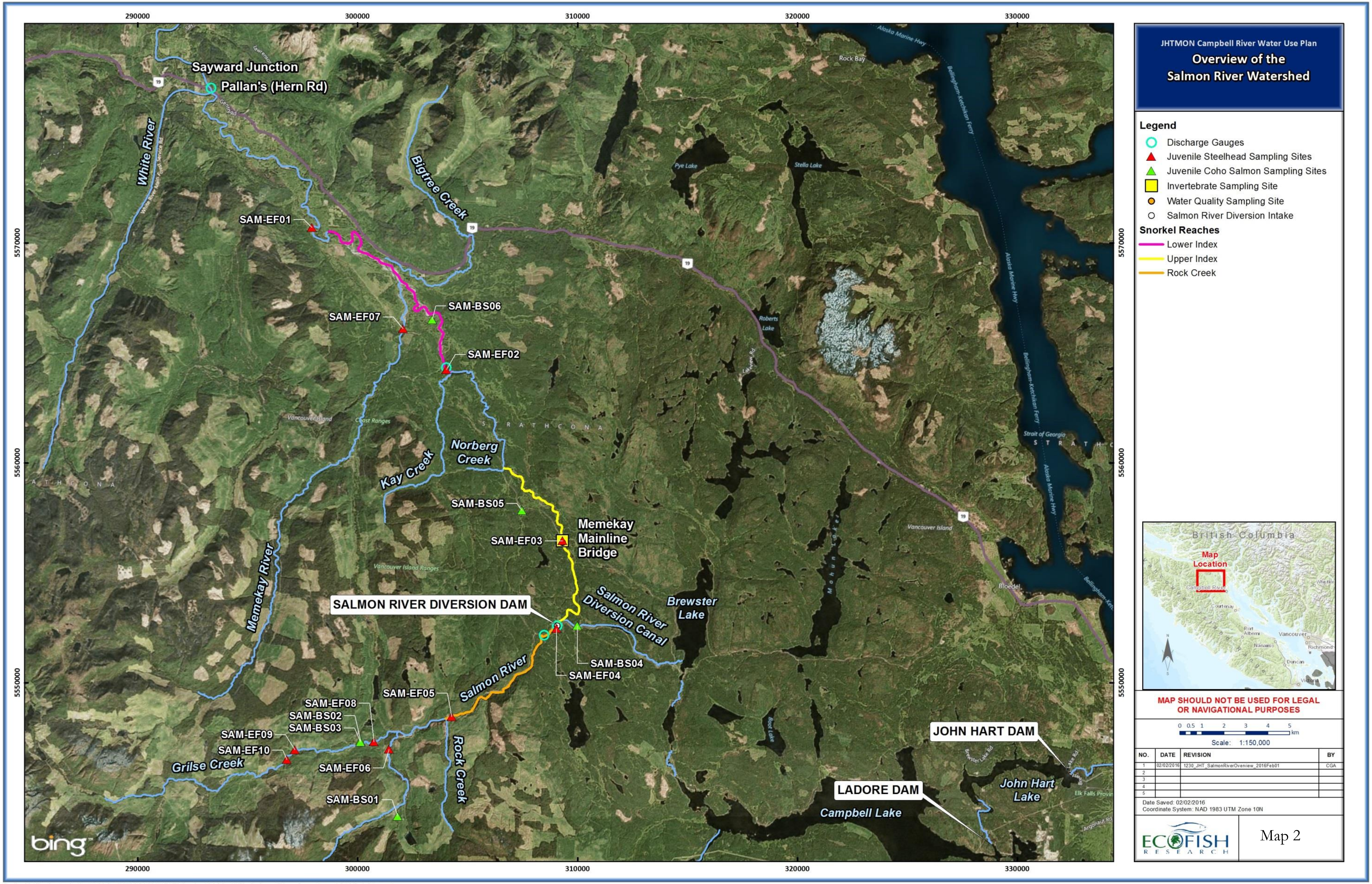
PROJECT MAPS



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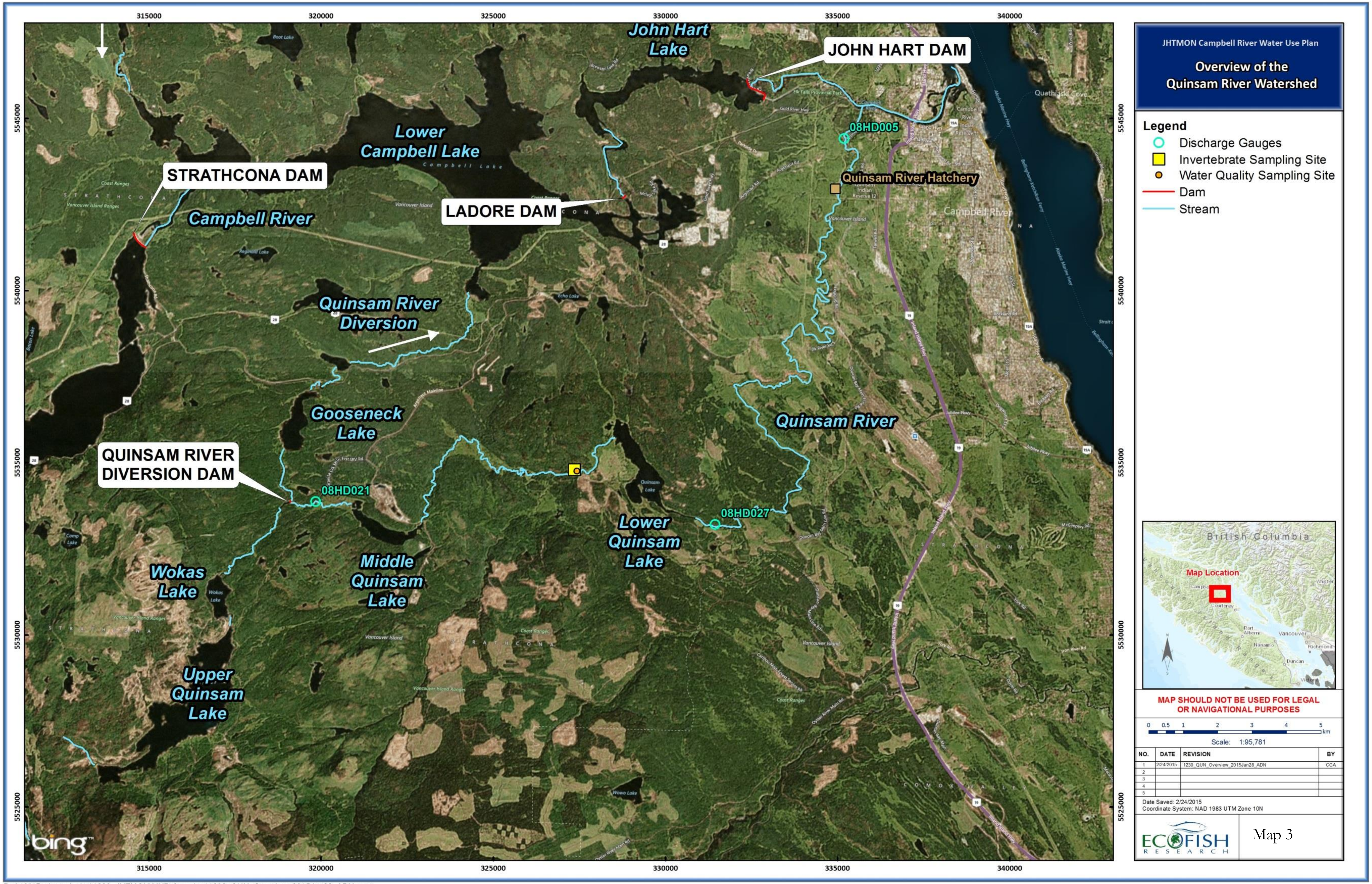

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APPENDICES

Appendix A. Compilation and Review of Historical Water Quality Data for the Salmon and Quinsam Rivers.

JHTMON-8:

Compilation and Review of Historical Water Quality Data for the Salmon and Quinsam Rivers

Prepared for:

BC Hydro
6911 Southpoint Drive
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October 12, 2016

Prepared by:

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Certification:

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Disclaimer:

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EXECUTIVE SUMMARY

The *Salmon River and Quinsam River Smolt and Spawner Abundance Assessments* (JHTMON-8) is one of the monitoring studies that are part the overall monitoring program for the Campbell River WUP. The study commenced in 2014 and includes monitoring fish abundance and environmental factors in the two watersheds for a total of ten years. The study aims to test six null hypotheses that are designed to examine if and how environmental factors influence annual population abundances of primary fish species of interest. The third null hypothesis ($H_0 3$) states:

Annual population abundance is not correlated with water quality

To test this hypothesis, water quality data are being collected at a single index site on each river.

Following monitoring during Year 1 (2014) of JHTMON-8, it was recommend that a background review of water quality data should be undertaken to compile and review existing water quality data previously identified for the Salmon River watershed (Abell *et al.* 2015a), and to review the status and key findings of existing and historical water quality monitoring in the Quinsam River (Abell *et al.* 2015b). This review has been completed and is presented here. The aims were to identify and collate available data that could support the JHTMON-8 study objectives, and to identify opportunities to incorporate data from other monitoring programs into future JHTMON-8 data analysis.

The review indicated that water quality monitoring has been conducted, or is ongoing, in the Salmon River watershed by British Columbia Conservation Foundation (BCCF) and Environment Canada. Water quality monitoring has been conducted, or is ongoing, in the Quinsam River watershed by the Quinsam River Hatchery, Environment Canada, and Quinsam Coal Corporation.

Data were obtained from all sources with the exception of Quinsam Coal Corporation. Results were summarized and discussed in the context of JHTMON-8 objectives. Monitoring programs most relevant to JHTMON-8 include: water quality data collected by BCCF during nutrient enrichment monitoring in the Salmon River watershed; historical and ongoing water temperature monitoring conducted by Environment Canada (Salmon River) and Quinsam River Hatchery (Quinsam River), and; biweekly water quality monitoring conducted by Environment Canada to examine the effects of industrial activities in the Quinsam River watershed.

Based on our review, we identified one proposal to improve the JHTMON-8 study related to the Salmon River:

Proposal 1: future analysis of factors that influence fish abundance during JHTMON-8 should incorporate the influence of fertilization in the Salmon River watershed.

We made two further proposals in relation to the Quinsam River:

Proposal 2: Ongoing analysis of Quinsam River water quality data undertaken by Environment Canada should be periodically reviewed throughout the duration of the JHTMON-8 program.

Proposal 3: Analysis of water temperature data collected by the Quinsam River Hatchery should continue as part of JHTMON–8.

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1. INTRODUCTION

1.1. Background

The *Salmon River and Quinsam River Smolt and Spawner Abundance Assessments* (JHTMON-8) is one of the monitoring studies that are part the overall monitoring program for the Campbell River WUP.

The JHTMON-8 monitoring program aims to address the following three management questions:

1. What are the primary factors that limit fish abundance in the Campbell River System and how are these factors influenced by BC Hydro operations?
2. Have WUP-based operations changed the influence of these primary factors on fish abundance, allowing carrying capacity to increase?
3. If the expected gains in fish abundance have not been fully realized, what factors if any are masking the response and are they influenced by BC Hydro operations?

To address these management questions, six null hypotheses have been developed that are designed to help examine if and how environmental factors influence annual population abundances of primary fish species of interest. The third null hypothesis ($H_0$3) states:

Annual population abundance is not correlated with water quality

To test this hypothesis, water quality data are being collected at single index sites on both the Salmon and Quinsam rivers. Water quality data collected over the ten-year course of the monitor will be analyzed in association with fisheries data to examine whether there are relationships between trends in population abundance and water quality variables.

In addition to this data collection, a desktop study of the Salmon River watershed (Abell *et al.* 2015a) identified a range of additional water quality datasets collected during historical and ongoing monitoring that could also be used to support the JHTMON-8 study. In particular, data collected during long-term monitoring of nutrient enrichment in the Salmon River by British Columbia Conservation Foundation (BCCF) could provide valuable information to test $H_0$3. These data had not been fully quality assured and compiled when the desktop study was prepared and, therefore, it was recommended that these data be reviewed at a later date as part of the JHTMON-8 study.

Following Year 1 JHTMON-8 monitoring, it was recommend that background water quality data for the Salmon River be reviewed during Year 2. In addition, it was also recommended that the review consider existing and historical monitoring in the Quinsam River. Accordingly, historical water quality data for the Salmon and Quinsam rivers were successfully compiled and reviewed during Year 2 of the JHTMON-8 study. This task is summarized here.

1.2. Objectives of this Review

The review was undertaken with the aims to identify and collate available data that could support the JHTMON-8 study objectives. Given that the JHTMON-8 study is currently in its early stages, the intention was not to conduct detailed analyses, although some data analysis was undertaken within the confines of the resources available.

2. METHODS

We conducted a review based on literature relating to the watersheds (e.g., Burt 2003, Burt 2010), internet searches and communication with professional colleagues to identify existing water quality data for the Quinsam and Salmon rivers. A meeting was held on November 27, 2015 with BCCF to discuss and receive data collected during nutrient enrichment monitoring in the Salmon River watershed. Time for BCCF to collate and quality assure the data was funded through the JHTMON-8 program.

Our review indicated that water quality monitoring has been conducted in the Salmon River watershed by BCCF and Environment Canada. Water quality monitoring has been conducted in the Quinsam River watershed by the Quinsam River Hatchery, Environment Canada, and Quinsam Coal Corporation.

We requested data from data owners and were provided with water chemistry and water temperature data from Environment Canada, the Water Survey of Canada, the Quinsam River Hatchery, and BCCF. Environment Canada and BCCF also provided us with periphyton and/or benthic invertebrate data. In some cases, raw data were not made available but details about the datasets were recorded to provide a complete record of known data sources (Table 1).

Water temperature data collected near-continuously at the Quinsam River Hatchery were analyzed by comparing measured mean weekly maximum water temperatures (MWMxT) with optimum ranges for fish species presented in provincial guidelines (Oliver and Fidler 2001). The MWMxT is an important indicator of the exposure of fish to prolonged periods of warm water temperatures. The guidelines for the protection of aquatic life state "Where fish distribution information is available, then mean weekly maximum water temperatures should only vary + or - 1 degrees C beyond the optimum temperature range of each life history phase (incubation, rearing, migration and spawning) for the most sensitive salmonid species present" (Oliver and Fidler 2001).

Specific parameters sampled, duration of sampling, and sample methods are described in Sections 3 and 4 below. Section 5 summarizes key results and proposal to improve the JHTMON-8 study based on our review.

Table 1. Data sources contacted during the water quality data review.

Data source	Contact	Data type	Data Available?	Data Form	Access Website
Quinsam River					
Environment Canada	Stephanie Strachan	Benthic invertebrates Water chemistry	Yes	Report	http://publications.gc.ca/site/eng/9.694209/publication.html
Environment Canada	NA	Water chemistry	Yes	csv files downloaded from website	http://aquatic.pyr.ec.gc.ca/webdataonlinenational/en/SiteDetails/BC08HD0004/Projects/PYLTM/Regions/0
Quinsam Fish Hatchery	Laurent Frisson Edward Siu	Water chemistry Water temperature	Yes	Excel files	NA
Quinsam Coal	Gary Gould Kathleen Russell	Water chemistry	No	Data sharing requested November 2015. Ecofish sent BC Hydro project leader contact November 9. No response to follow up email from Ecofish November 24.	NA
Salmon River					
BC Hydro		Water chemistry	Yes	Report	NA
Water Services Canada	Lynne Campo	Water temperature (from hydrometric gauges)	Yes	May 2014-November 2015 data is available on real-time website (30 minute intervals). Environment Canada sent Excel files with daily averages.	http://wateroffice.ec.gc.ca/google_map/google_map_e.html?searchBy=p&province=BC&doSearch=Go
British Columbia Conservation Foundation	Kevin Pellett	Water chemistry Periphyton	Yes	Excel files	NA

3. EXISTING WATER QUALITY DATA IN THE SALMON RIVER

3.1. Overview

Water chemistry of the Salmon River has been altered from its background state since the Province (Ministry of Environment) initiated a stream enrichment program in 1989. The purpose of the program was to enhance the growth and survival of juvenile steelhead (*Oncorhynchus mykiss*) and Coho Salmon (*O. kisutch*) through increased periphyton accrual, and subsequent improvement to invertebrate productivity and therefore food supply (Burt 2010). Perrin (1989) described the pre-enrichment water quality of the Salmon River as being typical of East Coast Vancouver Island streams – having exceptional clarity (high transparency), relatively stable pH, and moderate alkalinity. The river was described as nutrient-poor, and has since been categorized as phosphorus limited (Pellet 2014).

Water quality information prior to the fertilization program is limited to data provided in Ptolemy *et al.* (1977) and Lirette *et al.* (1987) that covers the period May to July, and does not include nutrient concentrations (Burt 2010). No data on nutrient concentrations (nitrogen and phosphorus) in the mainstem prior to the fertilization program were found. However, Perrin (1989) reports nutrient concentrations based on sampling in Grilse Creek and other sites in the upper Salmon River watershed in fall 1988.

BCCF conducted a nutrient enrichment and water quality monitoring program in the Salmon River watershed from 1989 to 2015. The number and frequency of sampling sites varied throughout the program; all associated data were provided to Ecofish. The Water Survey of Canada monitors water temperature at two flow gauges in the Salmon River above and below the Salmon River Diversion; Ecofish was provided with average daily temperatures for the monitoring periods (Campo pers. comm. 2015) (Table 2).

Table 2. Water quality data collected in the Salmon River Watershed from 1998-2015.

Data Type	Parameter(s) measured	Site location	Sampling frequency	Sampling method	Period	Data source	Reference	Key findings
Primary productivity	Chlorophyll *a* (periphyton proxy)	Salmon River (8) Grilse Creek (4) Memekay River (3)	Every two weeks during summer	Foam collector plates anchored in river	1998-2015	BC Conservation Foundation	Pellet 2015	Raw data provided by Kevin Pellet (pers. comm. 2015). Results summarized in Pellet 2010, 2011, 2014.
Water chemistry	Nutrients (nitrogen and phosphorus)	Salmon River (8) Grilse Creek (4) Memekay River (3)	Monthly during summer	Grab samples	1998-2015	BC Conservation Foundation	Pellet 2015	Raw data provided by Kevin Pellet (pers. comm. 2015). Results summarized in Pellet 2010, 2011, 2014.
Primary productivity	Chlorophyll *a* (periphyton proxy)	Salmon River (8) Grilse Creek (4) Memekay River (3)	Every two weeks during summer	Foam collector plates anchored in river	1998-2014	BC Conservation Foundation Report	Pellet 2010, 2011, 2014	Primary productivity was measured using chlorophyll *a*, which was elevated in treatment reaches compared to control reaches during years of nutrient enrichment in the Salmon River and Grilse Creek, but not in the Memekay River.
Water chemistry	Nutrients (nitrogen and phosphorus)	Salmon River (8) Grilse Creek (4) Memekay River (3)	Monthly during summer	Grab samples	1998-2014	BC Conservation Foundation Report	Pellet 2010, 2011, 2014	Orthophosphate was elevated in treatment areas compared to the control in nutrient enrichment years, but not in years without nutrient additions. Nitrogen in the Salmon River decreased during treatment years, likely because it was being rapidly consumed by primary producers in the presence of increased phosphorus.
Water temperature	Temperature	Salmon River above Campbell Lake Diversion	30 minutes	Logger on hydrometric gauges	2005-ongoing	Water Survey of Canada	Water Survey of Canada 2015a	Water temperature is similar upstream and downstream of the diversion dam, and at the Ecofish WQ monitoring site.
Water temperature	Temperature	Salmon River below Campbell Lake Diversion	30 minutes	Logger on hydrometric gauges	2010-ongoing	Water Survey of Canada	Water Survey of Canada 2015b	Water temperature is cooler in the Memekay River and Grilse Creek than in the main Salmon River.
Water chemistry	pH Total alkalinity Hardness Conductivity Nutrients	Salmon River mainstem	Various (from literature)	Various (from literature)	1977-1987 1989-1997	BC Hydro Report	Burt 2010	Water clarity is high, pH stable but can be acidic with high precipitation, moderate alkalinity. Both nitrogen and phosphorus could alternately be the limiting nutrients in the Salmon River system.
Water temperature	Temperature	Salmon River mainstem	Various (from literature)	Various (from literature)	1977-1987 1989-1997	BC Hydro Report	Burt 2010	Minimum daily winter temperatures 1^{o}C (bi-monthly winter mean 4^{o}C). Summer temperature range 16-19^{o}C. Mean annual water temperature was 8.5^{o}C. The general growing season for salmonids was 175 days (25 weeks). There is a lack of spatial coverage for temperature data in the Salmon River.

3.2. Summary of Existing Water Quality Data in the Salmon River Watershed

3.2.1. BCCF Nutrient Enhancement and Water Quality Monitoring

3.2.1.1. Overview

BCCF applied fertilizer to the Salmon River watershed from 1989 to 2010, halted fertilization for three years from 2011 to 2013, and then resumed fertilization in 2014 and 2015. There are currently no plans by BCCF to continue the nutrient enhancement or water quality monitoring program. Nitrogen and phosphorus concentrations were monitored during both nutrient-enriched and nonnutrient enriched years. Periphyton accrual was also measured, which provides a direct indicator of primary productivity response to the enrichment. This was monitored by measuring benthic chlorophyll *a* concentrations. Analysis and interpretation of results are discussed in Pellet (2010, 2011, 2014). Most notably, Pellett (2011) presents an analysis of data collected over a twenty year period (1989-2010). This report is summarized in Section 3.3, which also summarizes further reports related to the nutrient enrichment monitoring. These summaries provide further background information to the enrichment program.

Fertilizer application and monitoring predominantly took place in the Salmon River mainstem and two tributaries: Grilse Creek and the Memekay River (Map 1). However, locations and frequency of sampling varied over the years (Table 3) and fertilizer was occasionally applied to other tributaries. Fertilizer was applied throughout the growing season, with application typically commencing in June and ending in September. However, specific timing varied between years, with application start dates ranging from May 12 to August 09, and end dates ranging from August 08 to October 06 (based on 1989–2010 schedules; Pellett 2011). A variety of products was trialed: liquid fertilizer was initially used, before being replaced by solid fertilizer in the mid-1990s, which requires less maintenance, although provides for less precise control of application rates (Pellett 2011).

Table 3. Annual counts of nutrient and benthic chlorophyll *a* (periphyton proxy) samples collected in the Salmon River watershed by BCCF from 1988–2015. C, control; T, treatment.

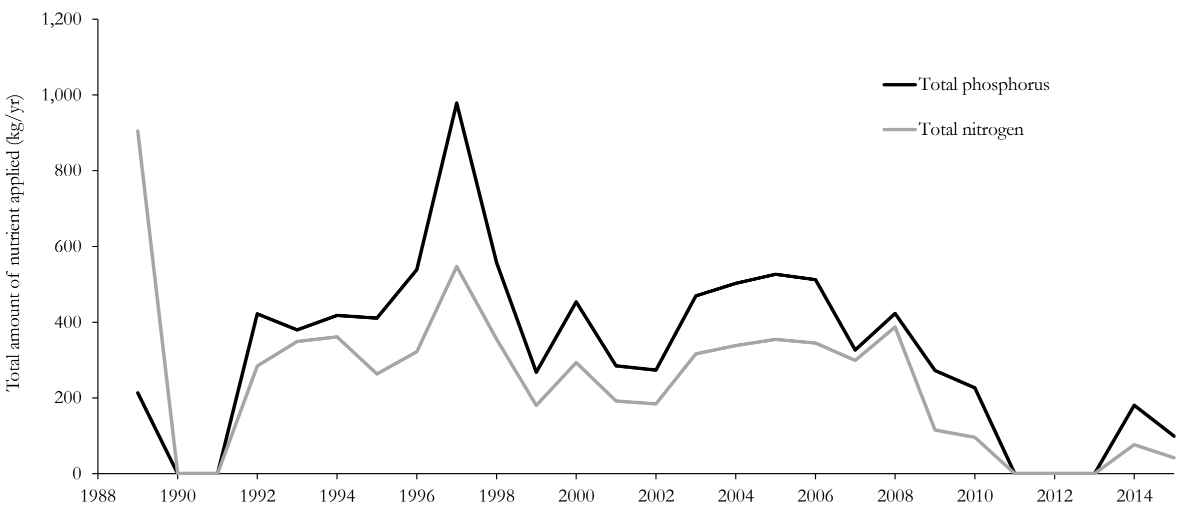
River	Site Name	C/T	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Salmon	WQ-Pallans	T								4, 3	4, 3	4, 3				4, 3	3, 3				3	3	3	3			3			
Salmon	WQ-Bigtree	T								4	4	4											5	6	3		4	3	3	3, 3
Salmon	WQ-Memekay ML	T								5, 3	5, 3	5, 3									3	3					3			
Salmon	WQ-Rock Creek	T										5, 3													2	1				
Salmon	WQ-Salmon Control (Washout)	C								5, 3	5, 3	5, 3				4, 3	3, 3				5, 3	2	5, 3	6	3, 3	1	4	3, 3	3, 3	3, 3
Salmon	WQ-Salmon Control Upper	C																												
Salmon	WQ-Bigtree Side Channel	T										5, 3									3	3	3	3	2		3	3	3	
Salmon	WQ-Smolt Screen																					2	5, 3	6, 3	3, 3	1	4, 3	3, 3	3, 3	3, 3
Grilse	WQ-Lower Grilse	T		5, 3	5, 3	5, 3	5, 3		5, 3																2					3, 3
Grilse	WQ-Upper Grilse (2001-2014)	T		5, 3	5, 3	5, 3	5, 3		5, 3							4, 3	3, 3				5, 3	2, 3	5, 3	6, 3	3	1	4, 3	3, 3	3, 3	
Grilse	WQ-Grilse Control	C	5, 3	5, 3	5, 3	5, 3	5, 3		5, 3							4, 3	3, 3				5, 3	2, 3	5, 3	6, 3	3	1	4, 3	3, 3	3, 3	3, 3
Grilse	WQ-Upper Grilse (2014-2015)	T																												3, 3
Memekay	WQ-Memekay Lower	T																												
Memekay	WQ-Memekay Upper	T														3	3				5	2	5	6	3	1	4	3	3	
Memekay	WQ-Memekay Control	C														3	3				5	2	5	6	3	1	4	3	3	

Samples were collected in the summer (July, August, September). Nutrients generally once per month, and periphyton twice per month.
Black text = periphyton samples
Orange text = nutrient samples

3.2.1.1. Fertilizer loading rates

Fertilizer type, composition and quantity varied over the course of the program (Figure 1). The quantity of fertilizer applied in 1990 is unknown, but nutrient concentration data indicate that fertilizer was applied in relatively high quantities.

Figure 1. Quantity of phosphorus and nitrogen applied at all sites in the Salmon River watershed from 1989 to 2015. Quantities were not recorded for 1990.



3.2.1.2. Chlorophyll *a* and nutrient data

Figure 2 presents a comparison of phosphorus, nitrogen, and chlorophyll *a* concentrations between control and treated sites based on pooled data for all sites, during all sample years. This figure is intended to illustrate the ranges in values that were measured. A formal statistical comparison of control and impact sites should reflect the range of streams, sampling dates and loading rates represented by the data (i.e., paired difference tests would be appropriate).

Soluble reactive phosphorus (SRP) concentrations in the Salmon River and Memekay River were <10 μg/L in all years at both treatment and control sites, and were <10 μg/L in all years except 1990 in Grilse Creek, likely due to a large application of fertilizer that year (Figure 3). This is characteristic of coastal BC streams, which typically have concentrations of orthophosphate <1μg/L (Slaney and Ward 1993, Ashley and Slaney 1997). CCME (2004) classifies oligotrophic water bodies as those with total phosphorus concentrations of 4–10 μg/L. Total phosphorus concentrations for these waterbodies are unknown, but are assumed to be somewhat higher than SRP. Regardless, the Salmon River, Memekay River and Grilse Creek are likely oligotrophic, and remain relatively low in nutrients, even after the application of fertilizer.

Nitrate (NO_3^-) plus nitrite (NO_2^-) concentrations in the Salmon River and Memekay River were <100 μg/L in all years at both treatment and control sites, and were <100 μg/L in all years except 1990 and 1994 in Grilse Creek, likely due to large applications of fertilizer in those years (Figure 4).

These concentrations are characteristic of BC streams, which typically have nitrite concentrations <1 μg/L and nitrate concentrations <100 μg/L. (RISC 1998, Nordin and Pommen 1986, CCME 2012). In oligotrophic lakes and streams nitrate concentrations are generally <400 μg/L (CCME 2012), which means that all three waterbodies are oligotrophic even after fertilizer application.

In oligotrophic waterbodies, any dissolved inorganic nutrients added are likely to be quickly consumed by biota. Periphyton (benthic algae) accrual is therefore a more appropriate indicator of whether fertilization is increasing primary productivity than dissolved nitrogen and phosphorus concentrations in the water column. Chlorophyll *a* was used as a proxy to measure periphyton abundance. BC water quality guidelines for chlorophyll *a* are 50 $\mu g/cm^2$ for human recreation, and 100 $\mu g/cm^2$ for the protection of aquatic life. Concentrations of chlorophyll *a* in the Salmon River, Memekay River, and Grilse Creek were much lower than both of these guidelines on all sample dates and at all sites. In Salmon River and Grilse Creek, chlorophyll *a* concentrations were generally higher at treatment sites than controls, but differences were less pronounced in the Memekay River. This may be due to the naturally higher concentration of nutrients in Memekay River, which are believed to reflect differences in geology (Pellet. pers. comm. 2015). Consequently, bottom–up control of primary productivity by nutrients may be less dominant in the Memekay River, and other factors such as light availability or grazing may limit periphyton biomass accumulation to a greater extent than in either the Salmon River mainstem or Grilse Creek.

Figure 2. **Comparisons of soluble reactive phosphorus (SRP, a), nitrate + nitrite nitrogen (NO_x-N, b) and benthic chlorophyll *a* concentrations between control and treated sites. Data provided by British Columbia Conservation Foundation (Pellett, pers. comm. 2015). Thick horizontal lines denote median values, boxes denote interquartile range (IR), whiskers extend to 1.5 × IR and circles show outlier data.**

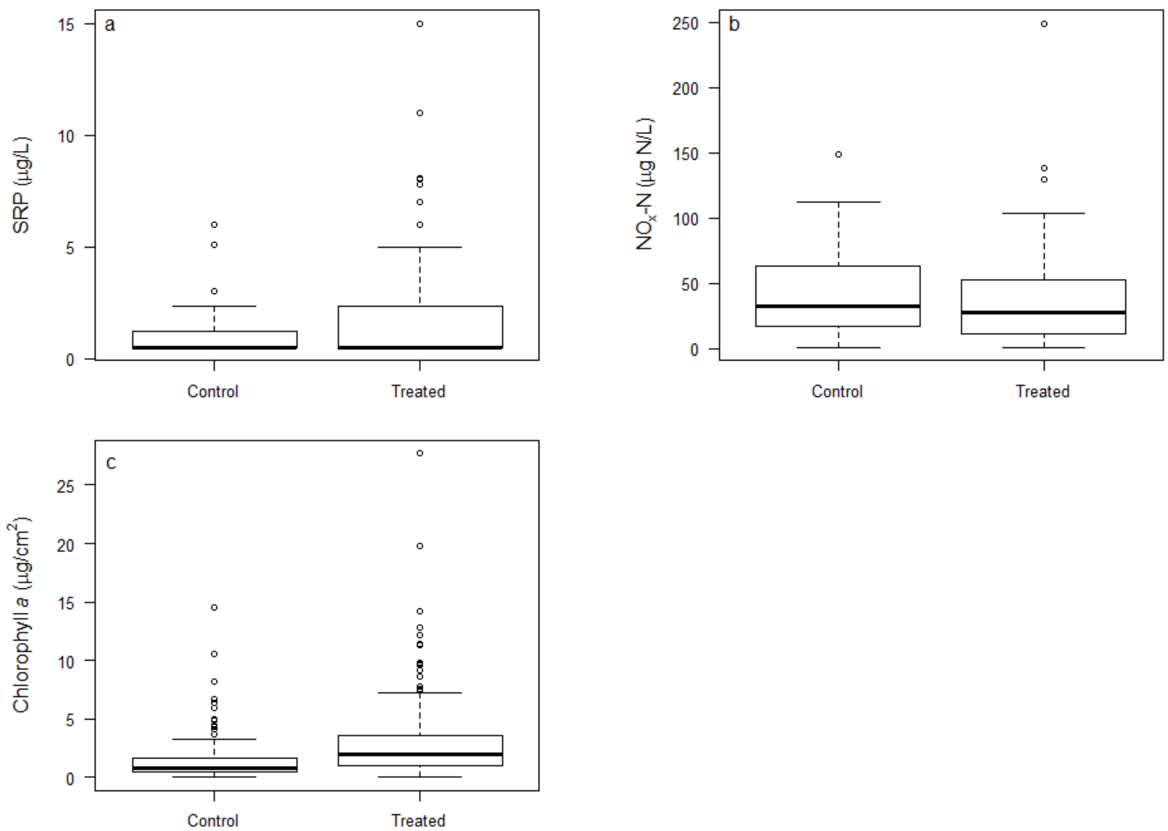
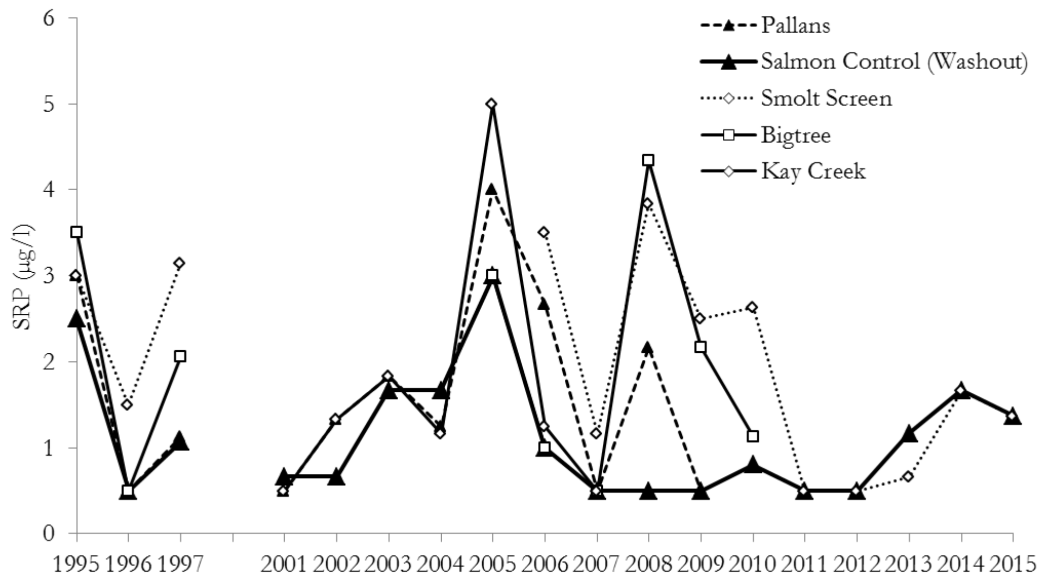
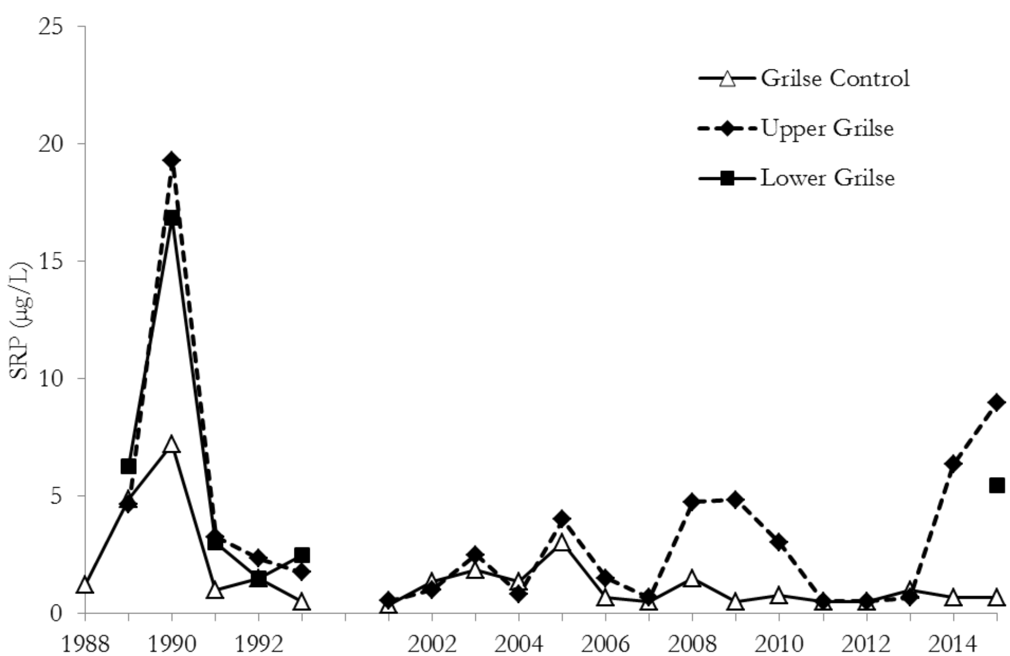


Figure 3. Soluble reactive phosphorus (SRP) concentrations at control and treatment sites in the Salmon River watershed from 1995–2015.

a) Salmon River mainstem



b) Grilse Creek



c) Memekay River

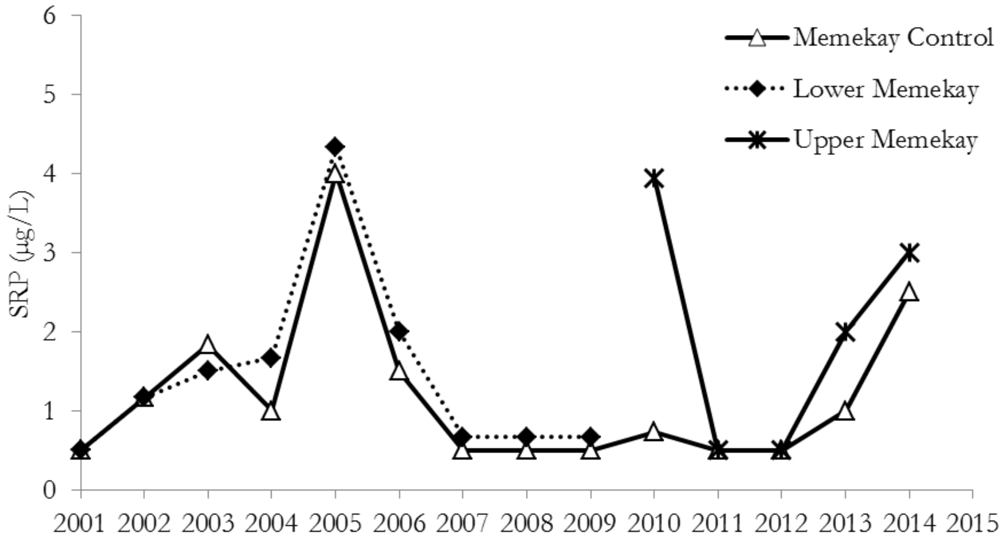
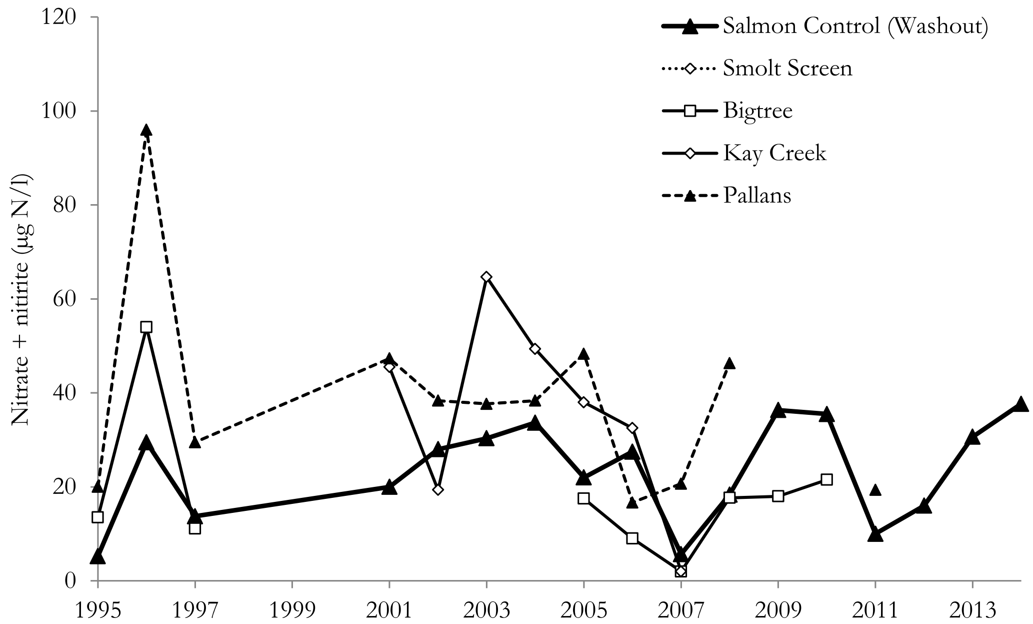
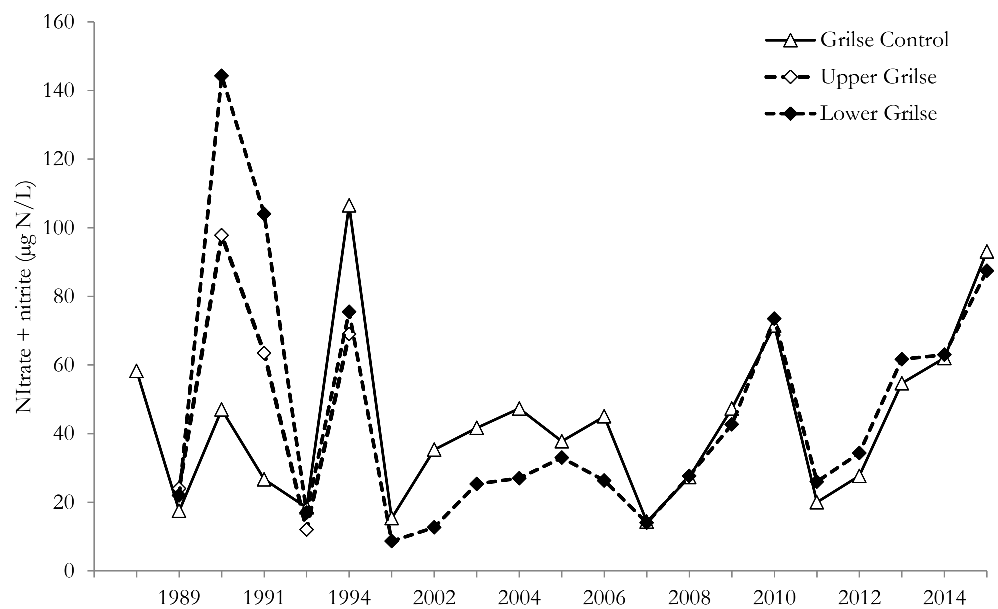


Figure 4. Nitrogen concentrations (nitrate plus nitrite) at control and treatment sites in the Salmon River watershed from 1995–2015.

a) Salmon River mainstem



b) Grilse Creek



c) Memekay River

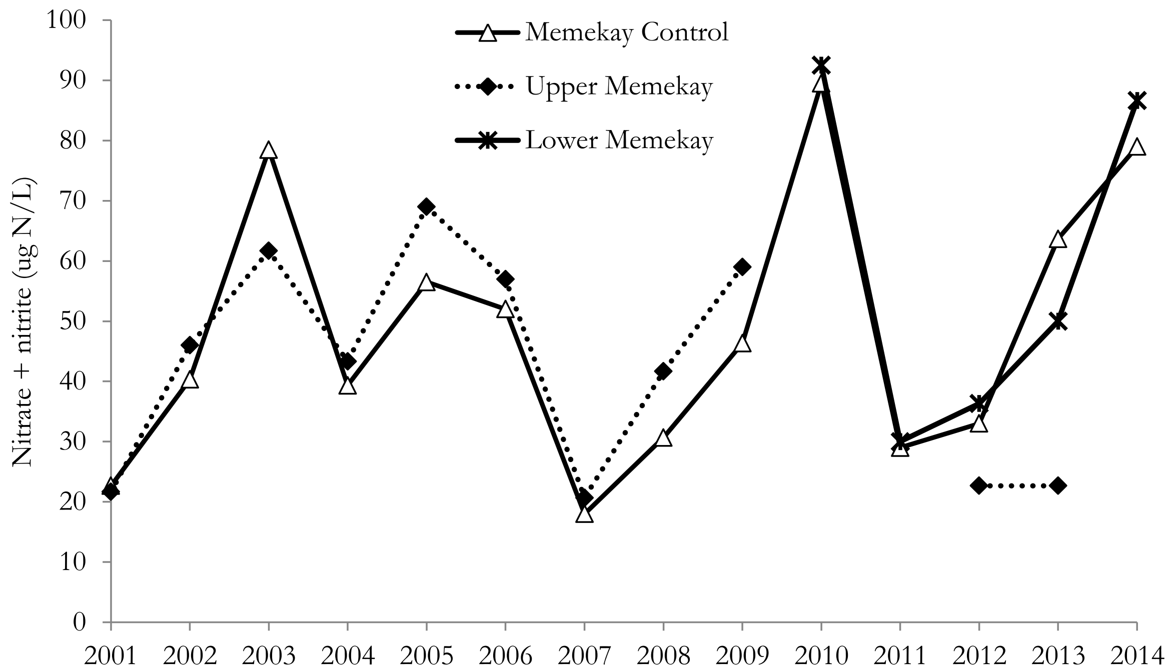
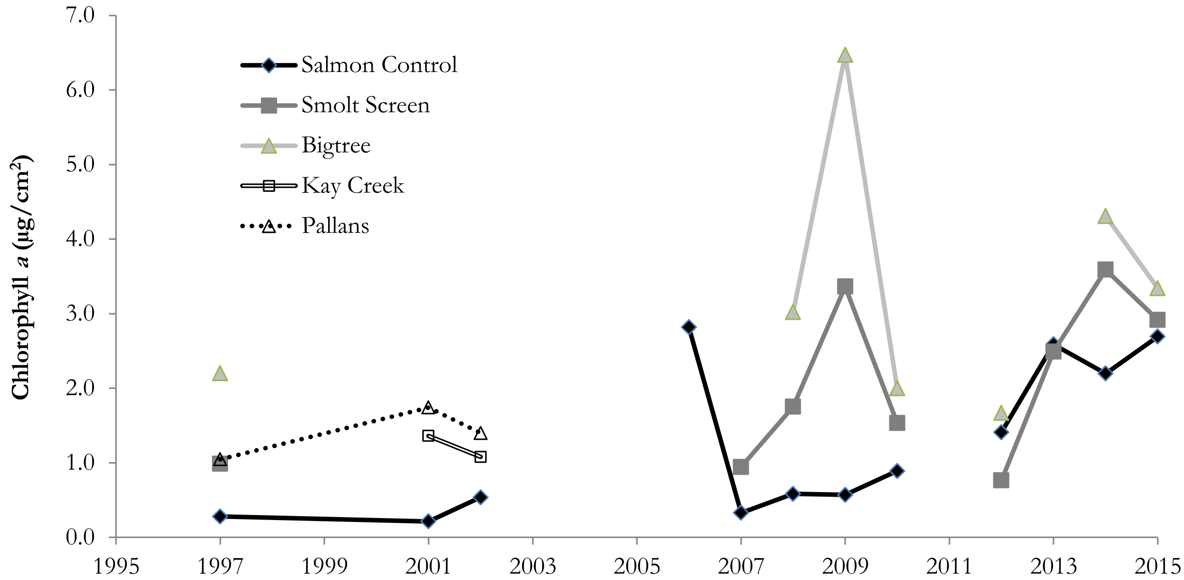
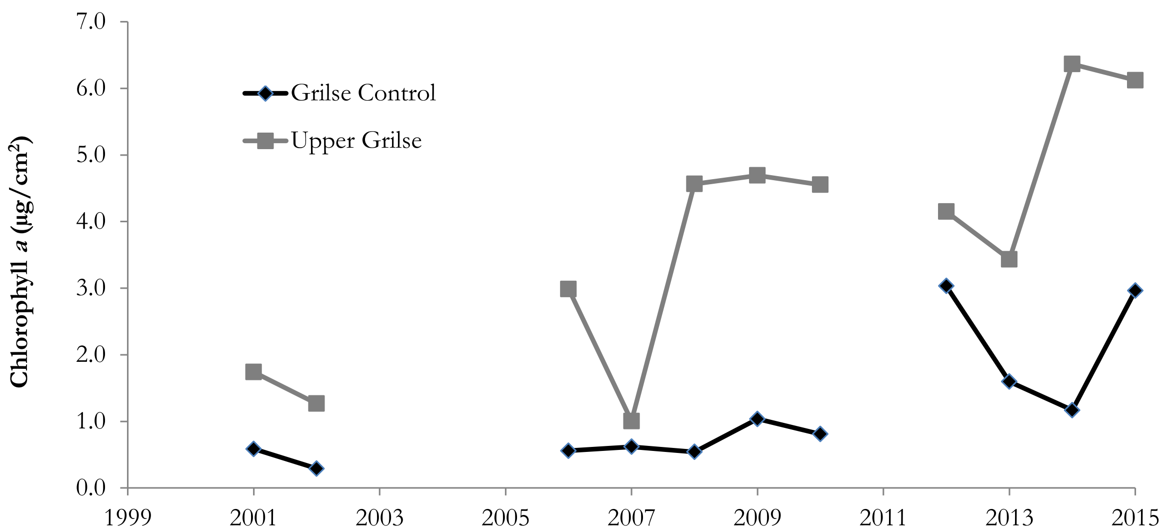


Figure 5. Chlorophyll *a* concentrations at control and treatment sites in the Salmon River watershed from 1997–2015.

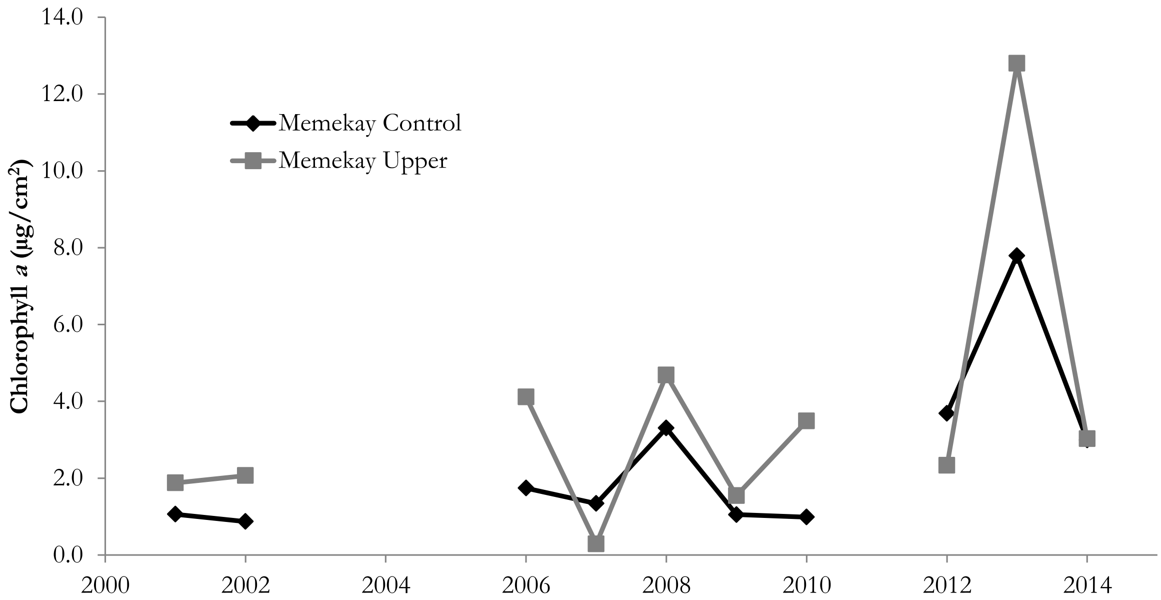
a) Salmon River mainstem



b) Grilse Creek



c) Memekay River



3.2.2. Water Temperature

Temperature in the Salmon River has been monitored by the Water Survey of Canada (WSC) from 2005 to present, BCCF from 2001 to 2007 (summer only), LKT from 2014 to 2015, and as part of various other small studies that are reviewed by Burt (2010). Raw data collected by BCCF and WSC were provided to Ecofish. The WSC maintains two temperature data loggers associated with hydrometric gauges: Station 08HD015 (above diversion dam) and 08HD032 (below diversion dam) (Map 1). Temperature data at the WSC stations was compared with JHTMON-8 data collected at SAM-WQ (Figure 6) to compare temperatures in different reaches of the Salmon River. Temperature appears to be generally uniform between the three sites (Figure 6), suggesting limited temperature changes upstream and downstream of the diversion, and limited influence on temperature by tributaries between the diversion and WSC-08HD032. Diurnal and annual temperature changes in the Salmon River follow a similar pattern as the Quinsam River as measured at QUN-WQ, but water temperature in the Quinsam River generally appears to be higher than that in the Salmon River (Figure 7).

Water temperature data for the Salmon River were collected by BCCF from 2001 to 2007 as part of nutrient enrichment monitoring, but data were only collected during the summer months (May to August) and monitoring stopped at most sites prior to 2005 when WSC began monitoring temperature. In Figure 8, water temperatures in Grilse Creek, Memekay River and Salmon River collected by BCCF in summers 2005, 2006, and 2007 are compared to corresponding temperatures at the WSC gauge to examine temperature differences between the mainstem Salmon River and its tributaries. In two of the three years, water temperatures in the tributaries (Grilse Creek and

Memekay River) were cooler than in the mainstem Salmon River. In the third year, temperatures were cooler at all sites, particularly in the Salmon River, and a temperature difference between watercourses was not observed (Figure 8).

Figure 6. **Daily average water temperature in the Salmon River from 2014–2015 at the JHTMON-8 monitoring site (SAM-WQ) and two WSC sites. Site WSC08HD015 is immediately upstream of the diversion dam; site WSC08HD032 is downstream of SAM-WQ, at Kay Creek confluence (Map 1).**

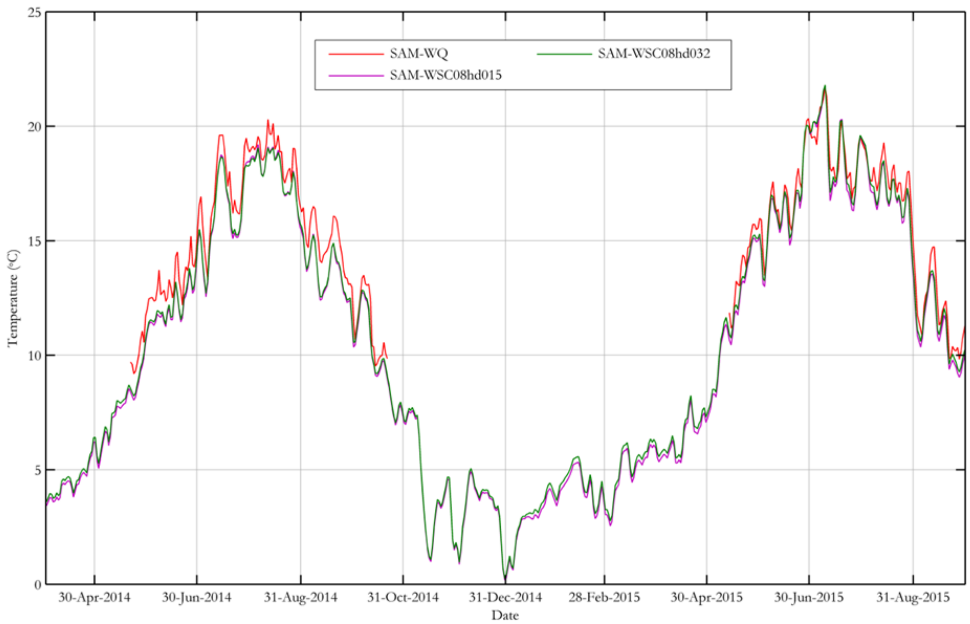


Figure 7. Near continuous (15–minute) water temperature in the Salmon and Quinsam Rivers at JHTMON-8 monitoring sites SAM-WQ and QUN-WQ, and daily average water temperatures at WSC gauges on the Salmon River mainstem from April 2014–January 2015.

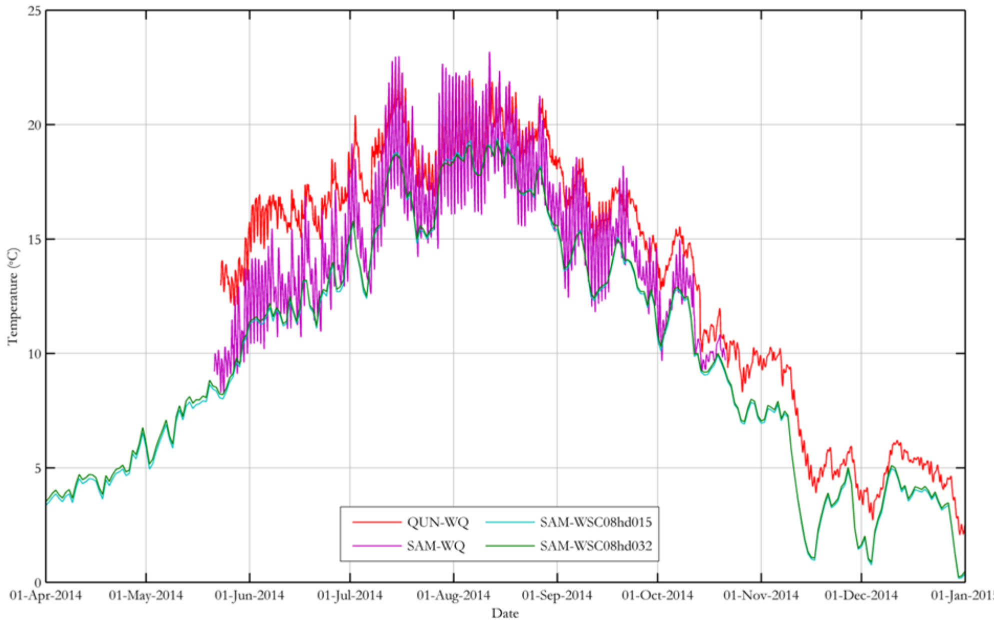
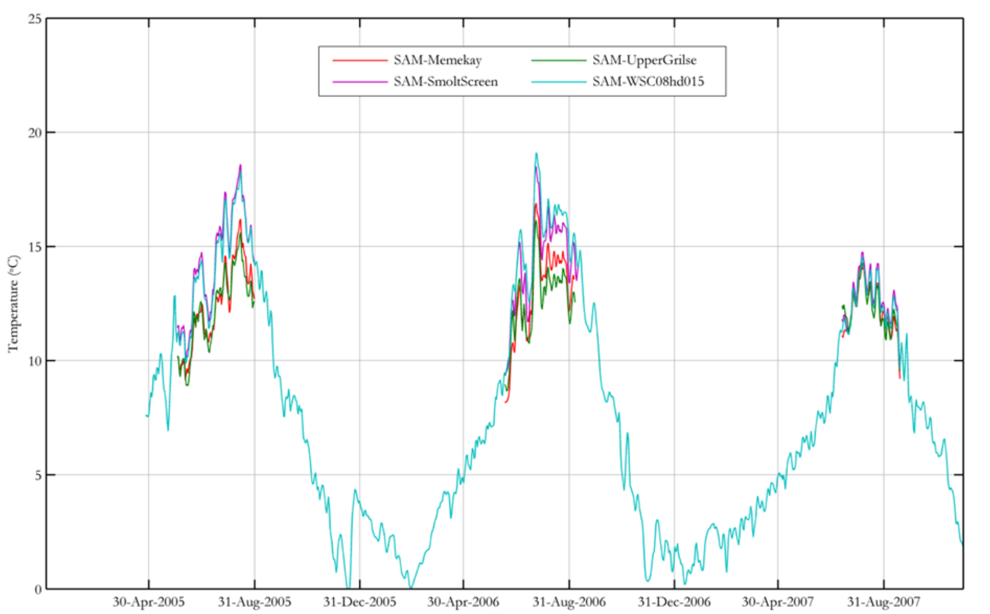


Figure 8. Daily average water temperature in the Salmon River (SAM-SmoltScreen and SAM-WSC08hd015; both at the diversion dam), Memekay River (SAM-Memekay) and Grilse Creek (SAM-Upper Grilse) from 2005–2007.



3.3. Summary of Key Reports Related to the Salmon River Watershed

a) Burt (2010) *Fisheries and Aquatic Resources of the Salmon River, Vancouver Island: Literature Review Update.*

In a review of existing aquatic and fisheries studies for the Salmon River up to 2009, Burt (2010) provides a detailed description of the Salmon River ecosystem, hydroelectric activities, and discussion of fish passage issues at the diversion dam. The main industry in the Salmon River watershed is forestry. Prior to initiation of the stream enrichment program (Pellet 2014), water quality in the Salmon River watershed was described as having exceptional clarity, relatively stable pH with acidic conditions during periods of high precipitation, and moderate alkalinity. The Salmon River is naturally nutrient poor, resulting in low primary productivity. Both nitrogen and phosphorus are suggested as potential limiting nutrients in the Salmon River system. The report provides a range of results for water quality parameters including pH, total alkalinity, total hardness, and specific conductance from 1977 to 1987 (prior to the nutrient enrichment program). A range of water quality values post-enrichment are provided for suspended solids, nutrients, pH, alkalinity, and specific conductance from 1989 to 1997.

Average annual temperature in the Salmon River from 1977 to 1997 was reconstructed using data from fish screen enumeration studies at the smolt screen, and from spot temperatures collected throughout the mainstem during various other studies. Results suggest minimum daily winter temperatures of 1ºC (bi-monthly winter mean of 4ºC), a summer temperature range of 16 to 19ºC, and a mean annual water temperature of 8.5ºC. The general growing season for salmonids in the Salmon River is 175 days (25 weeks). The annual out-migration of Coho Salmon and steelhead smolts in the Salmon River begins to increase when maximum daily temperatures attain 7ºC. Burt (2010) identified a lack of spatial resolution in Salmon River temperature data: there are no available data to examine temperature differences in the upper river relative to the lower river.

b) Pellet (2011) *A review of twenty years of nutrient enrichment in the Salmon River watershed, Vancouver Island (1989-2010).*

The Salmon River has been the focus of a nutrient enrichment program since 1989 to stimulate the growth of stream rearing salmonids. Increased fish growth prior to over-wintering increases smolt survival, and may positively influence marine survival. Nutrient enrichment is designed to decrease the average age of smolts, reducing cumulative over-winter mortality and increasing stock productivity. Pellet (2011) reviewed 22 years of nutrient enrichment monitoring, including data on periphyton, water chemistry, and fish growth.

Nutrient enrichment of the Salmon River watershed expanded from upper portions of Grilse Creek (enriched annually since 1989), to sites in lower Grilse Creek, and the main Salmon River (Rock Creek, the Memekay Mainline Bridge) by 1993, and the Memekay River (tributary to the Salmon River in 1997. A nutrient enrichment site was added at the Bigtree Mainline Bridge in 2008 and 2009 before being relocated upstream to Kay Creek in 2010 (Map 1). Target dissolved nutrient concentrations for nutrient addition from 1989-2007 were set at 5 µg/L soluble reactive phosphorus

(SRP) and 20 μg N/L dissolved inorganic nitrogen (DIN). In 2008, a target concentration of 2.5 μg/L SRP was implemented to align with nutrient enrichment programs in other Vancouver Island watersheds.

Periphyton biomass was quantified by measuring chlorophyll *a* concentrations on artificial substrates at control and treatment sites. Water samples were analyzed for nitrogen and phosphorus, and concentrations were compared between control and treatment sites. Data from all years were also pooled to examine natural seasonal variability at control sites, upstream of nutrient fertilization points. Fish growth response was assessed for steelhead fry and smolts.

Benthic chlorophyll *a* concentration in Grilse Creek was found to be significantly higher in treatment sites compared to the upstream control, as determined by a paired t-test. The response varies in the Memekay River, and chlorophyll *a* concentration was significantly higher at treatment sites in some years but not in others. In the Salmon River mainstem, monitoring sites were located several kilometres downstream of nutrient addition locations from 1997 to 2006 and showed a negligible response to treatments. Treatment monitoring sites from 2007 to 2010 were re-located closer to nutrient inputs and indicated a positive algal growth response. Eleven of the 20 treated sites evaluated had statistically higher biomass compared to controls, and largest responses were generally observed at sites closest to the nutrient source. Overall, the magnitude of algal growth response was strongly correlated with the quantity of phosphorus added upstream in Grilse Creek.

Nutrient concentrations varied widely between sites and between years. Concentrations were higher at treated sites than the control during years of significant nutrient loading (1989-1991) and were found to be lower in years of low nitrogen loading, occasionally lower than the control site. Seasonal variations in nutrient concentrations were also investigated. At Grilse Creek and Memekay River, nitrogen concentrations in control sites were found to increase throughout the summer and peak in September. SRP concentrations peaked in June and then decreased throughout the summer. Trends at treatment sites were similar, although nitrogen peaked earlier at treatment sites in Grilse Creek. In the Salmon River, SRP concentrations decreased throughout the season while nitrogen concentrations increased.

Overall, Pellet (2011) concluded that nutrient application timing had a significant effect on the growth response of juvenile steelhead, with the largest gains made in years when nutrient addition began in June. Specifically, nutrient loading was positively correlated with fry mass, while the length of two-year old smolts was positively correlated with loading rates two years prior, indicating that increased fry growth is sustained, resulting in larger smolts. The dataset for Grilse Creek was the longest and most consistent, and this region is also where the most significant water chemistry responses to treatment were observed. Background nutrient levels in the Memekay River appear to be higher than the extremely low concentrations in Grilse Creek and the Salmon River mainstem (Pellet pers. comm. 2015).

c) Pellet (2010) *Salmon River Watershed Enrichment for Fish Habitat Restoration 2009.*

In addition to the comprehensive review of the Salmon River nutrient enrichment program from 1989 to 2010, BCCF has produced monitoring reports detailing results from individual years of monitoring. Much of the information presented in report of the 2009 nutrient enrichment program is also covered in Pellet (2011). Pellet (2010) includes detailed descriptions of fertilizer compositions, the equations used for calculating fertilizer loading rates, and monitoring methods.

d) Pellet (2014) *Salmon River Stream Productivity Monitoring 2011-2013*.

Following a comprehensive review of 22 years of nutrient enrichment in the Salmon River watershed (Pellet 2011), a decision was made to suspend nutrient addition from 2011-2013 in order to compare background productivity to productivity under enriched conditions. Monitoring results during the enriched and non-enriched periods were tabulated for the main Salmon River, and two tributaries (Grilse Creek and Memekay River).

In all three watercourses, SRP was elevated in treatment areas compared to the control in nutrient enrichment years, but not in years without nutrient addition. Nitrogen was not generally elevated in nutrient enrichment years, and decreased at treatment sites during nutrient enrichment years in the Salmon River, likely because it was being rapidly consumed by primary producers in the presence of increased phosphorus[1]. Chlorophyll *a* increased during treatment reaches compared to the control in Grilse Creek and Salmon River, but not in the Memekay River.

[1] Nitrogen is also included in fertilizer but the ratio of nitrogen to phosphorus is below typical stoichiometric requirements of algal cells. As phosphorus is typically the primary limiting nutrient, phosphorus additions promote periphyton growth, depleting background dissolved nitrogen concentrations.

4. EXISTING WATER QUALITY DATA IN THE QUINSAM RIVER

Activities with the potential to impact water quality in the Quinsam River include the development of the Quinsam Coal Mine, forest fertilization practices, and effluents from the Quinsam Hatchery (Burt 2003, Environment Canada 2015). Operation of the Quinsam River Diversion is also relevant because it influences river discharge, affecting dilution rates, hydraulic residence time in several lakes, and water temperature. Reports reviewing and analysing water quality in the Quinsam Watershed have been published by Burt (2003), Phippen (2005), and Strachan *et al.* (2009). Ongoing water quality monitoring is conducted by Environment Canada, Quinsam Fish Hatchery, and Quinsam Coal. Data collected by Environment Canada and the Quinsam Fish Hatchery were provided to Ecofish, but data collected by Quinsam Coal were not obtained (Table 1). Key findings from Quinsam River water quality data collection and reports are summarized in Table 4.

Table 4. Summary of water quality monitoring in the Quinsam River watershed from 1983–2015.

Data type	Parameter(s) sampled	Site location	Sampling frequency	Sampling method	Period	Data source	Reference	Key findings
Water Temperature	Temperature	Mainstem Small tributaries Long Lake Middle Quinsam Lake	Varies: 30 minutes, bi-weekly, quarterly	Grab samples and continuous loggers	1983-1995	BC Hydro Report	Burt 2003	Summer water temperatures in the lower Quinsam River annually exceed the general provincial guidelines for the protection of aquatic life. There has been no long-term temperature monitoring in reaches above Middle Quinsam Lake to examine both the extent of temperature issues in these reaches, and the influence of water storage and diversion on downstream temperatures.
Water Chemistry	Turbidity Nutrients Total Suspended Solids pH	Near confluence with Campbell River (at Environment Canada WQ Sampling Site)	Bi-weekly	Grab samples	1986-1998	BC Hydro Report	Burt 2003	The lower Quinsam River is classified as oligotrophic due to low nutrient levels. Primary production is low due to either nitrogen or phosphorus limitation (sources disagree) The water is clear, with low turbidity and low total suspended solids. pH is generally neutral to alkaline, but is occasionally acidic after rainfall.
Benthic Invertebrates	Benthic invertebrate assemblages	5 in mainstem Cold Creek	Annually in fall	CABIN protocols (kick net) Invertebrates identified to genus or species	2001-2006	Environment Canada Report	Strachan *et al*. 2009	The benthic community was designated "Severely stressed" at the mouth of the Quinsam River in 2001, but improved each subsequent year to "Potentially Stressed" in 2006. Upstream sites were less stressed. Results suggest an environmental disturbance in the lower portion of the watershed, somewhere below the hatchery. This disturbance may be increasing nutrient enrichment, which pushed nutrients above oligotrophic levels.
Water Chemistry	General water quality Nutrients Dissolved oxygen	Near Quinsam River confluence with Campbell River	Bi-weekly	Grab samples plus analysis of bi-weekly sampling at Environment Canada WQ Sample Site	1986-2006	Environment Canada Report	Strachan *et al*. 2009	Sulphate increased until 1999, then levelled off. Some water quality variables do not meet site-specific guidelines, including alkalinity, copper, iron, nitrogen, phosphorus and water temperature. Copper and iron levels may be due to natural input from the Iron River, but may also be due to historical or current mining. Alkalinity is naturally low. Water temperature exceedances occurred with low flow in summer, and may be natural and/or a result of upstream dam operation. Pre-dam water temperature data are not available for comparison.
Water Chemistry	Metals pH Alkalinity Temperature Hardness Conductivity Nutrients	Upstream of Hatchery Fence	Quarterly	Grab samples	1995-ongoing	Quinsam Fish Hatchery	Frissan, pers. comm. 2015	Aluminum, iron, and temperature occasionally exceed general BC water quality guidelines for the protection of aquatic life in the lower Quinsam River above the Quinsam Fish Hatchery.
Water Chemistry	Sulphate	Upstream of Hatchery Fence	3 to 10 times per year	Grab samples	1995-ongoing	Quinsam River Hatchery	Frissan, pers. comm. 2015	Sulphate meets water quality guidelines for the protection of aquatic life, but is monitored closely because changes can indicate acid rock drainage, potentially due to mining.
Water Temperature	Temperature	Upstream of Hatchery Fence	30 minute intervals	Temperature data logger	1999-ongoing	Quinsam River Hatchery	Frissan, pers. comm. 2015	Temperature in the summer months frequently exceeds BC water quality guidelines for the protection of aquatic life.
Water Temperature	Temperature	Downstream of Hatchery Fence	30 minute intervals	Temperature data logger	1999-ongoing	Quinsam River Hatchery	Frissan, pers. comm. 2015	Temperature in the summer months frequently exceeds BC water quality guidelines for the protection of aquatic life.
Water Chemistry	Metals pH Alkalinity Temperature Hardness Conductivity Nutrients	Quinsam River near confluence with Campbell River	Bi-weekly	Grab samples	1986-ongoing	Environment Canada	Environment Canada 2015	There were deteriorating trends in sulphate and other major ions at the mouth of the Quinsam River due to the coal mine at Middle Quinsam Lake. These trends are not a direct threat to aquatic life at present, and are being addressed through additional monitoring near the mine.
Water Chemistry	Metals pH Turbidity Dissolved oxygen Nutrients	Middle Quinsam Lake and Quinsam River near mouth	Quarterly	Grab samples	1989-1993 2004	Ministry of Environment	Phippen *et al.* 2004	Water quality in the lower Quinsam River near the mouth was good from 1989-1993, and excellent in 2004.

ECOFISH RESEARCH

4.1. Summary of Existing Water Quality Monitoring in the Quinsam River Watershed

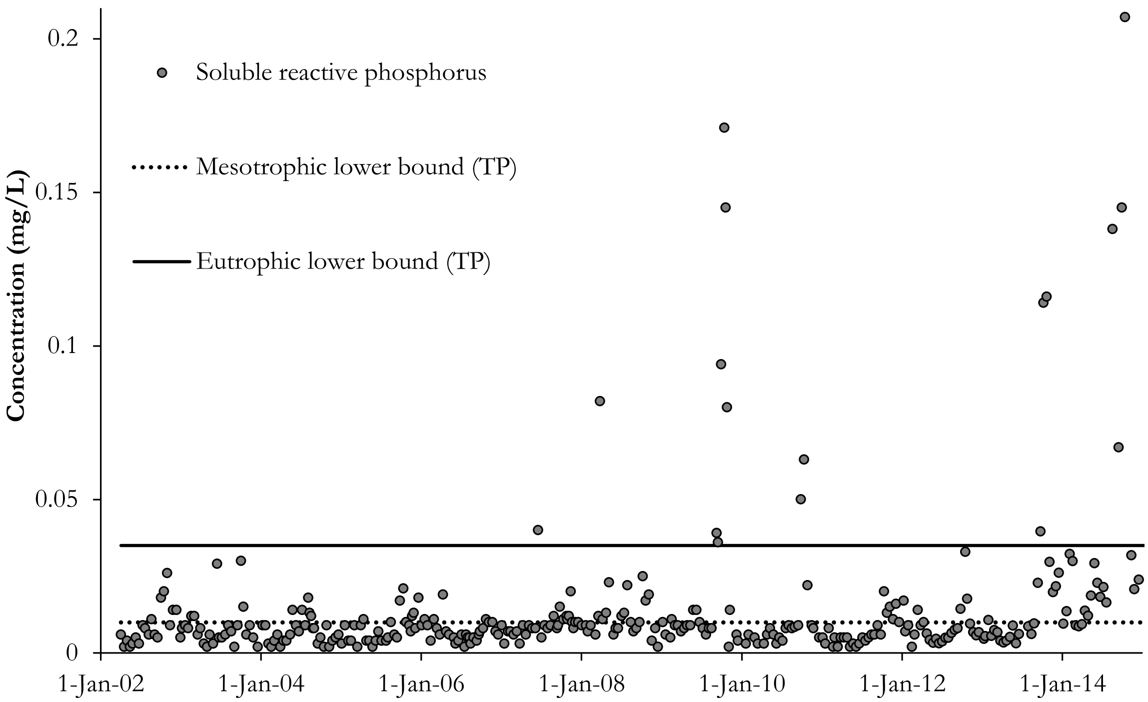
4.1.1. Environment Canada Water Quality Monitoring

The most consistent long-term monitoring in the Quinsam Watershed has been undertaken by Environment Canada. Monitoring began at Environment Canada water quality station 08HD0004 in 1986, a year prior to activation of the Quinsam Coal Mine near Middle Quinsam Lake, and is ongoing. Samples are collected every two weeks near the mouth of the river, from a site on the upstream side of the Highway 20 bridge (Environment Canada 2014 and 2015). The Environment Canada water quality sampling site is co-located with the Water Survey Hydrometric Station 08HD005 (Map 2). The goal of this sampling is to evaluate potential effects of mining operations and other industrial activities on water quality (Strachan *et al.* 2009). Samples are analyzed for metals (arsenic, iron, lead, zinc), pH, alkalinity, temperature, hardness, conductivity, nutrients, and anions. Data are available to download from the Environment Canada website (Environment Canada 2013). Environment Canada has analyzed and interpreted the data, and evaluated water quality and potential upstream impacts. Rather than repeat these efforts, Ecofish focused data compilation and analysis on a subset of nutrient data for comparison with information from key reports. However, all Environment Canada data are available online, and could potentially be used to support future analysis to examine relationships between water quality and fish productivity in the Quinsam River watershed.

Water quality at the mouth of the Quinsam River is rated "fair" based on the key index parameters alkalinity, arsenic, iron, lead, pH, and zinc (Environment Canada 2014). Since 1986, there have been increasing trends in sulphate and other major ions at the mouth of the Quinsam River, which were attributed to coal mining activities upstream. Environment Canada concluded that these trends were not a threat to aquatic life. The trends are being examined further with additional monitoring near the Quinsam Coal Mine (Environment Canada 2014).

Measurements of dissolved phosphorus (SRP) by Environment Canada from 2002 to 2015 show an increase in concentrations since approximately fall 2013 (Environment Canada 2014) (Figure 9). Federal trophic status classifications are based on total phosphorus concentrations (CCME 2004); these are shown in Figure 9. While the dissolved phosphorus measurements are not directly comparable with these trophic status boundaries, the data indicate that this part of the Quinsam River may now be considered mesotrophic or eutrophic, given that total phosphorus concentrations are at least equal to dissolved phosphorus concentrations.

Figure 9. Soluble reactive phosphorus (SRP) concentrations in the Quinsam River at Environment Canada WQ site (Map 2). Data from Environment Canada (2015). Trophic state boundaries (CCME 2004) are provided for context, although note that these are based on total phosphorus (TP) concentrations, which are ≥ SRP concentrations.



4.1.2. Quinsam River Hatchery Water Quality Monitoring

4.1.2.1. Overview

Staff from the Quinsam River Hatchery collect water quality samples two to four times per year, upstream of the hatchery fence (*Upper Hatchery* sampling site, see Map 2). Samples are analyzed for metals, pH, alkalinity, temperature, hardness, conductivity, sulphate, nutrients, and total dissolved solids. Temperature loggers have been installed upstream and downstream of the hatchery where temperature is logged at 30 minute intervals (*Upper Hatchery* and *Lower Hatchery* sampling sites, see Map 2). The Quinsam River Hatchery does not publish analysis of these water quality data, but data were provided to support this review.

Water quality in the Quinsam River upstream of the fish hatchery exceeded aquatic health water quality guidelines for some parameters, with occasional exceedances of guideline concentrations for aluminum, iron, total phosphorus and copper (Table 5; Table 6). Aluminum can precipitate on fish gills and increases respiration rate, causing stress and potentially death at very high concentrations (Butcher 1988). The sensitivity of fish and amphibians to aluminum increases as pH is reduced, and increases in softer water (Butcher 1988). Under current neutral pH and medium hardness conditions in Quinsam River at the *Upper Hatchery* site, fish and amphibians are unlikely to be sensitive to aluminum. Iron can also precipitate on fish gills, and at high concentrations it can reduce visibility in the water and cause impaired food perception and associated stress to fry and juvenile stages (Smith *et al.* 1973). Fish can acclimatize to iron exposure over time and regulate toxic concentrations (Phippen *et al.* 2008). A single minor exceedance of the copper guideline concentration (based on water hardness) was observed in 1995. High copper concentrations can cause a range of acute and chronic toxicity effects on fish (Singleton 1987).

The magnitude of aluminum, iron and copper exceedances in the Quinsam River are within the typical safety factors applied to known toxicity levels (MOE 2012) and this, along with their infrequent occurrences, suggest that these metals are not likely causing immediate harm to aquatic life near the *Upper Hatchery* sampling site. However, concentrations of metals in other regions of the Quinsam Watershed are unknown, and they may be higher closer to potential natural or anthropogenic sources such as the Iron River tributary or the Quinsam Coal Mine.

Table 5. General water quality in the Quinsam River at *Upper Hatchery* (Map 2) 1995-2015.

Date Unit	pH pH units	Alkalinity (as $CaCO_3$)	Temperature °C	Hardness (as $CaCO_3$) mg/L	Conductivity µS/cm	Extractable Phosphorus mg/L	Dissolved Phosphorus mg/L	Sulphate (SO_4) mg/L	Ammonia mg/L	Nitrate+ Nitrite mg/L	Total Dissolved Solids
BC Water Quality Guideline	6.5-9.0	-	*	80	-	No change from baseline trophic classification		100	0.7**	3.06	-
09-Sep-15	8.1	40	16.4	40	144	-	-	20.6	0.05	0.06	78
02-Jun-15	7.4	37	17.6	40	126	-	-	18.6	<0.01	0.02	96
16-Dec-14	7.1	16	5.6	21	54	-	-	5.7	0.03	0.07	32
11-Sep-14	7.3	46	13.3	36	138	-	-	19.1	0.07	0.21	78
02-Jun-14	7.1	33	19.4	30	94	-	-	13.3	0.02	0.04	76
10-Dec-13	7.6	28	-	33	90	-	-	12.7	0.02	0.1	84
09-Sep-13	7.7	38	18.2	37	127	-	-	20.8	0.21	0.33	66
12-Jun-13	7	27	15.4	28	75	<0.01	-	10.8	0.01	<0.01	54
03-Dec-12	7.5	20	5.4	24	68	0.01	-	9.1	0.09	0.06	72
05-Sep-12	8	29	17.3	30	83	<0.01	-	9.3	0.06	<0.01	64
06-Jun-12	7.8	28	13.9	26	78	<0.01	-	8.2	<0.01	0.03	74
03-Jan-12	7.6	23	3.7	26	74	<0.01	-	11.8	<0.01	0.03	58
08-Sep-11	7.9	30	17.5	31	89	0.01	-	11.1	0.03	0.15	78
09-Jun-11	8	24	14.7	22	59	<0.01	-	5.7	0.02	<0.01	38
01-Dec-10	6	20	3.9	20	61	<0.01	-	6.5	0.02	0.15	62
07-Sep-10	8.11	35	15.1	36	97	0.02	-	13.1	<0.01	0.05	52
02-Jun-10	8.07	27	12.6	28	80	<0.01	-	10.4	0.02	0.05	68
08-Dec-09	7.72	24	1.5	23	70	<0.01	-	8.4	<0.01	0.05	52
09-Sep-09	7.91	34	14.7	40	120	0.07	-	16.4	N/A	1	70
03-Jun-09	7.72	32	17.4	33	102	<0.01	-	14.2	0.02	0.03	74
10-Mar-09	6.18	24	1.9	25	75	<0.01	-	10.3	<0.01	0.1	54
23-Jun-08	7.46	30	16.3	30	77	0.01	-	7.8	0.008	0.004	54
20-Feb-08	7.41	25	3.2	23	82	-	-	13.0	0.016	0.054	46
20-Jun-07	7.49	27	16.5	27	64	-	<.02	5.8	0.003	0.003	46
14-Mar-07	7.28	24	4.5	25	79	-	<.05	15.2	<.002	0.014	64
05-Dec-06	7.57	20	2.6	23	65	-	<.05	6.7	<.002	0.161	58
19-Jul-06	7.66	31	18.2	36	100	-	<.1	13.6	0.003	<.002	66
15-Mar-06	7.44	17	4.5	23	75	-	<.1	10.0	0.008	0.101	43
11-Oct-05	7.71	29	11.3	37	99	-		3.4	0.079	0.043	72
20-Jul-05	7.41	35	17.9	36	120	-	<.005	10.4	0.002	0.006	70
02-Feb-05	7.17	24	4.9	25	63	-	<.05	9.1	0.002	0.066	55
06-Oct-04	7.77	31	12.5	29	125	0.22	-	5.3	0.001	0.007	76
11-May-04	7.48	30	14.6	33	94	0.68	-	13.5	0.003	0.015	64
28-Jan-04	7.22	20	3.7	18	68	<.06	-	9.4	<.001	0.033	53
10-Sep-03	n/a	30	15.5	29	105	<.06	-	12.5	0.004	0.011	74
04-Jun-03	7.47	28	16.9	19	86	<.06	-	11.9	0.003	0.018	60
22-Jan-03	6.88	16	4.3	24	74	<.06	-	9.6	0.002	0.067	61
10-Sep-02	7.99	30	15.6	32	99.1	<.06	-	12.0	<.001	0.004	13
28-May-02	7.8	29	13.7	28	85	<.06	-	11.5	0.004	0.011	72
06-Feb-02	7	20	4	22	52	<.06	-	6.9	0.012	0.061	48
03-Oct-01	7.42	33	11.5	36	93.6	0.09	-	11.3	0.36	0.115	53
05-Jun-01	7.34	30	13.6	33	85	<.06	-	11.3	0.002	0.007	64
06-Mar-01	7.32	24	4.6	33	95	<.05	-	15.9	0.002	0.1	73
06-Dec-00	7.37	20	3.7	32	83	<.06	-	11.6	0.009	0.075	64
10-Aug-00	8	29	18.5	45	110	<.06	-	17.1	0.007	0.01	75
27-Apr-00	7.78	25	9.2	36	88	<.06	-	14.2	0.001	0.029	75
23-Feb-00	6.8	19	3.9	22	63	<.06	-	8.2	0.003	0.088	56
04-Nov-99	6.89	-	5.8	28	68	<.06	-	5.6	-	-	-
26-Jul-99	7.42	-	18.3	23	54	<.06	-	3.3	-	-	-
28-Apr-99	7.32	-	9.3	30	82	<.06	-	14.9	-	-	-
23-Feb-99	6.93	17	2.8	21	69	<.06	-	14.7	<.005	0.06	-
16-Dec-98	-	-	4.5	42	62	0.11	-	9.9	-	-	-
05-Aug-98	7.73	-	18.6	36	96	<.06	-	7.3	-	-	-
14-Apr-98	7.54	-	10	-	74	<.06	-	9.7	-	-	-
27-Jan-98	6.9	23	3.6	23	54	<.06	-	8.7	<.01	<.005	-
26-Aug-97	7.67	-	16.1	-	75	<.06	-	4.8	-	-	-
27-May-97	7.83	-	14.8	29	76	<.06	-	10.5	<.01	0.053	-
12-May-97	7.8	-	13.7	-	-	-	-	-	-	-	-
25-Feb-97	7.40	19.0	3.5	26	71	<.06	-	12.0	<.01	0.13	-
17-Dec-96	7.59	-	1.8	26	70	-	-	-	-	-	-
28-Aug-96	8.37	-	18.4	-	-	-	-	-	-	-	-
29-Apr-96	-	9.2	-	-	-	-	-	-	-	-	-
14-Feb-96	7.28	2.4	-	-	-	-	-	-	-	-	-
18-Oct-95	6.81	-	11.0	-	-	-	-	-	-	-	-
09-Mar-95	-	-	3.8	-	-	-	-	-	-	-	-
01-Feb-95	-	-	3.9	-	-	-	-	-	-	-	-

Grey shading indicates that a concentration exceeds the water quality guideline for the protection of aquatic life.

*Optimum water temperature varies by fish species and life stage.

**Water quality guideline depends on the hardness of the water, and this guideline represents the limit at the average hardness.

Table 6. Metal concentrations in the Quinsam River at *Upper Hatchery* 1995-2015.

Date Unit	Hardness (as $CaCO_3$)	Aluminum mg/L	Calcium mg/L	Cadmium mg/L	Copper mg/L	Iron mg/L	Potassium mg/L	Magnesium mg/L	Manganese mg/L	Sodium mg/L	Iron mg/L	Zinc mg/L	Chlorine mg/L	Arsenic mg/L
BC Water Quality Guideline		0.10	-	0.0003	0.005*	0.3	-	-	0.08		0.004*	0.033	-	-
09-Sep-15	40	0.043	12.70	<0.00007	<0.001	0.146	0.3	1.90	0.015	13.30	<0.0001	<0.001	2.29	0.0007
02-Jun-15	40	0.056	12.80	<0.00007	0.001	0.201	0.3	2.00	0.012	12.40	<0.0001	<0.001	2.01	0.0008
16-Dec-14	21	0.207	6.72	<0.00007	0.002	0.280	0.2	0.97	0.014	2.50	<0.0001	0.001	0.78	0.0003
11-Sep-14	36	0.010	11.50	<0.00007	<0.001	0.136	0.3	1.81	0.015	9.80	<0.0001	<0.001	2.42	0.0009
02-Jun-14	30	0.028	9.63	<0.00007	<0.001	0.161	0.3	1.34	0.008	7.50	<0.0001	<0.001	1.29	0.0007
10-Dec-13	33	0.064	10.90	<0.00007	<0.001	0.235	0.3	1.36	0.008	6.00	<0.0001	<0.001	1.92	0.0005
09-Sep-13	37	0.009	11.90	<0.00007	<0.001	<0.005	0.5	1.76	0.009	11.20	<0.0001	0.001	2.02	0.0007
12-Jun-13	28	0.037	9.02	<0.00007	<0.001	0.158	0.3	1.29	0.006	4.70	<0.0001	<0.001	1.19	0.0006
03-Dec-12	24	0.008	7.80	<0.00007	0.001	0.328	0.2	1.10	0.010	3.70	<0.0001	<0.001	1.43	0.0005
05-Sep-12	30	0.016	10.10	<0.00007	<0.001	0.068	0.2	1.27	0.003	4.30	<0.0001	<0.001	1.46	0.0005
06-Jun-12	26	0.028	8.70	<0.00007	<0.001	0.089	<0.1	1.10	0.006	4.40	<0.0001	<0.001	1.00	0.0004
03-Jan-12	26	0.056	8.50	<0.00007	<0.001	0.130	0.2	1.20	0.001	5.10	<0.0001	<0.001	1.12	0.0005
08-Sep-11	31	0.012	10.50	<0.00007	<0.001	0.069	0.2	1.40	<0.001	5.50	<0.0001	<0.001	1.41	0.0004
09-Jun-11	22	0.035	7.30	<0.00007	<0.001	0.092	0.1	0.80	0.006	2.50	0.0004	<0.001	0.64	0.0004
01-Dec-10	20	0.112	6.20	<0.00007	<0.001	0.167	0.2	1.20	0.004	3.20	<0.0001	0.001	1.98	0.0003
07-Sep-10	36	0.029	11.30	<0.00007	<0.001	0.100	<0.1	1.80	0.009	6.50	<0.0001	<0.001	1.60	0.0006
02-Jun-10	28	0.047	9.30	<0.00007	<0.001	0.160	0.2	1.30	0.006	4.90	<0.0001	<0.001	1.19	0.0006
08-Dec-09	23	0.080	7.30	<0.00007	<0.001	0.120	0.2	1.10	0.008	4.80	<0.0001	<0.001	1.31	0.0004
09-Sep-09	40	<0.02	12.90	<0.00007	<0.001	0.100	0.5	2.00	0.015	7.80	<0.0001	<0.001	2.26	0.0008
03-Jun-09	33	0.02	8.40	<0.00007	<0.001	0.180	0.3	1.22	0.010	5.00	<0.0001	0.001	2.58	0.0007
10-Mar-09	25	0.05	7.78	<0.00007	0.001	0.140	<0.1	1.33	0.006	4.50	<0.0001	0.004	1.96	0.0004
23-Jun-08	30	0.03	9.80	<.00007	0.001	0.150	0.24	1.32	0.009	3.90	<.0001	0.005	1.46	0.0006
20-Feb-08	23	0.04	7.40	<.00007	<.001	0.140	0.16	1.19	0.005	5.90	<.0001	0.001	1.72	0.0003
20-Jun-07	27	0.03	8.50	<.00001	<.001	0.130	<.4	1.10	0.006	2.60	<.0001	0.002	1.00	0.0004
14-Mar-07	25	0.07	8.60	<.00001	<.001	0.130	<.4	1.30	<.005	5.50	<.0001	<.001	1.30	0.0003
05-Dec-06	23	0.15	7.70	<.00001	0.001	0.260	<.4	1.40	0.012	3.90	<.0001	0.002	1.94	0.0004
19-Jul-06	35.9	0.01	11.60	<.00001	<.001	0.090	<.4	1.70	<.005	6.00	<.0001	<.001	1.43	0.0006
15-Mar-06	23	0.12	7.40	<.00001	<.001	0.190	<.4	1.30	0.009	5.10	<.0001	<.001	1.63	0.0004
11-Oct-05	37	0.02	11.70	<.00001	<.001	0.140	0.4	1.70	<.005	5.80	<.0001	<.001	7.38	0.0006
20-Jul-05	35.9	0.02	9.20	<.00001	<.001	0.160	<.4	1.60	<.005	4.40	<.0001	<.001	1.40	0.0008
02-Feb-05	24.8	0.08	8.10	<.00001	<.001	0.140	<.4	1.20	0.007	3.60	<.0001	<.001	1.02	0.0003
06-Oct-04	29	<.01	10.00	<.0006	0.003	0.062	<1	0.85	<.0006	6.98	<.01	0.006	1.89	<0.04
11-May-04	33	0.01	11.30	<.0006	<.001	0.329	1.8	2.25	0.011	6.52	<.01	<.001	5.50	<0.04
28-Jan-04	18	0.08	5.93	<.0006	<.001	0.144	<.3	0.87	0.010	3.65	<.005	0.001	1.60	<0.02
10-Sep-03	29	0.01	10.00	<.0006	0.005	0.157	<.3	1.57	0.007	5.31	<.005	<.001	1.19	-
04-Jun-03	19	0.02	9.15	<.0006	0.001	0.080	<.3	1.19	0.003	4.72	<.005	<.001	2.27	-
22-Jan-03	24	0.20	7.20	<.0006	0.002	0.317	0.3	1.21	0.014	3.92	<.005	0.002	1.81	-
10-Sep-02	32	0.02	10.80	<.0006	<.001	0.092	0.8	1.42	0.008	5.17	<.005	<.001	0.70	-
28-May-02	28	0.04	9.82	<.0006	0.001	0.156	<.3	1.30	0.011	4.65	<.005	<.001	1.29	-
06-Feb-02	22	0.11	7.28	<.0006	0.001	0.161	<.3	1.26	0.005	3.45	<.005	0.003	1.66	-
03-Oct-01	36	0.07	11.50	<.0006	0.002	0.121	0.4	1.61	0.009	4.49	<.005	0.003	5.90	-
05-Jun-01	33	0.01	10.70	<.0006	<.001	0.131	<.3	1.50	0.003	4.42	<.006	0.002	1.30	-
06-Mar-01	32.5	0.04	10.20	<.0005	<.001	0.149	0.4	1.68	0.006	6.02	<.005	0.0022	1.80	-
06-Dec-00	31.5	0.05	10.20	<.0005	<.002	0.165	0.2	1.48	0.009	4.56	<.005	0.002	1.60	-
10-Aug-00	44.6	<.01	14.20	<.0005	<.002	0.170	0.9	2.18	0.009	6.94	0.008	0.034	<.5	-
27-Apr-00	36	0.04	11.50	<.0005	<.002	0.155	0.3	1.81	0.004	5.56	<.005	0.003	2.00	-
23-Feb-00	21.7	0.09	6.65	<.0005	<.002	0.210	<.2	1.25	0.008	3.48	<.005	0.01	1.61	-
04-Nov-99	27.6	0.01	8.86	<.0005	<.002	0.110	0.3	1.33	0.002	2.89	<.005	0.003	1.60	-
26-Jul-99	22.9	0.02	7.68	<.0005	<.002	0.141	<.2	0.91	0.005	1.62	<.005	0.001	0.60	-
28-Apr-99	29.7	0.03	9.74	<.0005	<.002	0.084	<.2	1.31	0.003	5.03	<.005	<.001	0.50	-
23-Feb-99	20.7	0.27	6.45	<.0005	<.002	0.428	0.2	1.11	0.017	4.30	<.005	<.001	1.10	-
16-Dec-98	41.5	0.11	12.60	<.0005	0.005	0.132	0.3	2.40	0.005	3.00	<.005	0.003	1.19	-
05-Aug-98	35.5	<.01	11.10	<.0005	<.002	0.122	0.3	1.85	0.005	4.62	<.005	<.001	2.21	-
14-Apr-98	na	0.05	8.47	<.0005	0.002	0.141	<.2	1.24	0.006	3.82	<.005	<.001	1.25	-
27-Jan-98	23.2	0.57	5.74	<.0005	0.003	0.753	<.2	1.10	0.022	3.08	<.005	0.002	1.10	-
26-Aug-97		0.01	9.69	<.0005	<.002	0.174	<.2	1.69	0.003	3.18	<.005	<.001	1.8	-
27-May-97	28.7	0.03	9.26	<.0005	0.003	0.133	<.2	1.25	0.007	3.80	<.005	<.001	0.92	-
25-Feb-97	25.6	0.05	7.74	<.0005	<.002	0.135	<.2	1.38	0.006	4.48	<.005	<.001	1.6	-
17-Dec-96	26.3	0.09	7.84	<.0005	<.002	0.166	0.3	1.44	0.006	3.91	<.005	<.001	-	-
28-Aug-96		0.02	10.70	<.0005	<.002	0.112	<.2	1.80	0.008	4.63	<.005	<.001	-	-
29-Apr-96		0.07	8.36	<.0005	<.002	0.161	<.2	1.36	0.006	4.20	<.005	<.001	-	-
14-Feb-96		0.13	6.66	<.0005	0.004	0.231	<.2	1.14	0.006	3.13	<.005	0.006	-	-
18-Oct-95		0.08	9.59	<.0005	0.004	0.177	0.3	1.46	0.005	3.98	<.005	0.005	-	-
09-Mar-95		0.83	6.89	<.0005	0.01	1.290	0.2	1.61	0.039	3.36	<.01	<.005	-	-
01-Feb-95		0.32	5.96	<.0005	0.007	0.474	<.2	1.10	0.013	2.15	<.01	<.005	-	-

Note: Metal concentrations refer to the extractable metal.

Grey shading indicates that a concentration exceeds the water quality guideline for the protection of aquatic life.

*Water quality guideline depends on the hardness of the water, and this guideline represents the limit at the average hardness.

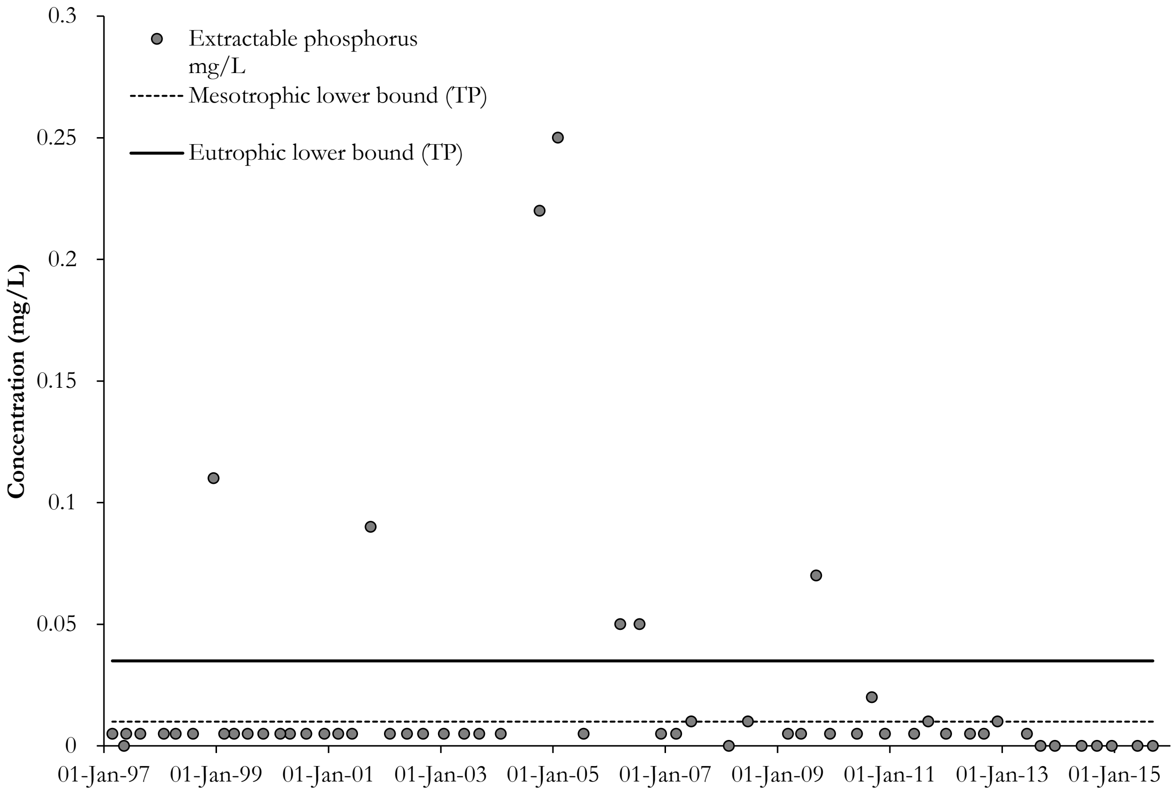
4.1.2.1. Nutrient sampling

Phosphorus concentrations were measured upstream of the Environment Canada monitoring site (at the mouth) at the *Upper Hatchery* WQ sampling site (see Map 2). The concentrations measured at this site since 2013 are considerably lower than those measured at the mouth (Figure 9) and typically indicate oligotrophic conditions. Concentrations presented in Figure 10 are 'extractable phosphorus'; these are presumed analogous to total phosphorus[2] and are therefore greater than the SRP fraction, which is represented in data presented in Figure 11.

As described in the main Year 2 Monitoring Report, 2013 and 2014 were notable as having record Pink Salmon escapement, with over 1 million fish estimated to have returned in each year (DFO 2016). High subsidy of marine derived nutrients associated with these high returns is therefore likely to account for the increase in phosphorus concentrations observed downstream of the hatchery since fall 2013.

[2] Laboratory determination of total phosphorus involves an initial extraction step (typically alkaline persulphate digestion) to hydrolyze particulate and organic forms, followed by determination of soluble reactive phosphorus. Thus, although details of the extraction step that was used were not provided with the data, it is reasonable to directly compare these concentrations with trophic status boundaries based on total phosphorus.

Figure 10. Extractable phosphorus concentrations in the Quinsam River at the *Upper Hatchery* WQ site, 1995–2015. Concentrations less than the method detection limit (MDL) were set equal to half of the MDL. Data from Environment Canada (2015).



4.1.2.1. Temperature analysis

Water temperatures measured at the *Upper Hatchery* and *Lower Hatchery* sites during 1999–2014 are presented in Figure 11. Data collected at the two sites are similar, although the annual range is typically greater at the *Upper Hatchery*, which most notably experiences warmer maximum water temperatures in summer. This likely reflects inputs of relatively cool water from tributaries that join the mainstem between the two sites (e.g., Cold Creek, Map 2), although shading by vegetation may be a contributing factor. Note that the Quinsam River flows through three lakes upstream of these sites and solar heating of surface waters in these lakes will elevate river water temperatures during summer.

As part of this review, we analysed the historical temperature records provided by Quinsam River Hatchery to better understand the potential for water temperatures to affect fish population abundance. This analysis complements comparable analysis undertaken using temperature measurements at QUN-WQ during Year 1 and Year 2, which is presented in the main Year 2 Monitoring Report. The additional analysis presented here helps to understand how temperatures at

QUN-WQ (upstream of Lower Quinsam Lake and upstream of the distributions of Pink Salmon *O gorbuscha* and Chinook Salmon *O. tshawytscha*) relate to temperatures at the two sites monitored by the hatchery (Map 2), which are within the distribution ranges of all JHTMON-8 priority species (based on distributions in Burt (2003)). In addition, the historical data provided by the hatchery span a greater period (1999–2014) than data collected so far during JHTMON-8 (2014–2015).

Results of the MWMxT analysis for the *Upper Hatchery* site are presented in Table 7; results for *Lower Hatchery* are presented in Table 8. Results for both sites are comparable, although the magnitudes of exceedances are lower at *Lower Hatchery*, reflecting the cooler summer temperatures discussed above. Key findings include the occurrence of undesirably warm water temperatures at the *Upper Hatchery* site during the rearing life stage of all relevant species, most notably for Chinook Salmon (e.g., MWMxT exceeds the upper boundary of the optimum range by > 1°C for 34.6% of the time). Also, undesirably warm water temperatures occur at both sites during the migration and spawning life stages of Pink Salmon, with the optimum range for migration exceeded for the majority of the period (54.9%) at the *Upper Hatchery* site. The analysis indicates that relatively cool water temperatures frequently occur during all relevant steelhead life stages; however, as discussed further in the main JHTMON-8 Year 2 Monitoring Report, the guideline temperature ranges relate to all life history variants of Rainbow Trout, and the lower bounds of these ranges are unlikely to be fully representative of anadromous Rainbow Trout.

Figure 11. Comparison of water temperatures measured at sites upstream and downstream of the Quinsam River Hatchery during 1999–2014. 'QUN-Hatchery' and 'QUN-DSHatchery' datasets were both collected at the *Lower Hatchery* site and 'QUN-USHatchery' data were collected at the *Upper Hatchery site* (Map 2)

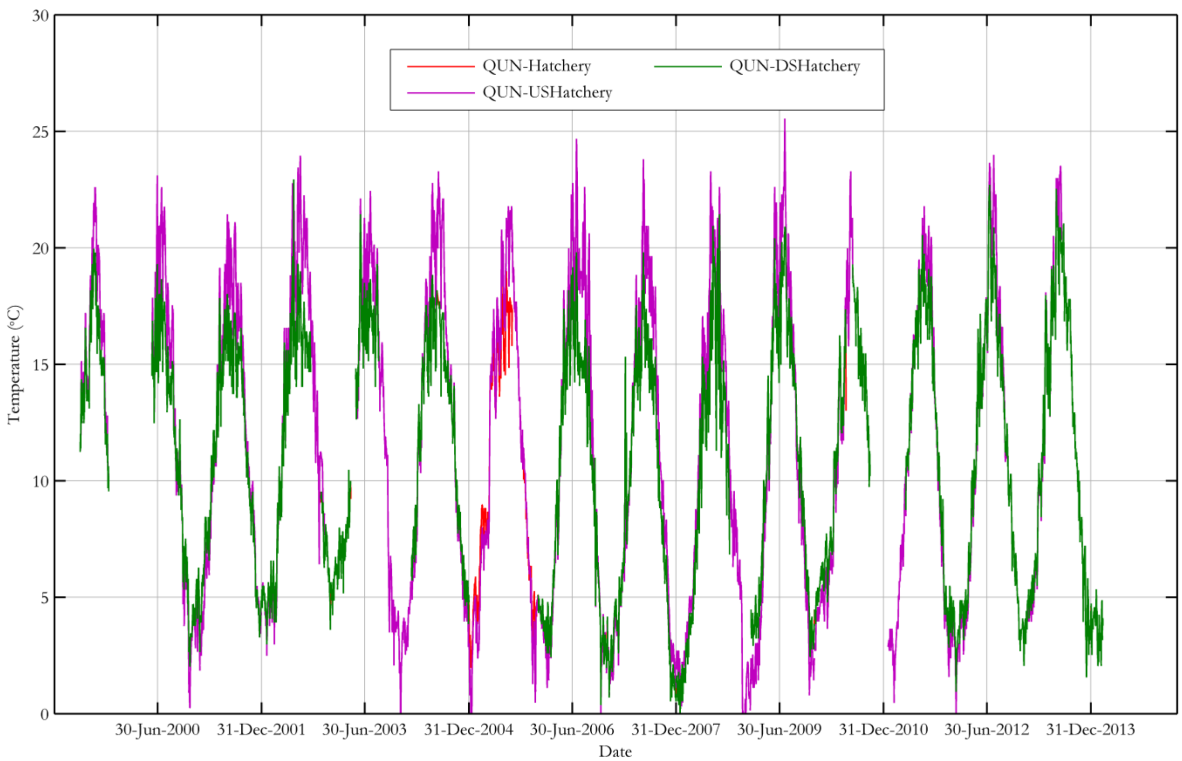


Table 7. Mean weekly maximum temperatures (MWMxT) at *Upper Hatchery* (Map 2) in 1999–2014, compared to optimum temperature ranges for fish species. Periodicity information is from Burt (2003).

Species	Life Stage			Year	Percent Complete	MWMxT (°C)		% of MWMxT				
	Periodicity	Optimum Temperature Range (°C)	Duration (days)			Min.	Max.	Below Lower Bound by >1°C	Below Lower Bound	Between Bounds	Above Upper Bound	Above Upper Bound by >1°C
Steelhead	Spawning (Feb. 15 to Apr. 15)	10.0-15.5	60	1999-2013	100	1.6	12.5	90.8	97.9	0.7	1.4	1.1
	Incubation (Feb. 15 to Jun. 15)	10.0-12.0	121	1999-2013	100	1.6	21.8	47.1	53.2	9.5	37.3	32.9
	Rearing (Jan. 01 to Dec. 31)	16.0-18.0	365	1999-2013	88	0.0	24.4	62.6	67.8	10.7	21.5	16.6
Chinook Salmon	Migration (Sep. 23 to Nov. 23)	3.3-19.0	62	1999-2013	100	4.1	20.0	0.0	0.0	99.3	0.7	0.0
	Spawning (Oct. 01 to Nov. 30)	5.6-13.9	61	1999-2013	100	1.9	17.0	6.7	13.3	83.1	3.6	1.3
	Incubation (Oct. 15 to Apr. 30)	5.0-14.0	198	1999-2013	100	0.0	15.3	33.6	50.1	49.2	0.8	0.2
	Rearing (Mar. 07 to Jul. 23)	10.0-15.5	139	1999-2013	100	2.5	23.8	26.7	32.0	26.6	41.4	34.6
Coho Salmon	Migration (Sep. 15 to Dec. 31)	7.2-15.6	108	1999-2013	97	0.0	20.0	36.2	41.6	52.9	5.5	2.3
	Spawning (Oct. 15 to Jan. 15)	4.4-12.8	93	1999-2013	95	0.0	13.5	24.0	38.5	60.7	0.8	0.0
	Incubation (Oct. 15 to Dec. 31)	4.0-13.0	78	1999-2013	95	0.0	13.5	15.5	27.1	72.5	0.4	0.0
	Rearing (Jan. 01 to Dec. 31)	9.0-16.0	365	1999-2013	88	0.0	24.4	37.8	41.2	26.6	32.2	27.4
Pink Salmon	Migration (Aug. 01 to Oct. 15)	7.2-15.6	76	1999-2013	100	9.7	23.0	0.0	0.0	33.7	66.3	54.9
	Spawning (Sep. 15 to Oct. 15)	7.2-12.8	31	1999-2013	100	9.7	20.0	0.0	0.0	38.1	61.9	47.5
	Incubation (Sep. 15 to Apr. 07)	4.0-13.0	205	1999-2013	94	0.0	20.0	16.3	29.5	59.5	11.1	8.7

Blue shading indicates provincial guideline exceedance of the lower bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001).
Red shading indicates provincial guideline exceedance of the upper bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001).

Table 8. Mean weekly maximum temperatures (MWMxT) at *Lower Hatchery* (Map 2) in 1999–2014, compared to optimum temperature ranges for fish species. Periodicity information is from Burt (2003).

Species	Life Stage			Year	Percent	MWMxT (°C)		% of MWMxT				
	Periodicity	Optimum Temperature Range (°C)	Duration (days)		Complete	Min.	Max.	Below Lower Bound by >1°C	Below Lower Bound	Between Bounds	Above Upper Bound	Above Upper Bound by >1°C
Steelhead	Spawning (Feb. 15 to Apr. 15)	10.0-15.5	60	1999-2014	92	1.7	12.7	85.6	93.2	2.9	3.9	2.3
	Incubation (Feb. 15 to Jun. 15)	10.0-12.0	121	1999-2014	97	1.7	20.6	43.6	49.9	10.7	39.4	34.7
	Rearing (Jan. 01 to Dec. 31)	16.0-18.0	365	1999-2014	84	0.9	22.3	67.2	75.7	16.4	7.8	3.3
Chinook Salmon	Migration (Sep. 23 to Nov. 23)	3.3-19.0	62	1999-2014	96	3.4	15.2	0.0	0.0	100.0	0.0	0.0
	Spawning (Oct. 01 to Nov. 30)	5.6-13.9	61	1999-2014	98	1.9	14.2	4.3	10.3	89.7	0.0	0.0
	Incubation (Oct. 15 to Apr. 30)	5.0-14.0	198	1999-2014	96	0.9	14.9	21.7	39.6	59.9	0.5	0.0
	Rearing (Mar. 07 to Jul. 23)	10.0-15.5	139	1999-2014	94	3.3	22.3	22.7	27.8	34.7	37.6	27.4
Coho Salmon	Migration (Sep. 15 to Dec. 31)	7.2-15.6	108	1999-2014	93	0.9	16.6	36.8	46.6	52.7	0.8	0.0
	Spawning (Oct. 15 to Jan. 15)	4.4-12.8	93	1999-2014	98	0.9	13.2	15.3	31.4	68.4	0.2	0.0
	Incubation (Oct. 15 to Dec. 31)	4.0-13.0	78	1999-2014	97	0.9	13.2	7.3	21.0	78.8	0.2	0.0
	Rearing (Jan. 01 to Dec. 31)	9.0-16.0	365	1999-2014	96	0.9	22.3	15.4	25.2	69.1	5.6	3.9
Pink Salmon	Migration (Aug. 01 to Oct. 15)	7.2-15.6	76	1999-2014	93	8.1	20.5	0.0	0.0	53.7	46.3	28.7
	Spawning (Sep. 15 to Oct. 15)	7.2-12.8	31	1999-2014	98	8.1	16.6	0.0	0.0	52.7	47.3	30.8
	Incubation (Sep. 15 to Apr. 07)	4.0-13.0	205	1999-2014	95	0.9	16.6	8.3	20.9	73.3	5.8	3.5

Blue shading indicates provincial guideline exceedance of the lower bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001).
Red shading indicates provincial guideline exceedance of the upper bound of the optimum temperature range by more than 1°C (Oliver and Fidler 2001).

4.1. Summary of Key Reports Related to the Quinsam River Watershed

e) Burt (2003) *Fisheries and Aquatic Resources of the Quinsam River System: A Review of Existing Information.*

In a review of existing aquatic and fisheries information on the Quinsam River watershed up to 2003, Burt provides a detailed description of the Quinsam River watershed, ecological classification, hydroelectric activities, and land-based developments. Water quality in the Quinsam River watershed is described as nutrient poor (oligotrophic) with high clarity. The pH is alkaline throughout much of the year, but slightly acidic conditions can occur during periods of rain or snowfall. The low nutrient levels have been attributed to weathering-resistant parental rock, low rates of chemical weathering and leaching of soils, combined with high flushing rates of lakes and streams. Primary production is also low and considered to be nutrient limited (Burt 2003).

The potential impact of the Quinsam Coal Mine on water quality in the Quinsam River has been examined in multiple studies. Burt (2003) reports that iron frequently exceeds water quality objectives, with occasional exceedances of phosphorus, nitrogen, dissolved zinc, and acid rock drainage indicators (conductivity, sulphate, hardness). Sulphate increases have been noted in Long Lake and Middle Quinsam Lake, as well as near the mouth of the Quinsam River (Environment Canada 2014). Concern over elevated sulphate levels led the Ministry of Environment to undertake bioassays using fish and fish eggs; however, to date, no significant effects have been identified (Burt 2003). The potential impact of forest fertilization and Quinsam River Hatchery effluent on water quality were also reviewed, but found to have no negative effects (Burt 2003).

Burt (2003) found that summer water temperatures in the Quinsam River annually exceed the general provincial guidelines for the protection of aquatic life, but that no studies had been undertaken to examine water temperatures in relation to specific fish species and life stage criteria. The temperature analyses that we report above (Section 4.1.2.1) and present in the main JHTMON-8 Year 2 Monitoring Report contribute to addressing this knowledge gap. Burt (2003) also identified a gap in long-term temperature monitoring in reaches above Middle Quinsam Lake. Temperature monitoring in the upper reaches would allow examination of the influence of water storage and diversion on downstream temperatures (Burt 2003). We understand that no additional long-term temperature monitoring has occurred above Middle Quinsam Lake since this gap was identified.

f) Strachan *et al.* (2009) *Benthic invertebrate and water quality assessment of the Quinsam River watershed in British Columbia 2001-2006*.

In 2001, Environment Canada conducted an assessment of the biological health of the Quinsam River at the confluence with the Campbell River by incorporating benthic invertebrate biomonitoring into the routine water quality monitoring program at the Environment Canada sampling site (Map 2). Biological assessments were conducted using the Canadian Aquatic Biomonitoring Network (CABIN) protocols, which use a kick net to collect benthic invertebrate samples, identify abundance and biomass of benthic invertebrate species, and community assemblages, and then use a reference condition approach to compare invertebrate assemblages to a standardized indicator site. Results from the 2001 assessment indicated that the benthic community was "severely stressed" near the mouth. Further sampling was subsequently done annually during 2003 through 2006, with further sampling sites added to investigate spatial variations in the benthic community along the length of the river and within sites (see Map 2 for Environment Canada benthic invertebrate sampling sites). Results from 2003 again showed that the benthic community was "severely stressed" near the mouth. Results in 2004 and 2005 showed an improvement to "stressed", with a further improvement to "potentially stressed" in 2006 (Strachan *et al.* 2009). Strachan *et al.* (2009) concluded that 2001 and 2003 results were due either to nutrient enrichment from a higher than usual abundance of salmon carcasses caused by high pre-spawning mortalities, or hydrologic disturbance. Several flood events from 1997 to 1999 followed by drought in 2000 caused physical habitat disturbance to the channel that may have impacted invertebrate communities.

In all sample years, benthic community health (potentially stressed to severely stressed) was rated lower than water quality (fair to good). This disparity in ratings may be due to several factors. Water quality sampling may have missed pulses of contaminants, and water quality samples cannot account for potentially synergistic negative effects of multiple contaminants on aquatic life (Strachan *et al.* 2009). Stress on the benthic community could also be caused by factors other than water quality, including habitat disturbance, drought, or invasive species. Strachan *et al.* (2009) examined the potential impact of nutrient inputs to the Quinsam River watershed on benthic invertebrate health.

Nutrient levels, as measured by dissolved phosphorus and nitrogen concentrations, appeared to be increasing near the mouth of the Quinsam River from 1995 to 2006, and Strachan *et al.* (2009) describe the river at this location as mesotrophic, in contrast to previous oligotrophic descriptions (Burt 2003). Dissolved nitrogen concentrations were measured at six sites in the Quinsam watershed and showed an increasing trend in the lower portion of the watershed (Strachan *et al.* 2009), occasionally exceeding the trigger range for total nitrogen in oligotrophic systems (see Sections 4.1.1 and 4.1.2 for presentation and discussion of phosphorus concentrations measured at the mouth and upstream of the hatchery).

Strachan *et al.* (2009) recommends further sampling to isolate the source of nutrient inputs or habitat disturbances in the lower Quinsam, monitoring of periphyton to test for nutrient enrichment that may not be captured by grab samples of water chemistry, and careful monitoring of increased sulphate concentrations, hardness, and alkalinity in case these factors are also impacting benthic communities in the lower Quinsam watershed.

g) *Phippen (2005). Water Quality in British Columbia: Objectives Attainment in 2004*

Phippen (2005) reviewed water quality monitoring at a number of sites throughout BC to examine the attainment of water quality objectives set by the Ministry of Environment. Nutrients, dissolved oxygen, turbidity, pH, and metals were measured in Middle Quinsam Lake and Quinsam River from 1989 to 2004. Average values of measured parameters are presented in the report. Middle Quinsam Lake had excellent water quality (CCME index 97) while the Quinsam River had good water quality (CCME index 92) based on measurements between 1989 and 1993. In 2004, both water bodies had excellent water quality with a CCME index of approximately 100.

5. CONCLUSIONS AND PROPOSALS TO IMPROVE THE JHTMON-8 STUDY

5.1. Salmon River

As part of this review, funding was provided to support the compilation of water quality data collected during the Salmon River nutrient enrichment program, which ran from 1989 to 2015. There are currently no plans to continue this program due to difficulties in securing funding for watershed restoration projects that do not have a defined duration (Pellett, pers. comm. 2015). Collating these data was an important accomplishment: steelhead is a priority species for JHTMON-8, and the enrichment program is one of the longest-running stream enrichment projects in the Pacific Northwest.

Previous analysis of these data (Pellett 2011, 2014) has shown that:

- periphyton growth in the Salmon River mainstem and upper tributaries is primarily phosphorus limited during the growing season; and
- nutrient fertilization results in statistically significant increases in juvenile steelhead growth.

These results have clear relevance to JHTMON-8 null hypotheses $H_0$3 (related to water quality) and $H_0$5 (related to food availability). Given these results, we propose that:

> *Proposal 1*: future analysis of factors that influence fish abundance during JHTMON-8 should incorporate the influence of fertilization in the Salmon River watershed.

Opportunities to do this include:

- fertilizer loads should be included as a covariate in analysis of steelhead juvenile abundance data pre 2015 to help to isolate fertilizer effects;
- additionally, fertilizer effects could also be examined at the end of JHTMON-8 monitoring by conducting a before-after analysis to compare steelhead abundance and condition metrics between the periods 1998–2015 (fertilization in most years) and 2016–2023 (no fertilization expected). This would help to address $H_0$3 and $H_0$5, and could provide context to interpret the magnitude of any changes in fish populations associated with other factors (e.g., flow diversion);
- fertilizer data could also be used to examine factors that limit Coho Salmon abundance by applying the analyses described above to the juvenile Coho Salmon data collected by DFO and as part of JHTMON-8. Although the nutrient enrichment program was undertaken with a focus on steelhead, nutrient enrichment can also have benefits (albeit likely different) for juvenile Coho Salmon productivity (Johnston *et al.* 1990). There are fewer juvenile Coho Salmon sampling sites than steelhead sampling sites (see Map 2 in Year 2 Monitoring Report) but the spatial distribution of these sites (including two sites in Grilse Creek) should allow for fertilization effects to be examined; and
- there is an opportunity to use historical and future adult steelhead count data collected during JHTMON-8 to examine whether changes in water chemistry, primary productivity and juvenile steelhead growth metrics have had a positive effect on the abundance of returning adult fish. Currently, it is unknown whether the positive effects on juvenile steelhead growth due to fertilization are translated into positive effects on adult abundance, given the major effect that variable marine survival rates have on adult steelhead abundance in BC (Smith and Ward 2011).

The review of available water temperature data showed that water temperatures measured at the JHTMON-8 water quality index site are very similar to temperatures that are measured at existing gauges maintained by the Water Survey of Canada elsewhere on the mainstem. Although this implies that there is some redundancy in the water temperature data collection, we note that water temperature is an important water quality variable, and it is unknown whether other monitoring will continue throughout the duration of the JHTMON-8 program. Therefore, we propose that JHTMON-8 water temperature monitoring continue as planned.

The comparisons of water temperatures shown in Figure 8 indirectly show that water temperatures measured at the JHTMON-8 water quality index site during summer are comparable to those measured in the upper watershed (Grilse Creek) during cool summers, but overestimate water temperatures in the upper watershed during warm summers. In future years, relationships derived using these data could be used to estimate water temperatures in the upper watershed. This could help to better understand whether high water temperatures during summer adversely affect rearing conditions for juvenile steelhead and Coho Salmon in the upper watershed.

5.2. Quinsam River

The review highlighted that Environment Canada already undertake regular water quality monitoring of the Quinsam River at a site at the mouth, where monitoring has been undertaken biweekly since 1986. This program includes numerous parameters that are not within the JHTMON-8 scope (notably metals), with a focus on evaluating potential effects due to industrial operations. This monitoring has indicated that industrial operations are associated with undesirable trends in some water quality variables, although this does not currently pose a threat to aquatic life (Environment Canada 2014). Nonetheless, biological stress has been observed in benthic invertebrate communities (Strachan *et al.* 2009), and ongoing monitoring by Environment Canada may identify water quality issues that have implications for fisheries in the future. Therefore we propose that:

> *Proposal 2*: Ongoing analysis of Quinsam River water quality data undertaken by Environment Canada should be reviewed at the end of the JHTMON-8 program.

This will help to evaluate the potential for water quality effects associated with industrial activities to affect fish populations. To avoid the need for additional resources, this should be restricted to the end of the JHTMON-8 program and be limited to a review of any key documents that are published between now and the end of the monitor. Inclusion of data collected by Environment Canada in statistical analyses conducted as part of JHTMON-8 is not proposed.

Although Environment Canada is already undertaking regular water quality monitoring, this does not imply that JHTMON-8 monitoring is redundant. The JHTMON-8 water quality index site is located in the middle part of the watershed, whereas the Environment Canada site is in the lower reaches (Map 2). Thus, ongoing monitoring at these two sites provides an opportunity to evaluate longitudinal trends in water quality of the river. In particular, this could help to examine a possible ongoing trend in eutrophication in the lower river (see Figure 9).

This review highlighted that temperature monitoring by the Quinsam River Hatchery is ongoing at two sites. Analysis of data collected at these sites during 1999–2014 indicated that water temperatures are undesirably high at times for some life stages. Most notably, this was the case for the rearing life stage for Chinook Salmon and Coho Salmon, and the migration and spawning stages for Pink Salmon. Given that the JHTMON-8 water quality index site is upstream of Lower Quinsam

Lake, the sites monitored by the hatchery are generally more representative of water temperatures experienced by anadromous species; e.g., Pink Salmon and Chinook Salmon do not migrate upstream of Lower Quinsam Lake (Burt 2003) and most steelhead and Coho Salmon also spawn downstream of the lake (Burt, pers. comm. 2016). However, considered together, data collected at the hatchery sites and the JHTMON-8 site help to understand how water temperatures vary spatially in the watershed. Staff at the Quinsam River Hatchery have confirmed that they are currently willing to continue sharing water quality data to support JHTMON-8 objectives. Therefore, we propose that:

> *Proposal 3* Analysis of water temperature data collected by the Quinsam River Hatchery should be undertaken as part of JHTMON–8.

The analysis presented in 4.1.2.1 provides a template for this. To avoid the need for additional resources, this analysis can be completed once at the end of the monitor.

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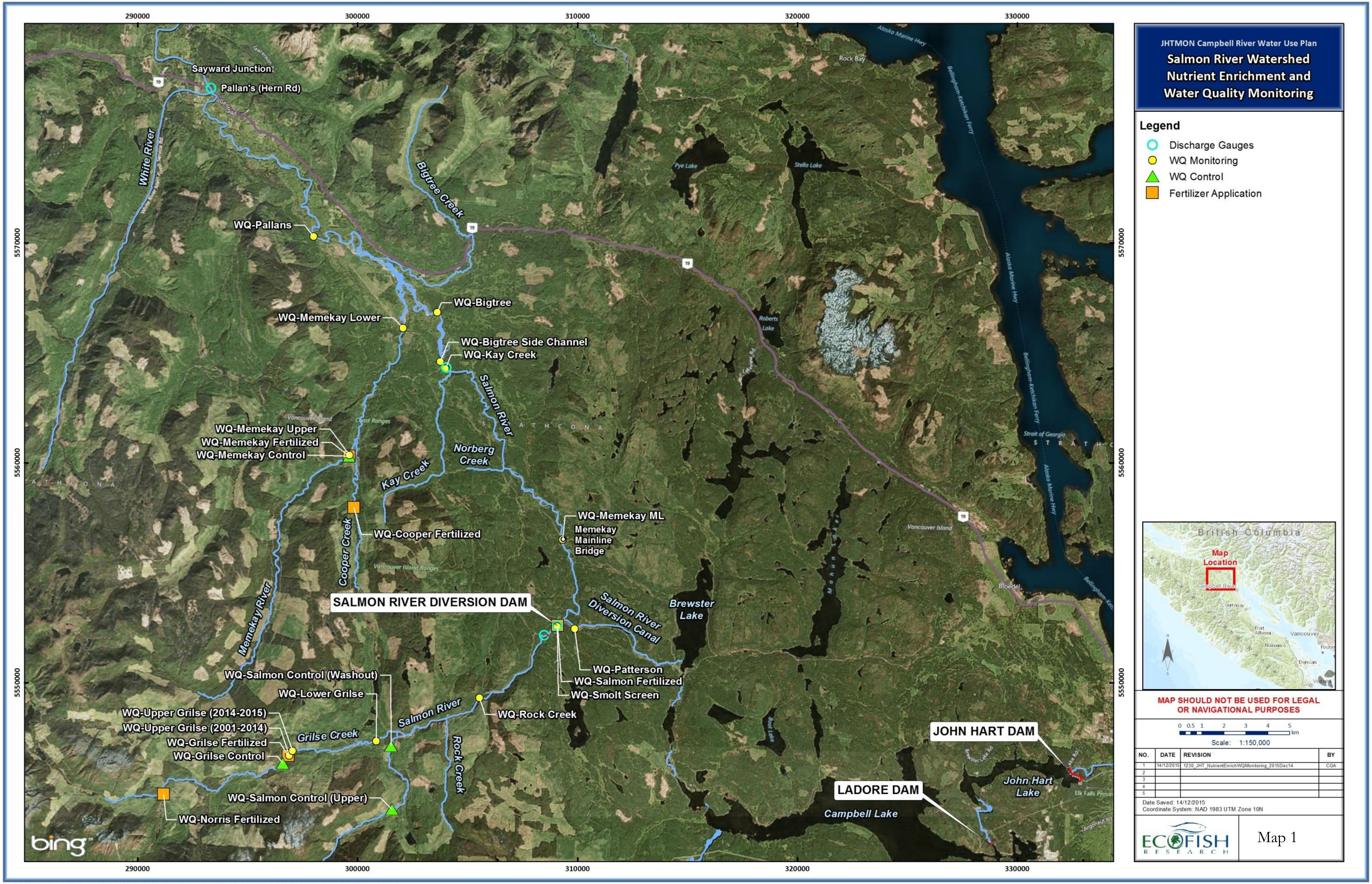

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JHTMON Campbell River Water Use Plan

Quinsam River Watershed Historical & Current Water Quality and Invertebrate Monitoring

Legend

- Discharge Gauges

Sampling Site

- Environment Canada WQ/Invertebrate
- Ecofish WQ/Invertebrate
- Quinsam River Hatchery WQ
- Dam
- Stream

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 0.5 1 2 3 4 5 km

Scale: 1:110,000

NO.	DATE	REVISION	BY
1	15/12/2015	1230_QUN_WQ_INV_Monitoring_2015Dec15	CGA
2			
3			
4			
5			

Date Saved: 15/12/2015
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 2

Path: M:\Projects-Active\1230_JHTMON\MXD\WQ\1230_QUN_WQ_INV_Monitoring_2015Dec15.mxd

Appendix B. Water Quality and Air Temperature Site Photographs for the Salmon River and the Quinsam River.

LIST OF FIGURES

Figure 1. Water temperature tidbit T1 at SAM-WQ on May 13, 2015.

Figure 2. Looking river right to river left to SAM-WQ on May 13, 2015.

Figure 3. Looking downstream from SAM-WQ on May 13, 2015.

Figure 4. Looking upstream to SAM-WQ on May 13, 2015.

Figure 5. Air temperature sensor at SAM-WQ on May 13, 2015.

Figure 6. Looking river left to river right from QUN-WQ on May 12, 2015.

Figure 7. Looking river right to river left to QUN-WQ on May 12, 2015.

Figure 8. Looking downstream from QUN-WQ on May 12, 2015.

Figure 9. Looking upstream from QUN-WQ on May 12, 2015.

Figure 10. Air temperature sensor at QUN-WQ on May 12, 2015.

Appendix C. ALS Laboratory Water Quality Results and QA/QC for the Salmon River, 2015.

ECOFISH RESEARCH LTD
ATTN: Kevin Ganshorn
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5

Date Received: 13-MAY-15
Report Date: 22-MAY-15 15:04 (MT)
Version: FINAL

Client Phone: 250-334-3042

Certificate of Analysis

Lab Work Order #: L1611677

Project P.O. #: NOT SUBMITTED
Job Reference: 1230 JHT-MON8
C of C Numbers: OL-1632
Legal Site Desc:

Ariel Tang, B.Sc.
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1611677-1	L1611677-2	L1611677-3	L1611677-4	
	Description	Water	Water	Water	Water	
	Sampled Date	13-MAY-15	13-MAY-15	13-MAY-15	13-MAY-15	
	Sampled Time	09:50	09:50	09:50	09:50	
	Client ID	SAM-FIELD BLANK	SAM-TRAVEL BLANK	SAM-WQA	SAM-WQB	
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	<2.0	<2.0	33.3	33.6	
	pH (pH)	5.50	6.77	7.33	7.42	
	Total Suspended Solids (mg/L)	<1.0	<1.0	<1.0	<1.0	
	Total Dissolved Solids (mg/L)	<10	<10	27	23	
	Turbidity (NTU)	<0.10	<0.10	0.14	0.17	
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	<2.0	<2.0	15.3	16.2	
	Ammonia, Total (as N) (mg/L)	<0.0050	0.0188	<0.0050	<0.0050	
	Nitrate (as N) (mg/L)	<0.0050	<0.0050	0.0123	0.0121	
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	
	Orthophosphate-Dissolved (as P) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	
	Phosphorus (P)-Total Dissolved (mg/L)	<0.0020	<0.0020	<0.0020	<0.0020	
	Phosphorus (P)-Total (mg/L)	<0.0020	<0.0020	<0.0020	<0.0020	

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Matrix Spike	Phosphorus (P)-Total	MS-B	L1611677-1, -2, -3, -4

Qualifiers for Individual Parameters Listed:

Qualifier	Description
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-COL-VA	Water	Alkalinity by Colourimetric (Automated)	EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-L-IC-N-VA	Water	Nitrite in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-L-IC-N-VA	Water	Nitrate in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-PRES-COL-VA	Water	Total P in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.

P-TD-COL-VA	Water	Total Dissolved P in Water by Colour	APHA 4500-P Phosphorous

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Dissolved Phosphorus is determined colourimetrically after persulphate digestion of a sample that has been lab or field filtered through a 0.45 micron membrane filter.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.

TDS-VA	Water	Total Dissolved Solids by Gravimetric	APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TSS-LOW-VA	Water	Total Suspended Solids by Grav. (1 mg/L)	APHA 2540D

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

Reference Information

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

OL-1632

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Workorder: L1611677 Report Date: 22-MAY-15

Client: ECOFISH RESEARCH LTD
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5

Contact: Kevin Ganshorn

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ALK-COL-VA	**Water**							
Batch R3190436								
WG2088831-2 CRM		**VA-ALKL-CONTROL**						
Alkalinity, Total (as CaCO3)			100.4		%		85-115	14-MAY-15
WG2088831-5 CRM		**VA-ALKM-CONTROL**						
Alkalinity, Total (as CaCO3)			102.1		%		85-115	14-MAY-15
WG2088831-8 CRM		**VA-ALKH-CONTROL**						
Alkalinity, Total (as CaCO3)			104.0		%		85-115	14-MAY-15
WG2088831-1 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	14-MAY-15
WG2088831-10 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	14-MAY-15
WG2088831-12 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	14-MAY-15
WG2088831-15 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	15-MAY-15
WG2088831-17 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	15-MAY-15
WG2088831-19 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	15-MAY-15
WG2088831-21 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	15-MAY-15
WG2088831-4 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	14-MAY-15
WG2088831-7 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	14-MAY-15
EC-PCT-VA	**Water**							
Batch R3191307								
WG2089226-17 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			99.1		%		90-110	15-MAY-15
WG2089226-18 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			97.8		%		90-110	15-MAY-15
WG2089226-19 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			98.9		%		90-110	15-MAY-15
WG2089226-20 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			98.8		%		90-110	15-MAY-15
WG2089226-21 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			99.0		%		90-110	15-MAY-15
WG2089226-22 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			99.7		%		90-110	15-MAY-15
WG2089226-1 MB								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
EC-PCT-VA	**Water**							
Batch R3191307								
WG2089226-1 MB								
Conductivity			<2.0		uS/cm		2	15-MAY-15
WG2089226-2 MB								
Conductivity			<2.0		uS/cm		2	15-MAY-15
WG2089226-3 MB								
Conductivity			<2.0		uS/cm		2	15-MAY-15
WG2089226-4 MB								
Conductivity			<2.0		uS/cm		2	15-MAY-15
WG2089226-5 MB								
Conductivity			<2.0		uS/cm		2	15-MAY-15
WG2089226-6 MB								
Conductivity			<2.0		uS/cm		2	15-MAY-15
Batch R3191978								
WG2089927-17 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			91.6		%		90-110	17-MAY-15
WG2089927-18 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			99.3		%		90-110	17-MAY-15
WG2089927-19 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			100.6		%		90-110	17-MAY-15
WG2089927-20 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.2		%		90-110	17-MAY-15
WG2089927-21 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.2		%		90-110	17-MAY-15
WG2089927-22 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			100.5		%		90-110	17-MAY-15
WG2089927-23 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.0		%		90-110	17-MAY-15
WG2089927-24 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.5		%		90-110	17-MAY-15
WG2089927-1 MB								
Conductivity			<2.0		uS/cm		2	17-MAY-15
WG2089927-2 MB								
Conductivity			<2.0		uS/cm		2	17-MAY-15
WG2089927-3 MB								
Conductivity			<2.0		uS/cm		2	17-MAY-15
WG2089927-4 MB								
Conductivity			<2.0		uS/cm		2	17-MAY-15
WG2089927-5 MB								
Conductivity			<2.0		uS/cm		2	17-MAY-15

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
EC-PCT-VA	**Water**							
Batch R3191978								
WG2089927-6 MB								
Conductivity			<2.0		uS/cm		2	17-MAY-15
WG2089927-7 MB								
Conductivity			<2.0		uS/cm		2	17-MAY-15
WG2089927-8 MB								
Conductivity			<2.0		uS/cm		2	17-MAY-15
NH3-F-VA	**Water**							
Batch R3192221								
WG2089381-2 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			95.2		%		85-115	19-MAY-15
WG2089381-4 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			105.8		%		85-115	19-MAY-15
WG2089381-6 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			95.6		%		85-115	19-MAY-15
WG2089381-8 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			104.8		%		85-115	19-MAY-15
WG2089381-1 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-MAY-15
WG2089381-3 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-MAY-15
WG2089381-5 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-MAY-15
WG2089381-7 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-MAY-15
Batch R3192255								
WG2090784-10 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			108.0		%		85-115	19-MAY-15
WG2090784-2 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			99.8		%		85-115	19-MAY-15
WG2090784-4 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			108.0		%		85-115	19-MAY-15
WG2090784-6 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			93.0		%		85-115	19-MAY-15
WG2090784-8 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			92.3		%		85-115	19-MAY-15
WG2090784-1 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-MAY-15
WG2090784-3 MB								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NH3-F-VA	**Water**							
Batch R3192255								
WG2090784-3 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-MAY-15
WG2090784-5 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-MAY-15
WG2090784-7 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-MAY-15
WG2090784-9 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-MAY-15
NO2-L-IC-N-VA	**Water**							
Batch R3189926								
WG2088102-15 LCS								
Nitrite (as N)			101.9		%		90-110	14-MAY-15
WG2088102-2 LCS								
Nitrite (as N)			102.0		%		90-110	14-MAY-15
WG2088102-1 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	14-MAY-15
WG2088102-10 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	14-MAY-15
WG2088102-13 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	14-MAY-15
WG2088102-4 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	14-MAY-15
WG2088102-7 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	14-MAY-15
NO3-L-IC-N-VA	**Water**							
Batch R3189926								
WG2088102-15 LCS								
Nitrate (as N)			101.4		%		90-110	14-MAY-15
WG2088102-2 LCS								
Nitrate (as N)			101.1		%		90-110	14-MAY-15
WG2088102-1 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	14-MAY-15
WG2088102-10 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	14-MAY-15
WG2088102-13 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	14-MAY-15
WG2088102-4 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	14-MAY-15

Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO3-L-IC-N-VA	**Water**							
Batch R3189926								
WG2088102-7 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	14-MAY-15
P-T-PRES-COL-VA	**Water**							
Batch R3190813								
WG2088125-10 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			108.7		%		80-120	15-MAY-15
WG2088125-2 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			102.5		%		80-120	15-MAY-15
WG2088125-6 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			102.9		%		80-120	15-MAY-15
WG2088125-1 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	15-MAY-15
WG2088125-5 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	15-MAY-15
WG2088125-9 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	15-MAY-15
WG2088125-12 MS		**L1611677-1**						
Phosphorus (P)-Total			96.8		%		70-130	15-MAY-15
P-TD-COL-VA	**Water**							
Batch R3190801								
WG2088923-2 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total Dissolved			107.6		%		80-120	15-MAY-15
WG2088923-6 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total Dissolved			110.9		%		80-120	15-MAY-15
WG2088923-3 DUP		**L1611677-3**						
Phosphorus (P)-Total Dissolved		<0.0020	<0.0020	RPD-NA	mg/L	N/A	20	15-MAY-15
WG2088923-1 MB								
Phosphorus (P)-Total Dissolved			<0.0020		mg/L		0.002	15-MAY-15
WG2088923-5 MB								
Phosphorus (P)-Total Dissolved			<0.0020		mg/L		0.002	15-MAY-15
WG2088923-4 MS		**L1611677-4**						
Phosphorus (P)-Total Dissolved			99.8		%		70-130	15-MAY-15
PH-PCT-VA	**Water**							
Batch R3191307								
WG2089226-25 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	15-MAY-15
WG2089226-26 CRM		**VA-PH7-BUF**						

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PH-PCT-VA	**Water**							
Batch R3191307								
WG2089226-26 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	15-MAY-15
WG2089226-27 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	15-MAY-15
WG2089226-28 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	15-MAY-15
WG2089226-29 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	15-MAY-15
WG2089226-30 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	15-MAY-15
Batch R3191978								
WG2089927-25 CRM		**VA-PH7-BUF**						
pH			7.06		pH		6.9-7.1	17-MAY-15
WG2089927-26 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	17-MAY-15
WG2089927-27 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	17-MAY-15
WG2089927-28 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	17-MAY-15
WG2089927-29 CRM		**VA-PH7-BUF**						
pH			7.00		pH		6.9-7.1	17-MAY-15
WG2089927-30 CRM		**VA-PH7-BUF**						
pH			6.99		pH		6.9-7.1	17-MAY-15
WG2089927-31 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	17-MAY-15
WG2089927-32 CRM		**VA-PH7-BUF**						
pH			6.98		pH		6.9-7.1	17-MAY-15
PO4-DO-COL-VA	**Water**							
Batch R3190218								
WG2088517-2 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			91.1		%		80-120	14-MAY-15
WG2088517-6 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			90.6		%		80-120	14-MAY-15
WG2088517-1 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	14-MAY-15
WG2088517-5 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	14-MAY-15
TDS-VA	**Water**							

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
TDS-VA	**Water**							
Batch R3192823								
WG2090547-2 LCS								
Total Dissolved Solids			100.8		%		85-115	19-MAY-15
WG2090547-5 LCS								
Total Dissolved Solids			102.8		%		85-115	19-MAY-15
WG2090547-8 LCS								
Total Dissolved Solids			103.8		%		85-115	19-MAY-15
WG2090547-1 MB								
Total Dissolved Solids			<10		mg/L		10	19-MAY-15
WG2090547-4 MB								
Total Dissolved Solids			<10		mg/L		10	19-MAY-15
WG2090547-7 MB								
Total Dissolved Solids			<10		mg/L		10	19-MAY-15
TSS-LOW-VA	**Water**							
Batch R3192477								
WG2090831-2 LCS								
Total Suspended Solids			98.3		%		85-115	19-MAY-15
WG2090831-4 LCS								
Total Suspended Solids			98.3		%		85-115	19-MAY-15
WG2090831-1 MB								
Total Suspended Solids			<1.0		mg/L		1	19-MAY-15
WG2090831-3 MB								
Total Suspended Solids			<1.0		mg/L		1	19-MAY-15
TURBIDITY-VA	**Water**							
Batch R3190385								
WG2088806-11 CRM		**VA-FORM-40**						
Turbidity			98.8		%		85-115	14-MAY-15
WG2088806-14 CRM		**VA-FORM-40**						
Turbidity			98.5		%		85-115	14-MAY-15
WG2088806-17 CRM		**VA-FORM-40**						
Turbidity			99.0		%		85-115	14-MAY-15
WG2088806-2 CRM		**VA-FORM-40**						
Turbidity			97.8		%		85-115	14-MAY-15
WG2088806-5 CRM		**VA-FORM-40**						
Turbidity			100.0		%		85-115	14-MAY-15
WG2088806-8 CRM		**VA-FORM-40**						
Turbidity			98.8		%		85-115	14-MAY-15
WG2088806-1 MB								
Turbidity			<0.10		NTU		0.1	14-MAY-15

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
TURBIDITY-VA	**Water**							
Batch R3190385								
WG2088806-10 MB								
Turbidity			<0.10		NTU		0.1	14-MAY-15
WG2088806-13 MB								
Turbidity			<0.10		NTU		0.1	14-MAY-15
WG2088806-16 MB								
Turbidity			<0.10		NTU		0.1	14-MAY-15
WG2088806-4 MB								
Turbidity			<0.10		NTU		0.1	14-MAY-15
WG2088806-7 MB								
Turbidity			<0.10		NTU		0.1	14-MAY-15

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
J	Duplicate results and limits are expressed in terms of absolute difference.
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH by Meter (Automated)							
	1	13-MAY-15 09:50	17-MAY-15 12:21	0.25	98	hours	EHTR-FM
	2	13-MAY-15 09:50	15-MAY-15 23:00	0.25	61	hours	EHTR-FM
	3	13-MAY-15 09:50	15-MAY-15 23:00	0.25	61	hours	EHTR-FM
	4	13-MAY-15 09:50	15-MAY-15 23:00	0.25	61	hours	EHTR-FM

Legend & Qualifier Definitions:

EHTR-FM:	Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR:	Exceeded ALS recommended hold time prior to sample receipt.
EHTL:	Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT:	Exceeded ALS recommended hold time prior to analysis.
Rec. HT:	ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1611677 were received on 13-MAY-15 19:55.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

L1611677-COFC

ALS Environ[mental]

[C]hain of Custody / Analytical Request Form
Canada Toll Free : 1 800 668 9878
www.alsglobal.com

COC #: OL-1632

Report To

Company:	ECOFISH RESEARCH LTD
Contact:	Kevin Ganshorn
Address:	Suite F, 450 - 8th Street Courtenay, BC Canada, V9N 1N5
Phone:	250-334-3042
Fax:	250-334-3097

Invoice To ☑Email ☐Mail

Company:	ECOFISH RESEARCH LTD
Contact:	Accounts Payable
Address:	Suite F, 450 - 8th Street Courtenay, BC Canada, V9N 1N5
Email:	accountspayable@ecofishresearch.com
Phone:	250-334-3042

Lab Work Order # (lab use only)

Reporting

Distribution:	☐Fax ☐Mail ☑Email
☐Criteria on Report (select from Guidelines below)	
Report Type:	☑Excel ☑Digital
Report Format:	CROSSTAB_ALSQC
Report Email(s):	kganshorn@ecofishresearch.com tkasubuchi@ecofishresearch.com
EDD Format:	ECF100
EDD Email(s):	kganshorn@ecofishresearch.com bbennett@ecofishresearch.com tkasubuchi@ecofishresearch.com

Project Info

Job #:	1230 JHT-MON8
PO/AFE:	
LSD:	
Quote #:	
ALS Contact:	Ariel Tang, B.Sc.
Sampler:	Leah Hull

Service Requested

- ⊙ Regular (Standard Turnaround Times - Business Days) - R
- ○ Priority (3 Days) - surcharge will apply - P
- ○ Priority (2 Days) - surcharge will apply - P2
- ○ Emergency (1-2 day) – surcharge will apply - E
- ○ Same Day or Weekend Emergency - surcharge will apply - E2
- ○ Specify date required - X

Analysis Requests

Please indicate below Filtered, Preserved or both(F, P, F/P)

Sample #	Sample Identification (This will appear on the report)	Longitude	Latitude	Date	Time	Sample Type	Number of Containers	Alkalinity by Colourimetric (Automated)	Ammonia in Water by Fluorescence	Conductivity (Automated)	Diss. Orthophosphate in Water by Colour	Nitrate in Water by Ion Chromatography	Nitrite in Water by Ion Chromatography	Total Dissolved P in Water by Colour	Total Dissolved Solids by Gravimetric	Total P in Water by Colour	Total Suspended Solids by Grav. (1 mg/L)	Turbidity by Meter	pH by Meter (Automated)
	SAM-FIELD BLANK			13-May-2015	9:50	Water	3	R	R	R	R	R	R	R	R	R	R	R	R
	SAM-TRAVEL BLANK			↓	↓	Water	3	R	R	R	R	R	R	R	R	R	R	R	R
	SAM-WQA			↓	↓	Water	3	R	R	R	R	R	R	R	R	R	R	R	R
	SAM-WQB			↓	↓	Water	3	R	R	R	R	R	R	R	R	R	R	R	R

Short Holding Time

Rush Processing

May 2015 Sampling

The questions below must be answered for water samples (check Yes or No)

Are any sample taken from a regulated DW system? ☐Yes ☒No

If yes, please use an authorized drinking water COC

Is the water sampled intended to be potable for human consumption? ☐Yes ☒No

Guidelines

SAMPLE CONDITION (lab use only)

☐Frozen ☐Cold ☐Ambient ☐Cooling Initiated

SHIPMENT RELEASE (client use)		
Released by: Leah Hull	Date: 13-May 2015	Time: 14:00

SHIPMENT RECEPTION (lab use only)			
Received by: Boren	Date: May 13	Time: 1955	Temperature: 8 °C

SHIPMENT VERIFICATION (lab use only)			
Verified by:	Date:	Time:	Observations: ☐Yes If Yes add SIF

ECOFISH RESEARCH LTD
ATTN: Kevin Ganshorn
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5

Date Received: 16-JUN-15
Report Date: 24-JUN-15 16:12 (MT)
Version: FINAL

Client Phone: 250-334-3042

Certificate of Analysis

Lab Work Order #: L1627899

Project P.O. #: NOT SUBMITTED
Job Reference: 1230 JHT-MON8
C of C Numbers: OL-1634
Legal Site Desc:

Ariel Tang, B.Sc.
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1627899-1	L1627899-2	L1627899-3	L1627899-4	
	Description	Water	Water	Water	Water	
	Sampled Date	16-JUN-15	16-JUN-15	16-JUN-15	16-JUN-15	
	Sampled Time	09:33	09:33	09:33	09:33	
	Client ID	SAM-FIELD BLANK	SAM-TRAVEL BLANK	SAM-WQA	SAM-WQB	
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	<2.0	<2.0	47.8	47.7	
	pH (pH)	6.32	6.22	7.65	7.66	
	Total Suspended Solids (mg/L)	<1.0	<1.0	<1.0	<1.0	
	Total Dissolved Solids (mg/L)	<10	<10	33	31	
	Turbidity (NTU)	0.10	<0.10	0.11	0.11	
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	<2.0	<2.0	22.4	20.8	
	Ammonia, Total (as N) (mg/L)	<0.0050	0.0436 RRV	<0.0050	<0.0050	
	Nitrate (as N) (mg/L)	<0.0050	<0.0050	0.0528	0.0528	
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	
	Orthophosphate-Dissolved (as P) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	
	Phosphorus (P)-Total (mg/L)	<0.0020	<0.0020	<0.0020	<0.0020	

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Duplicate	Nitrite (as N)	DLM	L1627899-1, -2, -3, -4
Duplicate	Nitrite (as N)	DLM	L1627899-1, -2, -3, -4
Duplicate	Nitrite (as N)	DLM	L1627899-1, -2, -3, -4
Duplicate	Nitrate (as N)	DLM	L1627899-1, -2, -3, -4

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLM	Detection Limit Adjusted due to sample matrix effects.
RRV	Reported Result Verified By Repeat Analysis

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-COL-VA	Water	Alkalinity by Colourimetric (Automated)	EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	APHA 4500 NH3-NITROGEN (AMMONIA)

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-L-IC-N-VA	Water	Nitrite in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-L-IC-N-VA	Water	Nitrate in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-PRES-COL-VA	Water	Total P in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.

TDS-VA	Water	Total Dissolved Solids by Gravimetric	APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TSS-LOW-VA	Water	Total Suspended Solids by Grav. (1 mg/L)	APHA 2540D

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

Reference Information

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

OL-1634

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Client: ECOFISH RESEARCH LTD
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5

Contact: Kevin Ganshorn

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ALK-COL-VA	**Water**							
Batch R3212993								
WG2112433-2 CRM		**VA-ALKL-CONTROL**						
Alkalinity, Total (as CaCO3)			99.4		%		85-115	20-JUN-15
WG2112433-5 CRM		**VA-ALKM-CONTROL**						
Alkalinity, Total (as CaCO3)			93.8		%		85-115	20-JUN-15
WG2112433-8 CRM		**VA-ALKH-CONTROL**						
Alkalinity, Total (as CaCO3)			106.5		%		85-115	20-JUN-15
WG2112433-1 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-JUN-15
WG2112433-10 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-JUN-15
WG2112433-4 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-JUN-15
WG2112433-7 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-JUN-15
Batch R3214036								
WG2115563-2 CRM		**VA-ALKL-CONTROL**						
Alkalinity, Total (as CaCO3)			99.5		%		85-115	24-JUN-15
WG2115563-1 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUN-15
EC-PCT-VA	**Water**							
Batch R3212352								
WG2113106-17 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			106.9		%		90-110	21-JUN-15
WG2113106-18 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			103.8		%		90-110	21-JUN-15
WG2113106-19 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			104.6		%		90-110	21-JUN-15
WG2113106-20 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			106.3		%		90-110	21-JUN-15
WG2113106-21 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			105.2		%		90-110	21-JUN-15
WG2113106-22 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			105.1		%		90-110	21-JUN-15
WG2113106-23 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			106.5		%		90-110	21-JUN-15
WG2113106-24 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			106.5		%		90-110	21-JUN-15
WG2113106-36 DUP		**L1627899-3**						

Quality Control Report

Test		Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
EC-PCT-VA		**Water**							
Batch	**R3212352**								
WG2113106-36	**DUP**		**L1627899-3**						
Conductivity			47.8	47.6		uS/cm	0.4	10	21-JUN-15
WG2113106-1	**MB**								
Conductivity				<2.0		uS/cm		2	21-JUN-15
WG2113106-2	**MB**								
Conductivity				<2.0		uS/cm		2	21-JUN-15
WG2113106-3	**MB**								
Conductivity				<2.0		uS/cm		2	21-JUN-15
WG2113106-4	**MB**								
Conductivity				<2.0		uS/cm		2	21-JUN-15
WG2113106-5	**MB**								
Conductivity				<2.0		uS/cm		2	21-JUN-15
WG2113106-6	**MB**								
Conductivity				<2.0		uS/cm		2	21-JUN-15
WG2113106-7	**MB**								
Conductivity				<2.0		uS/cm		2	21-JUN-15
WG2113106-8	**MB**								
Conductivity				<2.0		uS/cm		2	21-JUN-15
NH3-F-VA		**Water**							
Batch	**R3212974**								
WG2113977-2	**CRM**		**VA-NH3-F**						
Ammonia, Total (as N)				94.8		%		85-115	23-JUN-15
WG2113977-4	**CRM**		**VA-NH3-F**						
Ammonia, Total (as N)				95.1		%		85-115	23-JUN-15
WG2113977-6	**CRM**		**VA-NH3-F**						
Ammonia, Total (as N)				102.7		%		85-115	23-JUN-15
WG2113977-1	**MB**								
Ammonia, Total (as N)				<0.0050		mg/L		0.005	23-JUN-15
WG2113977-3	**MB**								
Ammonia, Total (as N)				<0.0050		mg/L		0.005	23-JUN-15
WG2113977-5	**MB**								
Ammonia, Total (as N)				<0.0050		mg/L		0.005	23-JUN-15
Batch	**R3213232**								
WG2114424-2	**CRM**		**VA-NH3-F**						
Ammonia, Total (as N)				101.5		%		85-115	23-JUN-15
WG2114424-4	**CRM**		**VA-NH3-F**						
Ammonia, Total (as N)				95.8		%		85-115	23-JUN-15
WG2114424-6	**CRM**		**VA-NH3-F**						

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NH3-F-VA	**Water**							
Batch R3213232								
WG2114424-6 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			100.1		%		85-115	23-JUN-15
WG2114424-8 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			97.4		%		85-115	23-JUN-15
WG2114424-1 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	23-JUN-15
WG2114424-3 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	23-JUN-15
WG2114424-5 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	23-JUN-15
WG2114424-7 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	23-JUN-15
NO2-L-IC-N-VA	**Water**							
Batch R3209358								
WG2109945-18 LCS								
Nitrite (as N)			99.9		%		90-110	17-JUN-15
WG2109945-2 LCS								
Nitrite (as N)			100.2		%		90-110	17-JUN-15
WG2109945-1 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-JUN-15
WG2109945-10 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-JUN-15
WG2109945-13 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-JUN-15
WG2109945-16 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-JUN-15
WG2109945-4 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-JUN-15
WG2109945-7 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-JUN-15
WG2109945-8 MS		**L1627899-2**						
Nitrite (as N)			99.9		%		75-125	17-JUN-15
NO3-L-IC-N-VA	**Water**							
Batch R3209358								
WG2109945-18 LCS								
Nitrate (as N)			102.5		%		90-110	17-JUN-15
WG2109945-2 LCS								
Nitrate (as N)			102.6		%		90-110	17-JUN-15

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO3-L-IC-N-VA	**Water**							
Batch R3209358								
WG2109945-1 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-JUN-15
WG2109945-10 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-JUN-15
WG2109945-13 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-JUN-15
WG2109945-16 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-JUN-15
WG2109945-4 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-JUN-15
WG2109945-7 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-JUN-15
WG2109945-8 MS		**L1627899-2**						
Nitrate (as N)			102.6		%		75-125	17-JUN-15
P-T-PRES-COL-VA	**Water**							
Batch R3212440								
WG2112922-10 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			102.2		%		80-120	21-JUN-15
WG2112922-2 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			98.9		%		80-120	21-JUN-15
WG2112922-6 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			98.1		%		80-120	21-JUN-15
WG2112922-1 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	21-JUN-15
WG2112922-5 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	21-JUN-15
WG2112922-9 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	21-JUN-15
PH-PCT-VA	**Water**							
Batch R3212352								
WG2113106-25 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	21-JUN-15
WG2113106-26 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	21-JUN-15
WG2113106-27 CRM		**VA-PH7-BUF**						
pH			6.99		pH		6.9-7.1	21-JUN-15
WG2113106-28 CRM		**VA-PH7-BUF**						
pH			6.98		pH		6.9-7.1	21-JUN-15

Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PH-PCT-VA	**Water**							
Batch R3212352								
WG2113106-29 CRM		**VA-PH7-BUF**						
pH			6.96		pH		6.9-7.1	21-JUN-15
WG2113106-30 CRM		**VA-PH7-BUF**						
pH			6.95		pH		6.9-7.1	21-JUN-15
WG2113106-36 DUP		**L1627899-3**						
pH		7.65	7.68	J	pH	0.03	0.3	21-JUN-15
Batch R3213279								
WG2114100-25 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	23-JUN-15
WG2114100-26 CRM		**VA-PH7-BUF**						
pH			7.04		pH		6.9-7.1	23-JUN-15
PO4-DO-COL-VA	**Water**							
Batch R3208865								
WG2109737-10 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			92.1		%		80-120	16-JUN-15
WG2109737-14 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			95.6		%		80-120	16-JUN-15
WG2109737-18 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			94.9		%		80-120	16-JUN-15
WG2109737-2 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			99.1		%		80-120	16-JUN-15
WG2109737-23 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			97.3		%		80-120	16-JUN-15
WG2109737-6 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			98.1		%		80-120	16-JUN-15
WG2109737-1 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-JUN-15
WG2109737-13 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-JUN-15
WG2109737-17 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-JUN-15
WG2109737-22 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-JUN-15
WG2109737-5 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-JUN-15
WG2109737-9 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-JUN-15
TDS-VA	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
TDS-VA	**Water**							
Batch R3213493								
WG2113519-11 LCS								
Total Dissolved Solids			98.2		%		85-115	22-JUN-15
WG2113519-2 LCS								
Total Dissolved Solids			104.1		%		85-115	22-JUN-15
WG2113519-5 LCS								
Total Dissolved Solids			99.6		%		85-115	22-JUN-15
WG2113519-8 LCS								
Total Dissolved Solids			98.5		%		85-115	22-JUN-15
WG2113519-1 MB								
Total Dissolved Solids			<10		mg/L		10	22-JUN-15
WG2113519-10 MB								
Total Dissolved Solids			<10		mg/L		10	22-JUN-15
WG2113519-4 MB								
Total Dissolved Solids			<10		mg/L		10	22-JUN-15
WG2113519-7 MB								
Total Dissolved Solids			<10		mg/L		10	22-JUN-15
TSS-LOW-VA	**Water**							
Batch R3211494								
WG2111230-2 LCS								
Total Suspended Solids			112.0		%		85-115	18-JUN-15
WG2111230-4 LCS								
Total Suspended Solids			93.3		%		85-115	18-JUN-15
WG2111230-1 MB								
Total Suspended Solids			<1.0		mg/L		1	18-JUN-15
WG2111230-3 MB								
Total Suspended Solids			<1.0		mg/L		1	18-JUN-15
TURBIDITY-VA	**Water**							
Batch R3210767								
WG2112042-2 CRM		**VA-FORM-40**						
Turbidity			98.0		%		85-115	19-JUN-15
WG2112042-5 CRM		**VA-FORM-40**						
Turbidity			99.5		%		85-115	19-JUN-15
WG2112042-8 CRM		**VA-FORM-40**						
Turbidity			98.8		%		85-115	19-JUN-15
WG2112042-3 DUP		**L1627899-3**						
Turbidity		0.11	0.10		NTU	2.8	15	19-JUN-15
WG2112042-1 MB								
Turbidity			<0.10		NTU		0.1	19-JUN-15

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
TURBIDITY-VA	**Water**							
Batch R3210767								
WG2112042-4 MB								
Turbidity			<0.10		NTU		0.1	19-JUN-15
WG2112042-7 MB								
Turbidity			<0.10		NTU		0.1	19-JUN-15

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
DLM	Detection Limit Adjusted due to sample matrix effects.
J	Duplicate results and limits are expressed in terms of absolute difference.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Quality Control Report

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH by Meter (Automated)							
	1	16-JUN-15 09:33	23-JUN-15 15:31	0.25	174	hours	EHTR-FM
	2	16-JUN-15 09:33	23-JUN-15 15:31	0.25	174	hours	EHTR-FM
	3	16-JUN-15 09:33	21-JUN-15 23:00	0.25	133	hours	EHTR-FM
	4	16-JUN-15 09:33	21-JUN-15 23:00	0.25	133	hours	EHTR-FM

Legend & Qualifier Definitions:

EHTR-FM:	Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR:	Exceeded ALS recommended hold time prior to sample receipt.
EHTL:	Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT:	Exceeded ALS recommended hold time prior to analysis.
Rec. HT:	ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1627899 were received on 16-JUN-15 17:30.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

L1627899-COFC

ALS Environmental

Chain of Custody / Analytical Request Form
Canada Toll Free : 1 800 668 9878
www.alsglobal.com

COC #: OL-1634

Report To

Company: ECOFISH RESEARCH LTD
Contact: Kevin Ganshorn
Address: Suite 906 - 595 Howe Street
Vancouver, BC
Canada, V6C 2T5
Phone: 604-608-6180 Fax:

Invoice To ☑Email ☐Mail
Company: ECOFISH RESEARCH LTD
Contact: Accounts Payable
Address: Suite F, 450 - 8th Street
Courtenay, BC
Canada, V9N 1N5
Email: accountspayable@ecofishresearch.com
Phone: 250-334-3042

Lab Work Order # (lab use only)

Reporting

Distribution: ☐Fax ☐Mail ☑Email
☐ Ciriteria on Report (select from Guidelines below)
Report Type: ☑Excel ☑Digital
Report Format: CROSSTAB_ALSQC
Report Email(s): kganshorn@ecofishresearch.com
tkasubuchi@ecofishresearch.com
EDD Format: ECF100
EDD Email(s): kganshorn@ecofishresearch.com
bbennett@ecofishresearch.com
tkasubuchi@ecofishresearch.com

Project Info

Job #: 1230 JHT-MON8
PO/AFE:
LSD:
Quote #:
ALS Contact: Ariel Tang, B.Sc. Sampler: LEAH HULL

Service Requested

- ⊙ Regular (Standard Turnaround Times - Business Days) - R
- ○ Priority (3 Days) - surcharge will apply - P
- ○ Priority (2 Days) - surcharge will apply - P2
- ○ Emergency (1-2 day) – surcharge will apply - E
- ○ Same Day or Weekend Emergency - surcharge will apply - E2
- ○ Specify date required - X

Analysis Requests

Please indicate below Filtered, Preserved or both(F, P, F/P)

Sample #	Sample Identification (This will appear on the report)	Longitude	Latitude	Date	Time	Sample Type	Number of Containers	Alkalinity by Colourimetric (Automated)	Ammonia in Water by Fluorescence	Conductivity (Automated)	Diss. Orthophosphate in Water by Colour	Nitrate in Water by Ion Chromatography	Nitrite in Water by Ion Chromatography	Total Dissolved Solids by Gravimetric	Total P in Water by Colour	Total Suspended Solids by Grav. (1 mg/L)	Turbidity by Meter	pH by Meter (Automated)
	SAM-FIELD BLANK			16-June-2015	09:33	WATER	3	R	R	R	R	R	R	R	R	R	R	R
	SAM-TRAVEL BLANK			↓	↓	WATER	3	R	R	R	R	R	R	R	R	R	R	R
	SAM-WQA			↓	↓	WATER	3	R	R	R	R	R	R	R	R	R	R	R
	SAM-WQB			↓	↓	WATER	3	R	R	R	R	R	R	R	R	R	R	R

Short Holding Time

Rush Processing

Special Instructions/Co...

June 2015 Sampling

The questions below must be answered for water samples (check Yes or No)

Are any sample taken from a regulated DW system? ☐Yes ☒No
If yes, please use an authorized drinking water COC
Is the water sampled intended to be potable for human consumption? ☐Yes ☒No

Guidelines

SAMPLE CONDITION (lab use only)
☐Frozen ☐Cold ☐Ambient ☐Cooling Initiated

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by: Leah Hull	Date: 16-June-2015	Time: 14:00	Received by: [signature]	Date: June 16	Time: 17:30	Temperature: 6 °C	Verified by:	Date:	Time:	Observations: ☐Yes If Yes add SIF

ECOFISH RESEARCH LTD
ATTN: Kevin Ganshorn
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5

Date Received: 23-JUL-15
Report Date: 31-JUL-15 11:29 (MT)
Version: FINAL

Client Phone: 250-334-3042

Certificate of Analysis

Lab Work Order #: L1647351

Project P.O. #: NOT SUBMITTED
Job Reference: 1230-08.40.08
C of C Numbers: OL-1636
Legal Site Desc:

Ariel Tang, B.Sc.
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID Description Sampled Date Sampled Time Client ID	L1647351-1 WATER 22-JUL-15 09:57 SAM-WQA	L1647351-2 WATER 22-JUL-15 09:57 SAM-WQB			
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	64.8	55.0			
	pH (pH)	7.70	7.68			
	Total Suspended Solids (mg/L)	<1.0	<1.0			
	Total Dissolved Solids (mg/L)	32	31			
	Turbidity (NTU)	0.13	0.12			
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	22.6	23.5			
	Ammonia, Total (as N) (mg/L)	<0.0050	<0.0050			
	Nitrate (as N) (mg/L)	0.0254	0.0246			
	Nitrite (as N) (mg/L)	<0.0010	<0.0010			
	Orthophosphate-Dissolved (as P) (mg/L)	<0.0010	<0.0010			
	Phosphorus (P)-Total (mg/L)	<0.0020	<0.0020			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Duplicate	Nitrite (as N)	DLM	L1647351-1, -2
Matrix Spike	Orthophosphate-Dissolved (as P)	MS-B	L1647351-1, -2

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLM	Detection Limit Adjusted due to sample matrix effects.
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**

ALK-COL-VA | Water | Alkalinity by Colourimetric (Automated) | EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

EC-PCT-VA | Water | Conductivity (Automated) | APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

NH3-F-VA | Water | Ammonia in Water by Fluorescence | APHA 4500 NH3-NITROGEN (AMMONIA)

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NH3-F-VA | Water | Ammonia in Water by Fluorescence | J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-L-IC-N-VA | Water | Nitrite in Water by IC (Low Level) | EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-L-IC-N-VA | Water | Nitrate in Water by IC (Low Level) | EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-PRES-COL-VA | Water | Total P in Water by Colour | APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.

PH-PCT-VA | Water | pH by Meter (Automated) | APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PH-PCT-VA | Water | pH by Meter (Automated) | APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PO4-DO-COL-VA | Water | Diss. Orthophosphate in Water by Colour | APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.

TDS-VA | Water | Total Dissolved Solids by Gravimetric | APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TSS-LOW-VA | Water | Total Suspended Solids by Grav. (1 mg/L) | APHA 2540D

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.

TURBIDITY-VA | Water | Turbidity by Meter | APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

TURBIDITY-VA | Water | Turbidity by Meter | APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

Reference Information

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

OL-1636

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Client: ECOFISH RESEARCH LTD
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5
Contact: Kevin Ganshorn

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ALK-COL-VA	**Water**							
Batch R3232386								
WG2136101-2 CRM		**VA-ALKL-CONTROL**						
Alkalinity, Total (as CaCO3)			107.0		%		85-115	24-JUL-15
WG2136101-5 CRM		**VA-ALKM-CONTROL**						
Alkalinity, Total (as CaCO3)			101.9		%		85-115	24-JUL-15
WG2136101-8 CRM		**VA-ALKH-CONTROL**						
Alkalinity, Total (as CaCO3)			102.8		%		85-115	24-JUL-15
WG2136101-1 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUL-15
WG2136101-10 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUL-15
WG2136101-4 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUL-15
WG2136101-7 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUL-15
EC-PCT-VA	**Water**							
Batch R3233226								
WG2136634-17 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.9		%		90-110	27-JUL-15
WG2136634-18 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			100.9		%		90-110	27-JUL-15
WG2136634-19 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.8		%		90-110	27-JUL-15
WG2136634-20 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.4		%		90-110	27-JUL-15
WG2136634-21 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			103.9		%		90-110	27-JUL-15
WG2136634-22 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.9		%		90-110	27-JUL-15
WG2136634-23 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			103.7		%		90-110	27-JUL-15
WG2136634-1 MB								
Conductivity			<2.0		uS/cm		2	27-JUL-15
WG2136634-2 MB								
Conductivity			<2.0		uS/cm		2	27-JUL-15
WG2136634-3 MB								
Conductivity			<2.0		uS/cm		2	27-JUL-15
WG2136634-4 MB								
Conductivity			<2.0		uS/cm		2	27-JUL-15
WG2136634-5 MB								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
EC-PCT-VA	**Water**							
Batch R3233226								
WG2136634-5 MB								
Conductivity			<2.0		uS/cm		2	27-JUL-15
WG2136634-6 MB								
Conductivity			<2.0		uS/cm		2	27-JUL-15
WG2136634-7 MB								
Conductivity			<2.0		uS/cm		2	27-JUL-15
NH3-F-VA	**Water**							
Batch R3234326								
WG2137561-2 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			103.8		%		85-115	28-JUL-15
WG2137561-4 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			99.4		%		85-115	28-JUL-15
WG2137561-6 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			103.8		%		85-115	28-JUL-15
WG2137561-8 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			99.8		%		85-115	28-JUL-15
WG2137561-1 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	28-JUL-15
WG2137561-3 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	28-JUL-15
WG2137561-5 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	28-JUL-15
WG2137561-7 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	28-JUL-15
NO2-L-IC-N-VA	**Water**							
Batch R3233253								
WG2135645-6 DUP		**L1647351-2**						
Nitrite (as N)		<0.0010	<0.0010	RPD-NA	mg/L	N/A	20	24-JUL-15
WG2135645-14 LCS								
Nitrite (as N)			100.6		%		90-110	24-JUL-15
WG2135645-2 LCS								
Nitrite (as N)			100.8		%		90-110	24-JUL-15
WG2135645-1 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	24-JUL-15
WG2135645-10 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	24-JUL-15
WG2135645-13 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	24-JUL-15

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO2-L-IC-N-VA	**Water**							
Batch R3233253								
WG2135645-4 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	24-JUL-15
WG2135645-7 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	24-JUL-15
WG2135645-8 MS		**L1647351-1**						
Nitrite (as N)			97.8		%		75-125	24-JUL-15
NO3-L-IC-N-VA	**Water**							
Batch R3233253								
WG2135645-6 DUP		**L1647351-2**						
Nitrate (as N)		0.0246	0.0246		mg/L	0.1	20	24-JUL-15
WG2135645-14 LCS								
Nitrate (as N)			101.3		%		90-110	24-JUL-15
WG2135645-2 LCS								
Nitrate (as N)			101.8		%		90-110	24-JUL-15
WG2135645-1 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	24-JUL-15
WG2135645-10 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	24-JUL-15
WG2135645-13 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	24-JUL-15
WG2135645-4 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	24-JUL-15
WG2135645-7 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	24-JUL-15
WG2135645-8 MS		**L1647351-1**						
Nitrate (as N)			98.5		%		75-125	24-JUL-15
P-T-PRES-COL-VA	**Water**							
Batch R3232560								
WG2136402-10 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			107.0		%		80-120	25-JUL-15
WG2136402-2 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			105.5		%		80-120	25-JUL-15
WG2136402-6 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			108.4		%		80-120	25-JUL-15
WG2136402-11 DUP		**L1647351-1**						
Phosphorus (P)-Total		<0.0020	<0.0020	RPD-NA	mg/L	N/A	20	25-JUL-15
WG2136402-1 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	25-JUL-15

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
P-T-PRES-COL-VA	**Water**							
Batch R3232560								
WG2136402-5 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	25-JUL-15
WG2136402-9 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	25-JUL-15
WG2136402-12 MS		**L1647351-2**						
Phosphorus (P)-Total			86.3		%		70-130	25-JUL-15
PH-PCT-VA	**Water**							
Batch R3233226								
WG2136634-25 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	27-JUL-15
WG2136634-26 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	27-JUL-15
WG2136634-27 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	27-JUL-15
WG2136634-28 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	27-JUL-15
WG2136634-29 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	27-JUL-15
WG2136634-30 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	27-JUL-15
WG2136634-31 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	27-JUL-15
PO4-DO-COL-VA	**Water**							
Batch R3231660								
WG2135501-10 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			108.0		%		80-120	24-JUL-15
WG2135501-14 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			107.8		%		80-120	24-JUL-15
WG2135501-2 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			101.6		%		80-120	24-JUL-15
WG2135501-6 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			101.8		%		80-120	24-JUL-15
WG2135501-15 DUP		**L1647351-2**						
Orthophosphate-Dissolved (as P)		<0.0010	<0.0010	RPD-NA	mg/L	N/A	20	24-JUL-15
WG2135501-1 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	24-JUL-15
WG2135501-13 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	24-JUL-15

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PO4-DO-COL-VA	**Water**							
Batch R3231660								
WG2135501-5 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	24-JUL-15
WG2135501-9 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	24-JUL-15
TDS-VA	**Water**							
Batch R3233839								
WG2136338-2 LCS								
Total Dissolved Solids			104.7		%		85-115	25-JUL-15
WG2136338-5 LCS								
Total Dissolved Solids			102.7		%		85-115	25-JUL-15
WG2136338-1 MB								
Total Dissolved Solids			<10		mg/L		10	25-JUL-15
WG2136338-4 MB								
Total Dissolved Solids			<10		mg/L		10	25-JUL-15
TSS-LOW-VA	**Water**							
Batch R3234835								
WG2138218-2 LCS								
Total Suspended Solids			101.9		%		85-115	28-JUL-15
WG2138218-4 LCS								
Total Suspended Solids			104.7		%		85-115	28-JUL-15
WG2138218-6 LCS								
Total Suspended Solids			102.3		%		85-115	28-JUL-15
WG2138218-1 MB								
Total Suspended Solids			<1.0		mg/L		1	28-JUL-15
WG2138218-3 MB								
Total Suspended Solids			<1.0		mg/L		1	28-JUL-15
WG2138218-5 MB								
Total Suspended Solids			<1.0		mg/L		1	28-JUL-15
TURBIDITY-VA	**Water**							
Batch R3232008								
WG2135858-2 CRM		**VA-FORM-40**						
Turbidity			93.3		%		85-115	24-JUL-15
WG2135858-5 CRM		**VA-FORM-40**						
Turbidity			92.0		%		85-115	24-JUL-15
WG2135858-1 MB								
Turbidity			<0.10		NTU		0.1	24-JUL-15
WG2135858-4 MB								
Turbidity			<0.10		NTU		0.1	24-JUL-15

Quality Control Report

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Quality Control Report

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH by Meter (Automated)							
	1	22-JUL-15 09:57	27-JUL-15 10:32	0.25	120	hours	EHTR-FM
	2	22-JUL-15 09:57	27-JUL-15 10:32	0.25	120	hours	EHTR-FM

Legend & Qualifier Definitions:

EHTR-FM:	Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR:	Exceeded ALS recommended hold time prior to sample receipt.
EHTL:	Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT:	Exceeded ALS recommended hold time prior to analysis.
Rec. HT:	ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1647351 were received on 23-JUL-15 17:05.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

L1647351-COFC

Chain of Custody / Analytical Request Form
Canada Toll Free : 1 800 668 9878
www.alsglobal.com

Report To

Company:	ECOFISH RESEARCH LTD
Contact:	Kevin Ganshorn
Address:	Suite F, 450 - 8th Street Courtenay, BC Canada, V9N 1N5
Phone:	250-334-3042
Fax:	250-334-3097

Invoice To ☑Email ☐Mail

Company:	ECOFISH RESEARCH LTD
Contact:	Accounts Payable
Address:	Suite F, 450 - 8th Street Courtenay, BC Canada, V9N 1N5
Email:	accountspayable@ecofishresearch.com
Phone:	250-334-3042

Lab Work Order # (lab use only)

Reporting

Distribution:	☐Fax ☐Mail ☑Email
☐Ciriteria on Report (select from Guidelines below)	
Report Type:	☑Excel ☑Digital
Report Format:	CROSSTAB_ALSQC
Report Email(s):	kganshorn@ecofishresearch.com tkasubuchi@ecofishresearch.com
EDD Format:	ECF100
EDD Email(s):	kganshorn@ecofishresearch.com bbennett@ecofishresearch.com tkasubuchi@ecofishresearch.com

Project Info

Job #:	1230 JHT-MON8 1230-08.40
PO/AFE:	
LSD:	
Quote #:	
ALS Contact:	Ariel Tang, B.Sc.
Sampler:	Leah Hull

Service Requested

- ⦿ Regular (Standard Turnaround Times - Business Days) - R
- ○ Priority (3 Days) - surcharge will apply - P
- ○ Priority (2 Days) - surcharge will apply - P2
- ○ Emergency (1-2 day) – surcharge will apply - E
- ○ Same Day or Weekend Emergency - surcharge will apply - E2
- ○ Specify date required - X

Analysis Requests

Please indicate below Filtered, Preserved or both(F, P, F/P)

Sample #	Sample Identification (This will appear on the report)	Longitude	Latitude	Date	Time	Sample Type	Number of Containers	Alkalinity by Colourimetric (Automated)	Ammonia in Water by Fluorescence	Conductivity (Automated)	Diss. Orthophosphate in Water by Colour	Nitrate in Water by Ion Chromatography	Nitrite in Water by Ion Chromatography	Total Dissolved Solids by Gravimetric	Total P in Water by Colour	Total Suspended Solids by Grav. (1 mg/L)	Turbidity by Meter	pH by Meter (Automated)
	~~SAM-FIELD BLANK~~					~~Water~~	3	R	R	R	R	R	R	R	R	R	R	R
	~~SAM-TRAVEL BLANK~~					~~Water~~	3	R	R	R	R	R	R	R	R	R	R	R
	SAM-WQA			22-July-2015	9:57	Water	3	R	R	R	R	R	R	R	R	R	R	R
	SAM-WQB			"	9:57	Water	3	R	R	R	R	R	R	R	R	R	R	R

Short Holding Time

Rush Processing

Spe... ...ons below must be answered for water samples (check Yes or No)

July 2015 Sampling

Are any sample taken from a regulated DW system? ☐Yes ☒No

If yes, please use an authorized drinking water COC

Is the water sampled intended to be potable for human consumption? ☐Yes ☒No

Guidelines

SAMPLE CONDITION (lab use only)

☐Frozen ☐Cold ☐Ambient ☐Cooling Initiated

SHIPMENT RELEASE (client use)

Released by:	Date:	Time:
Leah Hull	23-July-2015	13:30

SHIPMENT RECEPTION (lab use only)

Received by:	Date:	Time:	Temperature:
Shayan	July 23	18:05	10 °C

SHIPMENT VERIFICATION (lab use only)

Verified by:	Date:	Time:	Observations:
			☐Yes If Yes add SIF

ECOFISH RESEARCH LTD
ATTN: Kevin Ganshorn
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5

Date Received: 13-AUG-15
Report Date: 21-AUG-15 14:32 (MT)
Version: FINAL

Client Phone: 250-334-3042

Certificate of Analysis

Lab Work Order #: L1657614

Project P.O. #: 1230-08.40.08
Job Reference: 1230-08.40.08
C of C Numbers: OL-1638
Legal Site Desc:

Ariel Tang, B.Sc.
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1657614-1	L1657614-2			
	Description	WATER	WATER			
	Sampled Date	12-AUG-15	12-AUG-15			
	Sampled Time	10:30	10:30			
	Client ID	SAM-WQA	SAM-WQB			
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	51.6	51.2			
	pH (pH)	7.88	7.81			
	Total Suspended Solids (mg/L)	<1.0	<1.0			
	Total Dissolved Solids (mg/L)	48	45			
	Turbidity (NTU)	0.14	0.18			
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	23.4	21.7			
	Ammonia, Total (as N) (mg/L)	<0.0050	<0.0050			
	Nitrate (as N) (mg/L)	0.0973	0.0959			
	Nitrite (as N) (mg/L)	<0.0010	<0.0010			
	Orthophosphate-Dissolved (as P) (mg/L)	<0.0010	<0.0010			
	Phosphorus (P)-Total (mg/L)	<0.0020	<0.0020			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Matrix Spike	Phosphorus (P)-Total	MS-B	L1657614-1, -2

Qualifiers for Individual Parameters Listed:

Qualifier	Description
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-COL-VA	Water	Alkalinity by Colourimetric (Automated)	EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	APHA 4500 NH3-NITROGEN (AMMONIA)

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-L-IC-N-VA	Water	Nitrite in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-L-IC-N-VA	Water	Nitrate in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-PRES-COL-VA	Water	Total P in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.

TDS-VA	Water	Total Dissolved Solids by Gravimetric	APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TSS-LOW-VA	Water	Total Suspended Solids by Grav. (1 mg/L)	APHA 2540D

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

Reference Information

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

OL-1638

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Client: ECOFISH RESEARCH LTD
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5
Contact: Kevin Ganshorn

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ALK-COL-VA	**Water**							
Batch R3248171								
WG2151173-2 CRM		**VA-ALKL-CONTROL**						
Alkalinity, Total (as CaCO3)			97.9		%		85-115	17-AUG-15
WG2151173-5 CRM		**VA-ALKM-CONTROL**						
Alkalinity, Total (as CaCO3)			96.0		%		85-115	17-AUG-15
WG2151173-8 CRM		**VA-ALKH-CONTROL**						
Alkalinity, Total (as CaCO3)			102.2		%		85-115	17-AUG-15
WG2151173-1 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	17-AUG-15
WG2151173-11 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	17-AUG-15
WG2151173-13 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	17-AUG-15
WG2151173-15 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	17-AUG-15
WG2151173-4 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	17-AUG-15
WG2151173-7 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	17-AUG-15
EC-PCT-VA	**Water**							
Batch R3249486								
WG2152420-17 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.4		%		90-110	19-AUG-15
WG2152420-18 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.2		%		90-110	19-AUG-15
WG2152420-19 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.2		%		90-110	19-AUG-15
WG2152420-20 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.9		%		90-110	19-AUG-15
WG2152420-21 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.9		%		90-110	19-AUG-15
WG2152420-1 MB								
Conductivity			<2.0		uS/cm		2	19-AUG-15
WG2152420-2 MB								
Conductivity			<2.0		uS/cm		2	19-AUG-15
WG2152420-3 MB								
Conductivity			<2.0		uS/cm		2	19-AUG-15
WG2152420-4 MB								
Conductivity			<2.0		uS/cm		2	19-AUG-15
WG2152420-5 MB								

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
EC-PCT-VA	**Water**							
Batch R3249486								
WG2152420-5 MB								
Conductivity			<2.0		uS/cm		2	19-AUG-15
NH3-F-VA	**Water**							
Batch R3249735								
WG2152161-2 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			97.3		%		85-115	19-AUG-15
WG2152161-4 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			95.8		%		85-115	19-AUG-15
WG2152161-6 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			96.3		%		85-115	19-AUG-15
WG2152161-8 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			95.3		%		85-115	19-AUG-15
WG2152161-1 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-AUG-15
WG2152161-3 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-AUG-15
WG2152161-5 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-AUG-15
WG2152161-7 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-AUG-15
NO2-L-IC-N-VA	**Water**							
Batch R3249185								
WG2149422-18 LCS								
Nitrite (as N)			100.2		%		90-110	14-AUG-15
WG2149422-2 LCS								
Nitrite (as N)			100.6		%		90-110	14-AUG-15
WG2149422-1 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	14-AUG-15
WG2149422-10 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	14-AUG-15
WG2149422-13 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	14-AUG-15
WG2149422-16 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	14-AUG-15
WG2149422-4 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	14-AUG-15
WG2149422-7 MB								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO2-L-IC-N-VA	**Water**							
Batch R3249185								
WG2149422-7 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	14-AUG-15
NO3-L-IC-N-VA	**Water**							
Batch R3249185								
WG2149422-18 LCS								
Nitrate (as N)			101.4		%		90-110	14-AUG-15
WG2149422-2 LCS								
Nitrate (as N)			101.1		%		90-110	14-AUG-15
WG2149422-1 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	14-AUG-15
WG2149422-10 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	14-AUG-15
WG2149422-13 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	14-AUG-15
WG2149422-16 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	14-AUG-15
WG2149422-4 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	14-AUG-15
WG2149422-7 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	14-AUG-15
P-T-PRES-COL-VA	**Water**							
Batch R3247206								
WG2150164-14 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			104.5		%		80-120	15-AUG-15
WG2150164-13 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	15-AUG-15
PH-PCT-VA	**Water**							
Batch R3249486								
WG2152420-25 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	19-AUG-15
WG2152420-26 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	19-AUG-15
WG2152420-27 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	19-AUG-15
WG2152420-28 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	19-AUG-15
WG2152420-29 CRM		**VA-PH7-BUF**						

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PH-PCT-VA	**Water**							
Batch R3249486								
WG2152420-29 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	19-AUG-15
PO4-DO-COL-VA	**Water**							
Batch R3247033								
WG2150137-10 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			99.9		%		80-120	15-AUG-15
WG2150137-14 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			118.3		%		80-120	15-AUG-15
WG2150137-2 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			93.1		%		80-120	15-AUG-15
WG2150137-6 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			104.1		%		80-120	15-AUG-15
WG2150137-1 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	15-AUG-15
WG2150137-13 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	15-AUG-15
WG2150137-5 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	15-AUG-15
WG2150137-9 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	15-AUG-15
TDS-VA	**Water**							
Batch R3250426								
WG2152618-11 LCS								
Total Dissolved Solids			95.1		%		85-115	19-AUG-15
WG2152618-2 LCS								
Total Dissolved Solids			102.1		%		85-115	19-AUG-15
WG2152618-5 LCS								
Total Dissolved Solids			100.9		%		85-115	19-AUG-15
WG2152618-8 LCS								
Total Dissolved Solids			104.9		%		85-115	19-AUG-15
WG2152618-1 MB								
Total Dissolved Solids			<10		mg/L		10	19-AUG-15
WG2152618-10 MB								
Total Dissolved Solids			<10		mg/L		10	19-AUG-15
WG2152618-4 MB								
Total Dissolved Solids			<10		mg/L		10	19-AUG-15
WG2152618-7 MB								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
TDS-VA	**Water**							
Batch R3250426								
WG2152618-7 MB								
Total Dissolved Solids			<10		mg/L		10	19-AUG-15
TSS-LOW-VA	**Water**							
Batch R3249331								
WG2151556-4 LCS								
Total Suspended Solids			102.9		%		85-115	18-AUG-15
WG2151556-3 MB								
Total Suspended Solids			<1.0		mg/L		1	18-AUG-15
TURBIDITY-VA	**Water**							
Batch R3246255								
WG2149341-2 CRM		**VA-FORM-40**						
Turbidity			95.0		%		85-115	14-AUG-15
WG2149341-5 CRM		**VA-FORM-40**						
Turbidity			94.8		%		85-115	14-AUG-15
WG2149341-1 MB								
Turbidity			<0.10		NTU		0.1	14-AUG-15
WG2149341-4 MB								
Turbidity			<0.10		NTU		0.1	14-AUG-15

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Quality Control Report

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH by Meter (Automated)							
	1	12-AUG-15 10:30	19-AUG-15 11:23	0.25	169	hours	EHTR-FM
	2	12-AUG-15 10:30	19-AUG-15 11:23	0.25	169	hours	EHTR-FM

Legend & Qualifier Definitions:

EHTR-FM:	Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR:	Exceeded ALS recommended hold time prior to sample receipt.
EHTL:	Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT:	Exceeded ALS recommended hold time prior to analysis.
Rec. HT:	ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1657614 were received on 13-AUG-15 18:00.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

COC #: OL-1638

Chain of Custody / Analytical Request Form
Canada Toll Free : 1 800 668 9878
www.alsglobal.com

ALS Environmental

Report To

Company: ECOFISH RESEARCH LTD
Contact: Kevin Ganshorn
Address: Suite 906 - 595 Howe Street, Vancouver, BC, Canada, V6C 2T5
Phone: 604-608-6180 | Fax:

Invoice To ☑Email ☐Mail

Company: ECOFISH RESEARCH LTD
Contact: Accounts Payable
Address: Suite F, 450 - 8th Street, Courtenay, BC, Canada, V9N 1N5
Email: accountspayable@ecofishresearch.com
Phone: 250-334-3042

Reporting

Distribution: ☐Fax ☐Mail ☑Email
☐Criteria on Report (select from Guidelines below)
Report Type: ☑Excel ☑Digital
Report Format: CROSSTAB_ALSQC
Report Email(s): kganshorn@ecofishresearch.com, tkasubuchi@ecofishresearch.com
EDD Format: ECF100
EDD Email(s): kganshorn@ecofishresearch.com, bbennett@ecofishresearch.com, tkasubuchi@ecofishresearch.com

Project Info

Job #: ~~1230 JHT-MON8~~
PO/AFE: 1230-08.40.07
LSD:
Quote #:

Service Requested

- ◉ Regular (Standard Turnaround Times - Business Days) - R
- ○ Priority (3 Days) - surcharge will apply - P
- ○ Priority (2 Days) - surcharge will apply - P2
- ○ Emergency (1-2 day) – surcharge will apply - E
- ○ Same Day or Weekend Emergency - surcharge will apply - E2
- ○ Specify date required - X

Lab Work Order # (lab use only):
ALS Contact: Ariel Tang, B.Sc. | Sampler: LEAH HULL

Analysis Requests (Please indicate below Filtered, Preserved or both (F, P, F/P))

Sample #	Sample Identification (This will appear on the report)	Longitude	Latitude	Date	Time	Sample Type	Number of Containers	Alkalinity by Colourimetric (Automated)	Ammonia in Water by Fluorescence	Conductivity (Automated)	Diss. Orthophosphate in Water by Colour	Nitrate in Water by Ion Chromatography	Nitrite in Water by Ion Chromatography	Total Dissolved Solids by Gravimetric	Total P in Water by Colour	Total Suspended Solids by Grav. (1 mg/L)	Turbidity by Meter	pH by Meter (Automated)
	~~SAM-FIELD BLANK~~			[illegible]		WATER	3	R	R	R	R	R	R	R	R	R	R	R
	~~SAM-TRAVEL BLANK~~					WATER	3	R	R	R	R	R	R	R	R	R	R	R
	SAM-WQA			13-Aug-2015	10:30	WATER	3	R	R	R	R	R	R	R	R	R	R	R
	SAM-WQB			13-Aug-2015	10:30	WATER	3	R	R	R	R	R	R	R	R	R	R	R

Short Holding Time

Rush Processing

L1657614-COFC

August 2015 Sampling

The questions below must be answered for water samples (check Yes or No)

Are any sample taken from a regulated DW system? ☐Yes ☒No
If yes, please use an authorized drinking water COC
Is the water sampled intended to be potable for human consumption? ☐Yes ☒No

SAMPLE CONDITION (lab use only)
☐Frozen ☐Cold ☐Ambient ☐Cooling Initiated

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by: Leah Hull	Date: 13-Aug-2015	Time: 14:00	Received by: Shayan	Date: Aug. 13	Time: 18:00	Temperature: 7.1 °C	Verified by:	Date:	Time:	Observations: ☐Yes If Yes add SIF

ECOFISH RESEARCH LTD
ATTN: Kevin Ganshorn
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5

Date Received: 17-SEP-15
Report Date: 28-SEP-15 12:21 (MT)
Version: FINAL

Client Phone: 250-334-3042

Certificate of Analysis

Lab Work Order #: L1674882

Project P.O. #: NOT SUBMITTED
Job Reference: 1230-08.40.08
C of C Numbers: OL-1642
Legal Site Desc:

Ariel Tang, B.Sc.
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1674882-1	L1674882-2			
	Description	Water	Water			
	Sampled Date	17-SEP-15	17-SEP-15			
	Sampled Time	09:55	09:55			
	Client ID	SAM-WQA	SAM-WQB			
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	47.1	47.3			
	pH (pH)	7.70	7.74			
	Total Suspended Solids (mg/L)	<1.0	<1.0			
	Total Dissolved Solids (mg/L)	32	32			
	Turbidity (NTU)	0.19	0.16			
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	20.4	20.4			
	Ammonia, Total (as N) (mg/L)	<0.0050	<0.0050			
	Nitrate (as N) (mg/L)	0.0399	0.0400			
	Nitrite (as N) (mg/L)	<0.0010	<0.0010			
	Orthophosphate-Dissolved (as P) (mg/L)	<0.0010	<0.0010			
	Phosphorus (P)-Total (mg/L)	<0.0020	<0.0020			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Duplicate	Nitrite (as N)	DLM	L1674882-1, -2
Duplicate	Nitrate (as N)	DLM	L1674882-1, -2
Matrix Spike	Phosphorus (P)-Total	MS-B	L1674882-1, -2

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLM	Detection Limit Adjusted due to sample matrix effects.
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-COL-VA	Water	Alkalinity by Colourimetric (Automated)	EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	APHA 4500 NH3-NITROGEN (AMMONIA)

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-L-IC-N-VA	Water	Nitrite in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-L-IC-N-VA	Water	Nitrate in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-PRES-COL-VA	Water	Total P in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.

TDS-VA	Water	Total Dissolved Solids by Gravimetric	APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TSS-LOW-VA	Water	Total Suspended Solids by Grav. (1 mg/L)	APHA 2540D

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 Turbidity

Reference Information

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

OL-1642

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Client: ECOFISH RESEARCH LTD
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5
Contact: Kevin Ganshorn

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ALK-COL-VA	**Water**							
Batch R3272690								
WG2174165-2 CRM		**VA-ALKL-CONTROL**						
Alkalinity, Total (as CaCO3)			101.0		%		85-115	18-SEP-15
WG2174165-5 CRM		**VA-ALKM-CONTROL**						
Alkalinity, Total (as CaCO3)			106.1		%		85-115	18-SEP-15
WG2174165-8 CRM		**VA-ALKH-CONTROL**						
Alkalinity, Total (as CaCO3)			103.5		%		85-115	18-SEP-15
WG2174165-1 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	18-SEP-15
WG2174165-10 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	18-SEP-15
WG2174165-4 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	18-SEP-15
WG2174165-7 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	18-SEP-15
EC-PCT-VA	**Water**							
Batch R3273719								
WG2175534-17 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.1		%		90-110	22-SEP-15
WG2175534-18 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			100.3		%		90-110	22-SEP-15
WG2175534-19 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.3		%		90-110	22-SEP-15
WG2175534-20 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			100.1		%		90-110	22-SEP-15
WG2175534-21 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			100.1		%		90-110	23-SEP-15
WG2175534-22 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.0		%		90-110	23-SEP-15
WG2175534-1 MB								
Conductivity			<2.0		uS/cm		2	22-SEP-15
WG2175534-2 MB								
Conductivity			<2.0		uS/cm		2	22-SEP-15
WG2175534-4 MB								
Conductivity			<2.0		uS/cm		2	22-SEP-15
WG2175534-5 MB								
Conductivity			<2.0		uS/cm		2	23-SEP-15
WG2175534-6 MB								
Conductivity			<2.0		uS/cm		2	23-SEP-15

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NH3-F-VA	**Water**							
Batch R3276144								
WG2179116-2 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			99.2		%		85-115	25-SEP-15
WG2179116-4 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			100.3		%		85-115	25-SEP-15
WG2179116-6 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			101.1		%		85-115	25-SEP-15
WG2179116-8 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			99.0		%		85-115	25-SEP-15
WG2179116-1 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	25-SEP-15
WG2179116-3 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	25-SEP-15
WG2179116-5 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	25-SEP-15
WG2179116-7 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	25-SEP-15
NO2-L-IC-N-VA	**Water**							
Batch R3275134								
WG2174618-6 DUP		**L1674882-2**						
Nitrite (as N)		<0.0010	<0.0010	RPD-NA	mg/L	N/A	20	19-SEP-15
WG2174618-18 LCS								
Nitrite (as N)			98.5		%		90-110	19-SEP-15
WG2174618-2 LCS								
Nitrite (as N)			99.1		%		90-110	19-SEP-15
WG2174618-1 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	19-SEP-15
WG2174618-10 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	19-SEP-15
WG2174618-13 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	19-SEP-15
WG2174618-16 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	19-SEP-15
WG2174618-4 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	19-SEP-15
WG2174618-7 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	19-SEP-15
WG2174618-8 MS		**L1674882-1**						
Nitrite (as N)			98.5		%		75-125	19-SEP-15

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO3-L-IC-N-VA	**Water**							
Batch R3275134								
WG2174618-6 DUP		**L1674882-2**						
Nitrate (as N)		0.0400	0.0398		mg/L	0.5	20	19-SEP-15
WG2174618-18 LCS								
Nitrate (as N)			100.9		%		90-110	19-SEP-15
WG2174618-2 LCS								
Nitrate (as N)			100.9		%		90-110	19-SEP-15
WG2174618-1 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	19-SEP-15
WG2174618-10 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	19-SEP-15
WG2174618-13 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	19-SEP-15
WG2174618-16 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	19-SEP-15
WG2174618-4 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	19-SEP-15
WG2174618-7 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	19-SEP-15
WG2174618-8 MS		**L1674882-1**						
Nitrate (as N)			100.6		%		75-125	19-SEP-15
P-T-PRES-COL-VA	**Water**							
Batch R3273189								
WG2175937-2 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			103.4		%		80-120	22-SEP-15
WG2175937-1 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	22-SEP-15
PH-PCT-VA	**Water**							
Batch R3273719								
WG2175534-25 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	22-SEP-15
WG2175534-26 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	22-SEP-15
WG2175534-27 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	22-SEP-15
WG2175534-28 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	22-SEP-15
WG2175534-29 CRM		**VA-PH7-BUF**						
pH			7.04		pH		6.9-7.1	23-SEP-15

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PH-PCT-VA	**Water**							
Batch R3273719								
WG2175534-30 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	23-SEP-15
PO4-DO-COL-VA	**Water**							
Batch R3270161								
WG2174416-10 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			103.7		%		80-120	18-SEP-15
WG2174416-2 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			105.0		%		80-120	18-SEP-15
WG2174416-6 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			102.6		%		80-120	18-SEP-15
WG2174416-1 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	18-SEP-15
WG2174416-5 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	18-SEP-15
WG2174416-9 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	18-SEP-15
TDS-VA	**Water**							
Batch R3275096								
WG2177049-2 LCS								
Total Dissolved Solids			99.5		%		85-115	23-SEP-15
WG2177049-5 LCS								
Total Dissolved Solids			107.7		%		85-115	23-SEP-15
WG2177049-8 LCS								
Total Dissolved Solids			100.2		%		85-115	23-SEP-15
WG2177049-1 MB								
Total Dissolved Solids			<10		mg/L		10	23-SEP-15
WG2177049-4 MB								
Total Dissolved Solids			<10		mg/L		10	23-SEP-15
WG2177049-7 MB								
Total Dissolved Solids			<10		mg/L		10	23-SEP-15
TSS-LOW-VA	**Water**							
Batch R3274557								
WG2177422-2 LCS								
Total Suspended Solids			88.3		%		85-115	23-SEP-15
WG2177422-1 MB								
Total Suspended Solids			<1.0		mg/L		1	23-SEP-15
TURBIDITY-VA	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
TURBIDITY-VA	**Water**							
Batch R3269755								
WG2173882-2 CRM		**VA-FORM-40**						
Turbidity			95.5		%		85-115	18-SEP-15
WG2173882-5 CRM		**VA-FORM-40**						
Turbidity			95.5		%		85-115	18-SEP-15
WG2173882-1 MB								
Turbidity			<0.10		NTU		0.1	18-SEP-15
WG2173882-4 MB								
Turbidity			<0.10		NTU		0.1	18-SEP-15

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Quality Control Report

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH by Meter (Automated)							
	1	17-SEP-15 09:55	22-SEP-15 10:51	0.25	121	hours	EHTR-FM
	2	17-SEP-15 09:55	22-SEP-15 10:51	0.25	121	hours	EHTR-FM

Legend & Qualifier Definitions:

EHTR-FM:	Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR:	Exceeded ALS recommended hold time prior to sample receipt.
EHTL:	Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT:	Exceeded ALS recommended hold time prior to analysis.
Rec. HT:	ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1674882 were received on 17-SEP-15 19:55.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

L1674882-COFC

Chain of Custody / Analytical Request Form
Canada Toll Free : 1 800 668 9878
www.alsglobal.com

COC #: OL-1642

Report To
Company: ECOFISH RESEARCH LTD
Contact: Kevin Ganshorn
Address: Suite 906 - 595 Howe Street, Vancouver, BC, Canada, V6C 2T5
Phone: 604-608-6180 Fax:

Invoice To ☑Email ☐Mail
Company: ECOFISH RESEARCH LTD
Contact: Accounts Payable
Address: Suite F, 450 - 8th Street, Courtenay, BC, Canada, V9N 1N5
Email: accountspayable@ecofishresearch.com
Phone: 250-334-3042

Lab Work Order # (lab use only):

Reporting
Distribution: ☐Fax ☐Mail ☑Email
☐Criteria on Report (select from Guidelines below)
Report Type: ☑Excel ☑Digital
Report Format: CROSSTAB_ALSQC
Report Email(s): kganshorn@ecofishresearch.com, tkasubuchi@ecofishresearch.com
EDD Format: ECF100
EDD Email(s): kganshorn@ecofishresearch.com, bbennett@ecofishresearch.com, tkasubuchi@ecofishresearch.com
Project Info 1230-08.40.08
Job #: ~~1230-JHT-MON8~~
PO/AFE:
LSD:
Quote #:
ALS Contact: Ariel Tang, B.Sc. Sampler: LEAH HULL

Service Requested
⦿ Regular (Standard Turnaround Times - Business Days) - R
○ Priority (3 Days) - surcharge will apply - P
○ Priority (2 Days) - surcharge will apply - P2
○ Emergency (1-2 day) – surcharge will apply - E
○ Same Day or Weekend Emergency - surcharge will apply - E2
○ Specify date required - X

Analysis Requests (Please indicate below Filtered, Preserved or both (F, P, F/P))

Sample #	Sample Identification (This will appear on the report)	Longitude	Latitude	Date	Time	Sample Type	Number of Containers	Alkalinity by Colourimetric (Automated)	Ammonia in Water by Fluorescence	Conductivity (Automated)	Diss. Orthophosphate in Water by Colour	Nitrate in Water by Ion Chromatography	Nitrite in Water by Ion Chromatography	Total Dissolved Solids by Gravimetric	Total P in Water by Colour	Total Suspended Solids by Grav. (1 mg/L)	Turbidity by Meter	pH by Meter (Automated)
	SAM-FIELD BLANK	—	—	—	—	WATER	3	R	R	R	R	R	R	R	R	R	R	R
	SAM-TRAVEL BLANK	—	—	—	—	WATER	3	R	R	R	R	R	R	R	R	R	R	R
	SAM-WQA			17-Sept-2015	9:55	WATER	3	R	R	R	R	R	R	R	R	R	R	R
	SAM-WQB			17-Sept-2015	9:55	WATER	3	R	R	R	R	R	R	R	R	R	R	R

Short Holding Time
Rush Processing

Special Instructions/Comments
October 2015 Sampling

The questions below must be answered for water samples (check Yes or No)
Are any sample taken from a regulated DW system? ☐Yes ☒No
If yes, please use an authorized drinking water COC
Is the water sampled intended to be potable for human consumption? ☐Yes ☒No

Guidelines

SAMPLE CONDITION (lab use only)
☐Frozen ☐Cold ☐Ambient ☐Cooling Initiated

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by: Leah Hull	Date: 17 Sept 2015	Time: 16:00	Received by: ISAAC	Date: Sept 17	Time: 19:55	Temperature: 5 °C	Verified by:	Date:	Time:	Observations: ☐Yes If Yes add SIF

ECOFISH RESEARCH LTD
ATTN: Kevin Ganshorn
Suite 906 - 595 Howe Street
Vancouver BC V6C 2T5

Date Received: 16-OCT-15
Report Date: 23-OCT-15 13:47 (MT)
Version: FINAL

Client Phone: 604-608-6180

Certificate of Analysis

Lab Work Order #: L1689166

Project P.O. #: 1230-08.40.08
Job Reference: 1230-08.40.08
C of C Numbers: OL-1640
Legal Site Desc:

Ariel Tang, B.Sc.
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1689166-1	L1689166-2			
	Description	Water	Water			
	Sampled Date	15-OCT-15	15-OCT-15			
	Sampled Time	12:01	12:01			
	Client ID	SAM-WQA	SAM-WQB			
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	40.8	40.6			
	pH (pH)	7.43	7.43			
	Total Suspended Solids (mg/L)	<1.0	<1.0			
	Total Dissolved Solids (mg/L)	37	36			
	Turbidity (NTU)	0.48	0.24			
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	18.1	18.2			
	Ammonia, Total (as N) (mg/L)	<0.0050	<0.0050			
	Nitrate (as N) (mg/L)	0.0201	0.0200			
	Nitrite (as N) (mg/L)	<0.0010	<0.0010			
	Orthophosphate-Dissolved (as P) (mg/L)	<0.0010	<0.0010			
	Phosphorus (P)-Total (mg/L)	<0.0020	<0.0020			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Matrix Spike	Phosphorus (P)-Total	MS-B	L1689166-1, -2

Qualifiers for Individual Parameters Listed:

Qualifier	Description
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-COL-VA	Water	Alkalinity by Colourimetric (Automated)	EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	APHA 4500 NH3-NITROGEN (AMMONIA)

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-L-IC-N-VA	Water	Nitrite in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-L-IC-N-VA	Water	Nitrate in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-PRES-COL-VA	Water	Total P in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.

TDS-VA	Water	Total Dissolved Solids by Gravimetric	APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TSS-LOW-VA	Water	Total Suspended Solids by Grav. (1 mg/L)	APHA 2540D

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

Reference Information

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

OL-1640

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Workorder: L1689166 Report Date: 23-OCT-15

Client: ECOFISH RESEARCH LTD
Suite 906 - 595 Howe Street
Vancouver BC V6C 2T5

Contact: Kevin Ganshorn

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ALK-COL-VA	**Water**							
Batch R3293958								
WG2196845-2 CRM		**VA-ALKL-CONTROL**						
Alkalinity, Total (as CaCO3)			96.8		%		85-115	20-OCT-15
WG2196845-5 CRM		**VA-ALKM-CONTROL**						
Alkalinity, Total (as CaCO3)			97.3		%		85-115	20-OCT-15
WG2196845-8 CRM		**VA-ALKH-CONTROL**						
Alkalinity, Total (as CaCO3)			102.0		%		85-115	20-OCT-15
WG2196845-14 DUP		**L1689166-2**						
Alkalinity, Total (as CaCO3)		18.2	18.2		mg/L	0.0	20	20-OCT-15
WG2196845-1 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-OCT-15
WG2196845-11 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-OCT-15
WG2196845-13 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-OCT-15
WG2196845-15 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-OCT-15
WG2196845-17 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-OCT-15
WG2196845-19 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-OCT-15
WG2196845-4 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-OCT-15
WG2196845-7 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-OCT-15
EC-PCT-VA	**Water**							
Batch R3293078								
WG2195702-17 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.3		%		90-110	20-OCT-15
WG2195702-18 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.1		%		90-110	20-OCT-15
WG2195702-19 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.0		%		90-110	20-OCT-15
WG2195702-20 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			100.4		%		90-110	20-OCT-15
WG2195702-21 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.5		%		90-110	20-OCT-15
WG2195702-1 MB								
Conductivity			<2.0		uS/cm		2	20-OCT-15
WG2195702-2 MB								

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
EC-PCT-VA	**Water**							
Batch R3293078								
WG2195702-2 MB								
Conductivity			<2.0		uS/cm		2	20-OCT-15
WG2195702-3 MB								
Conductivity			<2.0		uS/cm		2	20-OCT-15
WG2195702-4 MB								
Conductivity			<2.0		uS/cm		2	20-OCT-15
WG2195702-5 MB								
Conductivity			<2.0		uS/cm		2	20-OCT-15
NH3-F-VA	**Water**							
Batch R3294890								
WG2197838-10 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			109.1		%		85-115	22-OCT-15
WG2197838-2 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			103.0		%		85-115	22-OCT-15
WG2197838-4 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			113.4		%		85-115	22-OCT-15
WG2197838-6 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			105.2		%		85-115	22-OCT-15
WG2197838-8 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			105.4		%		85-115	22-OCT-15
WG2197838-1 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	22-OCT-15
WG2197838-3 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	22-OCT-15
WG2197838-5 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	22-OCT-15
WG2197838-7 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	22-OCT-15
WG2197838-9 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	22-OCT-15
NO2-L-IC-N-VA	**Water**							
Batch R3291993								
WG2194852-16 LCS								
Nitrite (as N)			99.4		%		90-110	17-OCT-15
WG2194852-2 LCS								
Nitrite (as N)			99.3		%		90-110	17-OCT-15
WG2194852-1 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-OCT-15

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO2-L-IC-N-VA	**Water**							
Batch R3291993								
WG2194852-11 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-OCT-15
WG2194852-14 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-OCT-15
WG2194852-3 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-OCT-15
WG2194852-5 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-OCT-15
WG2194852-8 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-OCT-15
WG2194852-6 MS		**L1689166-1**						
Nitrite (as N)			99.2		%		75-125	17-OCT-15
NO3-L-IC-N-VA	**Water**							
Batch R3291993								
WG2194852-16 LCS								
Nitrate (as N)			101.1		%		90-110	17-OCT-15
WG2194852-2 LCS								
Nitrate (as N)			101.0		%		90-110	17-OCT-15
WG2194852-1 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-OCT-15
WG2194852-11 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-OCT-15
WG2194852-14 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-OCT-15
WG2194852-3 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-OCT-15
WG2194852-5 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-OCT-15
WG2194852-8 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-OCT-15
WG2194852-6 MS		**L1689166-1**						
Nitrate (as N)			101.0		%		75-125	17-OCT-15
P-T-PRES-COL-VA	**Water**							
Batch R3291332								
WG2194764-6 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			106.0		%		80-120	17-OCT-15
WG2194764-5 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	17-OCT-15

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PH-PCT-VA	**Water**							
Batch R3293078								
WG2195702-25 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	20-OCT-15
WG2195702-26 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	20-OCT-15
WG2195702-27 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	20-OCT-15
WG2195702-28 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	20-OCT-15
WG2195702-29 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	20-OCT-15
PO4-DO-COL-VA	**Water**							
Batch R3291158								
WG2194704-10 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			100.2		%		80-120	16-OCT-15
WG2194704-14 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			97.1		%		80-120	16-OCT-15
WG2194704-18 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			92.9		%		80-120	16-OCT-15
WG2194704-2 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			95.4		%		80-120	16-OCT-15
WG2194704-22 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			92.2		%		80-120	16-OCT-15
WG2194704-6 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			97.9		%		80-120	16-OCT-15
WG2194704-1 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-OCT-15
WG2194704-13 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-OCT-15
WG2194704-17 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-OCT-15
WG2194704-21 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-OCT-15
WG2194704-5 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-OCT-15
WG2194704-9 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-OCT-15
TDS-VA	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
TDS-VA	**Water**							
Batch R3291930								
WG2194751-2 LCS								
Total Dissolved Solids			101.4		%		85-115	17-OCT-15
WG2194751-1 MB								
Total Dissolved Solids			<10		mg/L		10	17-OCT-15
TSS-LOW-VA	**Water**							
Batch R3292340								
WG2194728-4 LCS								
Total Suspended Solids			105.0		%		85-115	17-OCT-15
WG2194728-3 MB								
Total Suspended Solids			<1.0		mg/L		1	17-OCT-15
TURBIDITY-VA	**Water**							
Batch R3291165								
WG2194745-2 CRM		**VA-FORM-40**						
Turbidity			94.8		%		85-115	17-OCT-15
WG2194745-5 CRM		**VA-FORM-40**						
Turbidity			95.0		%		85-115	17-OCT-15
WG2194745-1 MB								
Turbidity			<0.10		NTU		0.1	17-OCT-15
WG2194745-4 MB								
Turbidity			<0.10		NTU		0.1	17-OCT-15

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Quality Control Report

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH by Meter (Automated)							
	1	15-OCT-15 12:01	20-OCT-15 08:36	0.25	117	hours	EHTR-FM
	2	15-OCT-15 12:01	20-OCT-15 08:36	0.25	117	hours	EHTR-FM

Legend & Qualifier Definitions:

EHTR-FM:	Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR:	Exceeded ALS recommended hold time prior to sample receipt.
EHTL:	Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT:	Exceeded ALS recommended hold time prior to analysis.
Rec. HT:	ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1689166 were received on 16-OCT-15 11:15.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

COC #: OL-1640

Chain of Custody / Analytical Request Form
Canada Toll Free : 1 800 668 9878
www.alsglobal.com

ALS Environmental

Report To

Company: ECOFISH RESEARCH LTD
Contact: Kevin Ganshorn
Address: Suite 906 - 595 Howe Street, Vancouver, BC, Canada, V6C 2T5
Phone: 604-608-6180 Fax:

Invoice To ☑Email ☐Mail
Company: ECOFISH RESEARCH LTD
Contact: Accounts Payable
Address: Suite F, 450 - 8th Street, Courtenay, BC, Canada, V9N 1N5
Email: accountspayable@ecofishresearch.com
Phone: 250-334-3042

Lab Work Order # (lab use only)

Reporting

Distribution: ☐Fax ☐Mail ☑Email
☐Criteria on Report (select from Guidelines below)
Report Type: ☑Excel ☑Digital
Report Format: CROSSTAB_ALSQC
Report Email(s): kganshorn@ecofishresearch.com, tkasubuchi@ecofishresearch.com
EDD Format: ECF100
EDD Email(s): kganshorn@ecofishresearch.com, bbennett@ecofishresearch.com, tkasubuchi@ecofishresearch.com

Project Info

Job #: ~~1230-JHT-MON8~~ 1230-08.40.08
PO/AFE:
LSD:
Quote #:

ALS Contact: Ariel Tang, B.Sc. Sampler: LEAH HULL

Service Requested

⊙ Regular (Standard Turnaround Times - Business Days) - R
○ Priority (3 Days) - surcharge will apply - P
○ Priority (2 Days) - surcharge will apply - P2
○ Emergency (1-2 day) – surcharge will apply - E
○ Same Day or Weekend Emergency - surcharge will apply - E2
○ Specify date required - X

Analysis Requests (Please indicate below Filtered, Preserved or both (F, P, F/P))

Sample #	Sample Identification (This will appear on the report)	Longitude	Latitude	Date	Time	Sample Type	Number of Containers	Alkalinity by Colourimetric (Automated)	Ammonia in Water by Fluorescence	Conductivity (Automated)	Diss. Orthophosphate in Water by Colour	Nitrate in Water by Ion Chromatography	Nitrite in Water by Ion Chromatography	Total Dissolved Solids by Gravimetric	Total P in Water by Colour	Total Suspended Solids by Grav. (1 mg/L)	Turbidity by Meter	pH by Meter (Automated)
	~~SAM-FIELD BLANK~~					~~WATER~~	3	R	R	R	R	R	R	R	R	R	R	R
	~~SAM-TRAVEL BLANK~~					~~WATER~~	3	R	R	R	R	R	R	R	R	R	R	R
	SAM-WQA			15-Oct-2015	12:01	WATER	3	R	R	R	R	R	R	R	R	R	R	R
	SAM-WQB			15-Oct-2015	12:01	WATER	3	R	R	R	R	R	R	R	R	R	R	R

L1689166-COFC

Guideline

Special Instructions/Comments

~~September~~ Oct 2015 Sampling

The questions below must be answered for water samples (check Yes or No)

Are any sample taken from a regulated DW system? ☐Yes ☒No
If yes, please use an authorized drinking water COC
Is the water sampled intended to be potable for human consumption? ☐Yes ☒No

SAMPLE CONDITION (lab use only)
☐Frozen ☐Cold ☐Ambient ☐Cooling Initiated

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by: Leah Hull	Date: 15-Oct-2015	Time: 18:00	Received by:	Date:	Time:	Temperature: 7 °C	Verified by: Edward	Date: OCT 16 2015	Time: 1115	Observations: ☐Yes If Yes add SIF

Appendix D. ALS Laboratory Water Quality Results and QA/QC for the Quinsam River, 2015.

ECOFISH RESEARCH LTD
ATTN: Kevin Ganshorn
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5

Date Received: 12-MAY-15
Report Date: 21-MAY-15 16:46 (MT)
Version: FINAL

Client Phone: 250-334-3042

Certificate of Analysis

Lab Work Order #: L1610788

Project P.O. #: NOT SUBMITTED
Job Reference: 1230 JHT-MON8
C of C Numbers: OL-1631
Legal Site Desc:

Ariel Tang, B.Sc.
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1610788-1	L1610788-2	L1610788-3	L1610788-4	
	Description	Water	Water	Water	Water	
	Sampled Date	12-MAY-15	12-MAY-15	12-MAY-15	12-MAY-15	
	Sampled Time	10:04	10:04	10:04	10:04	
	Client ID	QUN-FIELD BLANK	QUN-TRIP BLANK	QUN-WQA	QUN-WQB	
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	<2.0	<2.0	143	143	
	pH (pH)	5.84	5.80	7.78	7.80	
	Total Suspended Solids (mg/L)	<1.0	<1.0	<1.0	<1.0	
	Total Dissolved Solids (mg/L)	<10	<10	89	93	
	Turbidity (NTU)	<0.10	<0.10	0.39	0.37	
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	<2.0	<2.0	41.0	40.6	
	Ammonia, Total (as N) (mg/L)	<0.0050	0.0110	<0.0050	<0.0050	
	Nitrate (as N) (mg/L)	<0.0050	<0.0050	0.0231	0.0229	
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	
	Orthophosphate-Dissolved (as P) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	
	Phosphorus (P)-Total (mg/L)	<0.0020	<0.0020	0.0033	0.0025	

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Duplicate	Nitrite (as N)	DLM	L1610788-1, -2, -3, -4
Duplicate	Nitrate (as N)	DLM	L1610788-1, -2, -3, -4
Matrix Spike	Ammonia, Total (as N)	MS-B	L1610788-1, -3, -4

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLM	Detection Limit Adjusted due to sample matrix effects.
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-COL-VA	Water	Alkalinity by Colourimetric (Automated)	EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-L-IC-N-VA	Water	Nitrite in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-L-IC-N-VA	Water	Nitrate in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-PRES-COL-VA	Water	Total P in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.

TDS-VA	Water	Total Dissolved Solids by Gravimetric	APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TSS-LOW-VA	Water	Total Suspended Solids by Grav. (1 mg/L)	APHA 2540D

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

Reference Information

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

OL-1631

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Client: ECOFISH RESEARCH LTD
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5

Contact: Kevin Ganshorn

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ALK-COL-VA	**Water**							
Batch R3189637								
WG2087752-2 CRM		**VA-ALKL-CONTROL**						
Alkalinity, Total (as CaCO3)			102.2		%		85-115	13-MAY-15
WG2087752-5 CRM		**VA-ALKM-CONTROL**						
Alkalinity, Total (as CaCO3)			98.6		%		85-115	13-MAY-15
WG2087752-8 CRM		**VA-ALKH-CONTROL**						
Alkalinity, Total (as CaCO3)			104.1		%		85-115	13-MAY-15
WG2087752-1 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	13-MAY-15
WG2087752-4 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	13-MAY-15
WG2087752-7 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	13-MAY-15
EC-PCT-VA	**Water**							
Batch R3190863								
WG2088093-17 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			99.7		%		90-110	14-MAY-15
WG2088093-18 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			98.7		%		90-110	14-MAY-15
WG2088093-19 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			99.9		%		90-110	14-MAY-15
WG2088093-20 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			99.9		%		90-110	14-MAY-15
WG2088093-21 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			100.3		%		90-110	14-MAY-15
WG2088093-1 MB								
Conductivity			<2.0		uS/cm		2	14-MAY-15
WG2088093-2 MB								
Conductivity			<2.0		uS/cm		2	14-MAY-15
WG2088093-3 MB								
Conductivity			<2.0		uS/cm		2	14-MAY-15
WG2088093-4 MB								
Conductivity			<2.0		uS/cm		2	14-MAY-15
WG2088093-5 MB								
Conductivity			<2.0		uS/cm		2	14-MAY-15
NH3-F-VA	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NH3-F-VA	**Water**							
Batch R3191045								
WG2088763-2 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			93.8		%		85-115	15-MAY-15
WG2088763-4 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			98.0		%		85-115	15-MAY-15
WG2088763-6 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			88.9		%		85-115	15-MAY-15
WG2088763-9 DUP		**L1610788-4**						
Ammonia, Total (as N)		<0.0050	<0.0050	RPD-NA	mg/L	N/A	20	15-MAY-15
WG2088763-1 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	15-MAY-15
WG2088763-3 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	15-MAY-15
WG2088763-5 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	15-MAY-15
WG2088763-10 MS		**L1610788-4**						
Ammonia, Total (as N)			86.2		%		75-125	15-MAY-15
Batch R3192255								
WG2090784-10 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			108.0		%		85-115	19-MAY-15
WG2090784-2 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			99.8		%		85-115	19-MAY-15
WG2090784-4 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			108.0		%		85-115	19-MAY-15
WG2090784-6 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			93.0		%		85-115	19-MAY-15
WG2090784-8 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			92.3		%		85-115	19-MAY-15
WG2090784-1 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-MAY-15
WG2090784-3 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-MAY-15
WG2090784-5 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-MAY-15
WG2090784-7 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-MAY-15
WG2090784-9 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-MAY-15
NO2-L-IC-N-VA	**Water**							

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO2-L-IC-N-VA	**Water**							
Batch R3189991								
WG2087270-15 LCS								
Nitrite (as N)			102.8		%		90-110	13-MAY-15
WG2087270-2 LCS								
Nitrite (as N)			102.0		%		90-110	13-MAY-15
WG2087270-1 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	13-MAY-15
WG2087270-10 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	13-MAY-15
WG2087270-13 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	13-MAY-15
WG2087270-4 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	13-MAY-15
WG2087270-7 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	13-MAY-15
WG2087270-11 MS		**L1610788-1**						
Nitrite (as N)			102.0		%		75-125	13-MAY-15
NO3-L-IC-N-VA	**Water**							
Batch R3189991								
WG2087270-15 LCS								
Nitrate (as N)			101.5		%		90-110	13-MAY-15
WG2087270-2 LCS								
Nitrate (as N)			102.0		%		90-110	13-MAY-15
WG2087270-1 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	13-MAY-15
WG2087270-10 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	13-MAY-15
WG2087270-13 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	13-MAY-15
WG2087270-4 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	13-MAY-15
WG2087270-7 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	13-MAY-15
WG2087270-11 MS		**L1610788-1**						
Nitrate (as N)			101.0		%		75-125	13-MAY-15
P-T-PRES-COL-VA	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
P-T-PRES-COL-VA	**Water**							
Batch R3189211								
WG2087168-2 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			106.0		%		80-120	13-MAY-15
WG2087168-6 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			105.5		%		80-120	13-MAY-15
WG2087168-7 DUP		**L1610788-1**						
Phosphorus (P)-Total		<0.0020	<0.0020	RPD-NA	mg/L	N/A	20	13-MAY-15
WG2087168-1 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	13-MAY-15
WG2087168-5 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	13-MAY-15
WG2087168-8 MS		**L1610788-2**						
Phosphorus (P)-Total			100.2		%		70-130	13-MAY-15
PH-PCT-VA	**Water**							
Batch R3190863								
WG2088093-25 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	14-MAY-15
WG2088093-26 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	14-MAY-15
WG2088093-27 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	14-MAY-15
WG2088093-28 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	14-MAY-15
WG2088093-29 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	14-MAY-15
PO4-DO-COL-VA	**Water**							
Batch R3189008								
WG2087123-10 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			96.3		%		80-120	12-MAY-15
WG2087123-2 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			94.2		%		80-120	12-MAY-15
WG2087123-6 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			98.3		%		80-120	12-MAY-15
WG2087123-1 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	12-MAY-15
WG2087123-5 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	12-MAY-15
WG2087123-9 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	12-MAY-15

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
TDS-VA	**Water**							
Batch R3192129								
WG2089530-2 LCS								
Total Dissolved Solids			95.7		%		85-115	15-MAY-15
WG2089530-5 LCS								
Total Dissolved Solids			101.4		%		85-115	15-MAY-15
WG2089530-1 MB								
Total Dissolved Solids			<10		mg/L		10	15-MAY-15
WG2089530-4 MB								
Total Dissolved Solids			<10		mg/L		10	15-MAY-15
TSS-LOW-VA	**Water**							
Batch R3189259								
WG2087175-2 LCS								
Total Suspended Solids			96.0		%		85-115	13-MAY-15
WG2087175-1 MB								
Total Suspended Solids			<1.0		mg/L		1	13-MAY-15
TURBIDITY-VA	**Water**							
Batch R3189468								
WG2087269-2 CRM		**VA-FORM-40**						
Turbidity			97.5		%		85-115	13-MAY-15
WG2087269-1 MB								
Turbidity			<0.10		NTU		0.1	13-MAY-15

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
DLM	Detection Limit Adjusted due to sample matrix effects.
J	Duplicate results and limits are expressed in terms of absolute difference.
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Quality Control Report

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH by Meter (Automated)							
	1	12-MAY-15 10:04	14-MAY-15 13:12	0.25	51	hours	EHTR-FM
	2	12-MAY-15 10:04	14-MAY-15 13:12	0.25	51	hours	EHTR-FM
	3	12-MAY-15 10:04	14-MAY-15 13:12	0.25	51	hours	EHTR-FM
	4	12-MAY-15 10:04	14-MAY-15 13:12	0.25	51	hours	EHTR-FM

Legend & Qualifier Definitions:

EHTR-FM:	Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR:	Exceeded ALS recommended hold time prior to sample receipt.
EHTL:	Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT:	Exceeded ALS recommended hold time prior to analysis.
Rec. HT:	ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1610788 were received on 12-MAY-15 19:25.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

Short Holding Time

Rush Processing

ALS Environmental

Chain of Custody / Analytical Request Form
Canada Toll Free : 1 800 668 9878
www.alsglobal.com

L1610788-COFC

COC #: OL-1631

Report To

Company: ECOFISH RESEARCH LTD
Contact: Kevin Ganshorn
Address: Suite F, 450 - 8th Street
Courtenay, BC
Canada, V9N 1N5
Phone: 250-334-3042 Fax: 250-334-3097

Invoice To ☑Email ☐Mail

Company: ECOFISH RESEARCH LTD
Contact: Accounts Payable
Address: Suite F, 450 - 8th Street
Courtenay, BC
Canada, V9N 1N5
Email: accountspayable@ecofishresearch.com
Phone: 250-334-3042

Lab Work Order # (lab use only)

Reporting

Distribution: ☐Fax ☐Mail ☑Email
☐Cirlteria on Report (select from Guidelines below)
Report Type: ☑Excel ☑Digital
Report Format: CROSSTAB_ALSQC
Report Email(s): kganshorn@ecofishresearch.com
tkasubuchi@ecofishresearch.com
EDD Format: ECF100
EDD Email(s): pdinn@ecofishresearch.com
kganshorn@ecofishresearch.com
bbennett@ecofishresearch.com

Project Info

Job #: 1230 JHT-MON8
PO/AFE:
LSD:
Quote #:
ALS Contact: Ariel Tang, B.Sc. Sampler: Leah Hull

Service Requested

◉ Regular (Standard Turnaround Times - Business Days) - R
○ Priority (3 Days) - surcharge will apply - P
○ Priority (2 Days) - surcharge will apply - P2
○ Emergency (1-2 day) – surcharge will apply - E
○ Same Day or Weekend Emergency - surcharge will apply - E2
○ Specify date required - X

Analysis Requests

Please indicate below Filtered, Preserved or both(F, P, F/P)

Sample #	Sample Identification (This will appear on the report)	Longitude	Latitude	Date	Time	Sample Type	Number of Containers	Alkalinity by Colourimetric (Automated)	Ammonia in Water by Fluorescence	Conductivity (Automated)	Diss. Orthophosphate in Water by Colour	Nitrate in Water by Ion Chromatography	Nitrite in Water by Ion Chromatography	Total Dissolved Solids by Gravimetric	Total P in Water by Colour	Total Suspended Solids by Grav. (1 mg/L)	Turbidity by Meter	pH by Meter (Automated)
	QUN-FIELD BLANK			12-May-2015	10:04	Water	3	R	R	R	R	R	R	R	R	R	R	R
	QUN-TRIP BLANK			↓	↓	Water	3	R	R	R	R	R	R	R	R	R	R	R
	QUN-WQA			↓	↓	Water	3	R	R	R	R	R	R	R	R	R	R	R
	QUN-WQB			↓	↓	Water	3	R	R	R	R	R	R	R	R	R	R	R

Special Instructions/Comments

May 2015 Sampling

The questions below must be answered for water samples (check Yes or No)

Are any sample taken from a regulated DW system? ☐Yes ☒No
If yes, please use an authorized drinking water COC
Is the water sampled intended to be potable for human consumption? ☐Yes ☒No

Guidelines

SAMPLE CONDITION (lab use only)

☐Frozen ☐Cold ☐Ambient ☐Cooling Initiated

SHIPMENT RELEASE (client use)

Released by:	Date:	Time:
Leah Hull	12-May 2015	13:00

SHIPMENT RECEPTION (lab use only)

Received by:	Date:	Time:	Temperature:
PAUL	MAY 12	19:25	7 °C

SHIPMENT VERIFICATION (lab use only)

Verified by:	Date:	Time:	Observations:
			☐Yes If Yes add SIF

ECOFISH RESEARCH LTD
ATTN: Kevin Ganshorn
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5

Date Received: 17-JUN-15
Report Date: 25-JUN-15 17:11 (MT)
Version: FINAL

Client Phone: 250-334-3042

Certificate of Analysis

Lab Work Order #: L1628832

Project P.O. #: NOT SUBMITTED
Job Reference: 1230 JHT-MON8
C of C Numbers: OL-1633
Legal Site Desc:

Ariel Tang, B.Sc.
Account Manager

[This report shall not be reproduced except in full without the written authority of the Laboratory.]

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1628832-1	L1628832-2	L1628832-3	L1628832-4	
	Description	Water	Water	Water	Water	
	Sampled Date	17-JUN-15	17-JUN-15	17-JUN-15	17-JUN-15	
	Sampled Time	10:29	10:29	10:29	10:29	
	Client ID	QUN-FIELD BLANK	QUN-TRIP BLANK	QUN-WQA	QUN-WQB	
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	3.2	<2.0	157	157	
	pH (pH)	6.22	5.91	7.90	7.92	
	Total Suspended Solids (mg/L)	<1.0	<1.0	<1.0	<1.0	
	Total Dissolved Solids (mg/L)	<10	<10	100	94	
	Turbidity (NTU)	<0.10	<0.10	0.40	0.42	
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	<2.0	<2.0	43.9	43.8	
	Ammonia, Total (as N) (mg/L)	<0.0050	0.0585	<0.0050	<0.0050	
	Nitrate (as N) (mg/L)	<0.0050	<0.0050	0.0239	0.0236	
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	
	Orthophosphate-Dissolved (as P) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	
	Phosphorus (P)-Total (mg/L)	<0.0020	<0.0020	<0.0020	<0.0020	

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Duplicate	Nitrite (as N)	DLM	L1628832-1, -2, -3, -4

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLM	Detection Limit Adjusted due to sample matrix effects.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**

ALK-COL-VA | Water | Alkalinity by Colourimetric (Automated) | EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

EC-PCT-VA | Water | Conductivity (Automated) | APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

NH3-F-VA | Water | Ammonia in Water by Fluorescence | APHA 4500 NH3-NITROGEN (AMMONIA)

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NH3-F-VA | Water | Ammonia in Water by Fluorescence | J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-L-IC-N-VA | Water | Nitrite in Water by IC (Low Level) | EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-L-IC-N-VA | Water | Nitrate in Water by IC (Low Level) | EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-PRES-COL-VA | Water | Total P in Water by Colour | APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.

PH-PCT-VA | Water | pH by Meter (Automated) | APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PH-PCT-VA | Water | pH by Meter (Automated) | APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PO4-DO-COL-VA | Water | Diss. Orthophosphate in Water by Colour | APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.

TDS-VA | Water | Total Dissolved Solids by Gravimetric | APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TSS-LOW-VA | Water | Total Suspended Solids by Grav. (1 mg/L) | APHA 2540D

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.

TURBIDITY-VA | Water | Turbidity by Meter | APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

TURBIDITY-VA | Water | Turbidity by Meter | APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

Reference Information

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

OL-1633

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Client: ECOFISH RESEARCH LTD
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5
Contact: Kevin Ganshorn

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ALK-COL-VA	**Water**							
Batch R3214036								
WG2115563-2 CRM		**VA-ALKL-CONTROL**						
Alkalinity, Total (as CaCO3)			99.5		%		85-115	24-JUN-15
WG2115563-5 CRM		**VA-ALKM-CONTROL**						
Alkalinity, Total (as CaCO3)			108.8		%		85-115	24-JUN-15
WG2115563-8 CRM		**VA-ALKH-CONTROL**						
Alkalinity, Total (as CaCO3)			96.1		%		85-115	24-JUN-15
WG2115563-1 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUN-15
WG2115563-10 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUN-15
WG2115563-12 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUN-15
WG2115563-14 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUN-15
WG2115563-16 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUN-15
WG2115563-18 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUN-15
WG2115563-21 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUN-15
WG2115563-23 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUN-15
WG2115563-25 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUN-15
WG2115563-4 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUN-15
WG2115563-7 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUN-15
EC-PCT-VA	**Water**							
Batch R3212901								
WG2113140-17 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.7		%		90-110	22-JUN-15
WG2113140-18 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.8		%		90-110	22-JUN-15
WG2113140-19 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.8		%		90-110	22-JUN-15
WG2113140-20 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			103.3		%		90-110	22-JUN-15
WG2113140-21 CRM		**VA-EC-PCT-CONTROL**						

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
EC-PCT-VA	**Water**							
Batch R3212901								
WG2113140-21 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			103.3		%		90-110	22-JUN-15
WG2113140-22 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			103.2		%		90-110	22-JUN-15
WG2113140-23 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			103.5		%		90-110	22-JUN-15
WG2113140-24 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			104.1		%		90-110	22-JUN-15
WG2113140-35 DUP		**L1628832-4**						
Conductivity		157	158		uS/cm	0.3	10	22-JUN-15
WG2113140-1 MB								
Conductivity			<2.0		uS/cm		2	22-JUN-15
WG2113140-2 MB								
Conductivity			<2.0		uS/cm		2	22-JUN-15
WG2113140-3 MB								
Conductivity			<2.0		uS/cm		2	22-JUN-15
WG2113140-4 MB								
Conductivity			<2.0		uS/cm		2	22-JUN-15
WG2113140-5 MB								
Conductivity			<2.0		uS/cm		2	22-JUN-15
WG2113140-6 MB								
Conductivity			<2.0		uS/cm		2	22-JUN-15
WG2113140-7 MB								
Conductivity			<2.0		uS/cm		2	22-JUN-15
WG2113140-8 MB								
Conductivity			<2.0		uS/cm		2	22-JUN-15
Batch R3213927								
WG2115046-17 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			99.6		%		90-110	24-JUN-15
WG2115046-18 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			98.7		%		90-110	24-JUN-15
WG2115046-19 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			99.9		%		90-110	24-JUN-15
WG2115046-20 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			99.7		%		90-110	24-JUN-15
WG2115046-21 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			100.2		%		90-110	24-JUN-15
WG2115046-22 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			100.4		%		90-110	24-JUN-15

Quality Control Report

Workorder: L1628832 Report Date: 25-JUN-15

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
EC-PCT-VA	**Water**							
Batch R3213927								
WG2115046-23 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			99.1		%		90-110	24-JUN-15
WG2115046-24 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			99.7		%		90-110	24-JUN-15
WG2115046-1 MB								
Conductivity			<2.0		uS/cm		2	24-JUN-15
WG2115046-2 MB								
Conductivity			<2.0		uS/cm		2	24-JUN-15
WG2115046-3 MB								
Conductivity			<2.0		uS/cm		2	24-JUN-15
WG2115046-4 MB								
Conductivity			<2.0		uS/cm		2	24-JUN-15
WG2115046-5 MB								
Conductivity			<2.0		uS/cm		2	24-JUN-15
WG2115046-6 MB								
Conductivity			<2.0		uS/cm		2	24-JUN-15
WG2115046-7 MB								
Conductivity			<2.0		uS/cm		2	24-JUN-15
WG2115046-8 MB								
Conductivity			<2.0		uS/cm		2	24-JUN-15
NH3-F-VA	**Water**							
Batch R3213724								
WG2114941-2 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			94.8		%		85-115	23-JUN-15
WG2114941-4 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			99.4		%		85-115	23-JUN-15
WG2114941-6 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			101.6		%		85-115	23-JUN-15
WG2114941-8 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			99.2		%		85-115	23-JUN-15
WG2114941-11 DUP		**L1628832-3**						
Ammonia, Total (as N)		<0.0050	<0.0050	RPD-NA	mg/L	N/A	20	23-JUN-15
WG2114941-1 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	23-JUN-15
WG2114941-3 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	23-JUN-15
WG2114941-5 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	23-JUN-15
WG2114941-7 MB								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NH3-F-VA	**Water**							
Batch R3213724								
WG2114941-7 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	23-JUN-15
WG2114941-12 MS		**L1628832-3**						
Ammonia, Total (as N)			103.2		%		75-125	23-JUN-15
Batch R3214119								
WG2115397-2 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			100.4		%		85-115	24-JUN-15
WG2115397-4 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			101.3		%		85-115	24-JUN-15
WG2115397-6 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			95.5		%		85-115	24-JUN-15
WG2115397-8 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			95.3		%		85-115	24-JUN-15
WG2115397-1 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	24-JUN-15
WG2115397-3 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	24-JUN-15
WG2115397-5 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	24-JUN-15
WG2115397-7 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	24-JUN-15
NO2-L-IC-N-VA	**Water**							
Batch R3212102								
WG2112795-3 DUP		**L1628832-2**						
Nitrite (as N)		<0.0010	<0.0010	RPD-NA	mg/L	N/A	20	20-JUN-15
WG2112795-18 LCS								
Nitrite (as N)			99.6		%		90-110	20-JUN-15
WG2112795-2 LCS								
Nitrite (as N)			100.1		%		90-110	20-JUN-15
WG2112795-1 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	20-JUN-15
WG2112795-10 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	20-JUN-15
WG2112795-13 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	20-JUN-15
WG2112795-16 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	20-JUN-15
WG2112795-4 MB								

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO2-L-IC-N-VA	**Water**							
Batch R3212102								
WG2112795-4 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	20-JUN-15
WG2112795-7 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	20-JUN-15
NO3-L-IC-N-VA	**Water**							
Batch R3212102								
WG2112795-3 DUP		**L1628832-2**						
Nitrate (as N)		<0.0050	<0.0050	RPD-NA	mg/L	N/A	20	20-JUN-15
WG2112795-18 LCS								
Nitrate (as N)			102.4		%		90-110	20-JUN-15
WG2112795-2 LCS								
Nitrate (as N)			102.3		%		90-110	20-JUN-15
WG2112795-1 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	20-JUN-15
WG2112795-10 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	20-JUN-15
WG2112795-13 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	20-JUN-15
WG2112795-16 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	20-JUN-15
WG2112795-4 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	20-JUN-15
WG2112795-7 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	20-JUN-15
P-T-PRES-COL-VA	**Water**							
Batch R3213607								
WG2114479-10 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			96.9		%		80-120	24-JUN-15
WG2114479-2 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			98.1		%		80-120	24-JUN-15
WG2114479-6 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			101.3		%		80-120	24-JUN-15
WG2114479-1 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	24-JUN-15
WG2114479-5 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	24-JUN-15
WG2114479-9 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	24-JUN-15

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
P-T-PRES-COL-VA	**Water**							
Batch R3213607								
WG2114479-8 MS		**L1628832-1**						
Phosphorus (P)-Total			79.9		%		70-130	24-JUN-15
PH-PCT-VA	**Water**							
Batch R3212901								
WG2113140-25 CRM		**VA-PH7-BUF**						
pH			7.06		pH		6.9-7.1	22-JUN-15
WG2113140-26 CRM		**VA-PH7-BUF**						
pH			7.07		pH		6.9-7.1	22-JUN-15
WG2113140-27 CRM		**VA-PH7-BUF**						
pH			7.05		pH		6.9-7.1	22-JUN-15
WG2113140-28 CRM		**VA-PH7-BUF**						
pH			7.04		pH		6.9-7.1	22-JUN-15
WG2113140-29 CRM		**VA-PH7-BUF**						
pH			7.04		pH		6.9-7.1	22-JUN-15
WG2113140-30 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	22-JUN-15
WG2113140-31 CRM		**VA-PH7-BUF**						
pH			7.04		pH		6.9-7.1	22-JUN-15
WG2113140-32 CRM		**VA-PH7-BUF**						
pH			7.05		pH		6.9-7.1	22-JUN-15
WG2113140-35 DUP		**L1628832-4**						
pH		7.92	7.93	J	pH	0.00	0.3	22-JUN-15
PO4-DO-COL-VA	**Water**							
Batch R3211261								
WG2112380-10 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			83.9		%		80-120	19-JUN-15
WG2112380-14 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			84.5		%		80-120	19-JUN-15
WG2112380-2 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			94.1		%		80-120	19-JUN-15
WG2112380-6 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			91.1		%		80-120	19-JUN-15
WG2112380-1 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	19-JUN-15
WG2112380-13 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	19-JUN-15
WG2112380-5 MB								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PO4-DO-COL-VA	**Water**							
Batch R3211261								
WG2112380-5 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	19-JUN-15
WG2112380-9 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	19-JUN-15
TDS-VA	**Water**							
Batch R3214333								
WG2114666-2 LCS								
Total Dissolved Solids			102.5		%		85-115	23-JUN-15
WG2114666-5 LCS								
Total Dissolved Solids			101.0		%		85-115	23-JUN-15
WG2114666-8 LCS								
Total Dissolved Solids			103.5		%		85-115	23-JUN-15
WG2114666-1 MB								
Total Dissolved Solids			<10		mg/L		10	23-JUN-15
WG2114666-4 MB								
Total Dissolved Solids			<10		mg/L		10	23-JUN-15
WG2114666-7 MB								
Total Dissolved Solids			<10		mg/L		10	23-JUN-15
TSS-LOW-VA	**Water**							
Batch R3213700								
WG2114311-2 LCS								
Total Suspended Solids			99.3		%		85-115	23-JUN-15
WG2114311-4 LCS								
Total Suspended Solids			100.1		%		85-115	23-JUN-15
WG2114311-6 LCS								
Total Suspended Solids			104.2		%		85-115	23-JUN-15
WG2114311-8 LCS								
Total Suspended Solids			102.9		%		85-115	23-JUN-15
WG2114311-1 MB								
Total Suspended Solids			<1.0		mg/L		1	23-JUN-15
WG2114311-3 MB								
Total Suspended Solids			<1.0		mg/L		1	23-JUN-15
WG2114311-5 MB								
Total Suspended Solids			<1.0		mg/L		1	23-JUN-15
WG2114311-7 MB								
Total Suspended Solids			<1.0		mg/L		1	23-JUN-15
TURBIDITY-VA	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
TURBIDITY-VA	**Water**							
Batch R3211360								
WG2112623-2 CRM		**VA-FORM-40**						
Turbidity			101.0		%		85-115	19-JUN-15
WG2112623-5 CRM		**VA-FORM-40**						
Turbidity			100.8		%		85-115	19-JUN-15
WG2112623-1 MB								
Turbidity			<0.10		NTU		0.1	19-JUN-15
WG2112623-4 MB								
Turbidity			<0.10		NTU		0.1	19-JUN-15

Quality Control Report

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
DLM	Detection Limit Adjusted due to sample matrix effects.
J	Duplicate results and limits are expressed in terms of absolute difference.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH by Meter (Automated)							
	1	17-JUN-15 10:29	22-JUN-15 23:00	0.25	132	hours	EHTR-FM
	2	17-JUN-15 10:29	22-JUN-15 23:00	0.25	132	hours	EHTR-FM
	3	17-JUN-15 10:29	22-JUN-15 23:00	0.25	132	hours	EHTR-FM
	4	17-JUN-15 10:29	22-JUN-15 23:00	0.25	132	hours	EHTR-FM

Legend & Qualifier Definitions:

EHTR-FM: Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR: Exceeded ALS recommended hold time prior to sample receipt.
EHTL: Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT: Exceeded ALS recommended hold time prior to analysis.
Rec. HT: ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1628832 were received on 17-JUN-15 17:50.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

ALS Environmental

L1628832-COFC

COC #: OL-1633

Report To	
Company:	ECOFISH RESEARCH LTD
Contact:	Kevin Ganshorn
Address:	Suite 906 - 595 Howe Street Vancouver, BC Canada, V6C 2T5
Phone:	604-608-6180 Fax:
Invoice To	☑Email ☐Mail
Company:	ECOFISH RESEARCH LTD
Contact:	Accounts Payable
Address:	Suite F, 450 - 8th Street Courtenay, BC Canada, V9N 1N5
Email:	accountspayable@ecofishresearch.com
Phone:	250-334-3042
Lab Work Order # (lab use only)	L1628832

Reporting	
Distribution:	☐Fax ☐Mail ☑Email
☐Criteria on Report (select from Guidelines below)	
Report Type:	☑Excel ☑Digital
Report Format:	CROSSTAB_ALSQC
Report Email(s):	kganshorn@ecofishresearch.com tkasubuchi@ecofishresearch.com
EDD Format:	ECF100
EDD Email(s):	kganshorn@ecofishresearch.com bbennett@ecofishresearch.com tkasubuchi@ecofishresearch.com
Project Info	
Job #:	1230 JHT-MON8
PO/AFE:	
LSD:	
Quote #:	
ALS Contact: Ariel Tang, B.Sc.	Sampler: Leah Hull

Service Requested

- ⊙ Regular (Standard Turnaround Times - Business Days) - R
- ○ Priority (3 Days) - surcharge will apply - P
- ○ Priority (2 Days) - surcharge will apply - P2
- ○ Emergency (1-2 day) – surcharge will apply - E
- ○ Same Day or Weekend Emergency - surcharge will apply - E2
- ○ Specify date required - X

Analysis Requests — Please indicate below Filtered, Preserved or both(F, P, F/P)

Sample #	Sample Identification (This will appear on the report)	Longitude	Latitude	Date	Time	Sample Type	Number of Containers	Alkalinity by Colourimetric (Automated)	Ammonia in Water by Fluorescence	Conductivity (Automated)	Diss. Orthophosphate in Water by Colour	Nitrate in Water by Ion Chromatography	Nitrite in Water by Ion Chromatography	Total Dissolved Solids by Gravimetric	Total P in Water by Colour	Total Suspended Solids by Grav. (1 mg/L)	Turbidity by Meter	pH by Meter (Automated)
	QUN-FIELD BLANK			17-June-2015	10:29	WATER	3	R	R	R	R	R	R	R	R	R	R	R
	QUN-TRIP BLANK			↓	↓	WATER	3	R	R	R	R	R	R	R	R	R	R	R
	QUN-WQA			↓	↓	WATER	3	R	R	R	R	R	R	R	R	R	R	R
	QUN-WQB			↓	↓	WATER	3	R	R	R	R	R	R	R	R	R	R	R

Short Holding Time

Rush Processing

Special Instructions/Comments

June 2015 Sampling

The questions below must be answered for water samples (check Yes or No)

Are any sample taken from a regulated DW system? ☐Yes ☒No

If yes, please use an authorized drinking water COC

Is the water sampled intended to be potable for human consumption? ☐Yes ☒No

Guidelines

SAMPLE CONDITION (lab use only)

☐Frozen ☐Cold ☐Ambient ☐Cooling Initiated

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by: Leah Hull	Date: 17-June 2015	Time: 13:00	Received by: Shafu	Date: 17 June	Time: 19:50	Temperature: 7 °C	Verified by:	Date:	Time:	Observations: ☐Yes If Yes add SIF

ECOFISH RESEARCH LTD
ATTN: Kevin Ganshorn
Suite 906 - 595 Howe Street
Vancouver BC V6C 2T5

Date Received: 23-JUL-15
Report Date: 31-JUL-15 13:20 (MT)
Version: FINAL

Client Phone: 604-608-6180

Certificate of Analysis

Lab Work Order #: L1647348

Project P.O. #: 1230-08.40.07
Job Reference: 1230-08.40.07
C of C Numbers: OL-1635
Legal Site Desc:

Ariel Tang, B.Sc.
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1647348-1	L1647348-2			
	Description	WATER	WATER			
	Sampled Date	23-JUL-15	23-JUL-15			
	Sampled Time	09:53	09:53			
	Client ID	QUN-WQA	QUN-WQB			
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	206	206			
	pH (pH)	8.01	7.99			
	Total Suspended Solids (mg/L)	<1.0	<1.0			
	Total Dissolved Solids (mg/L)	120	120			
	Turbidity (NTU)	0.49	0.49			
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	51.7	54.0			
	Ammonia, Total (as N) (mg/L)	<0.0050	<0.0050			
	Nitrate (as N) (mg/L)	0.0305	0.0293			
	Nitrite (as N) (mg/L)	<0.0010	<0.0010			
	Orthophosphate-Dissolved (as P) (mg/L)	<0.0010	<0.0010			
	Phosphorus (P)-Total (mg/L)	0.0021	<0.0020			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Duplicate	Nitrite (as N)	DLM	L1647348-1, -2
Matrix Spike	Orthophosphate-Dissolved (as P)	MS-B	L1647348-1, -2

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLM	Detection Limit Adjusted due to sample matrix effects.
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-COL-VA	Water	Alkalinity by Colourimetric (Automated)	EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	APHA 4500 NH3-NITROGEN (AMMONIA)

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-L-IC-N-VA	Water	Nitrite in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-L-IC-N-VA	Water	Nitrate in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-PRES-COL-VA	Water	Total P in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.

TDS-VA	Water	Total Dissolved Solids by Gravimetric	APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TSS-LOW-VA	Water	Total Suspended Solids by Grav. (1 mg/L)	APHA 2540D

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

Reference Information

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

OL-1635

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

ALS Environmental

Quality Control Report

Workorder: L1647348 Report Date: 31-JUL-15

Client: ECOFISH RESEARCH LTD
Suite 906 - 595 Howe Street
Vancouver BC V6C 2T5

Contact: Kevin Ganshorn

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ALK-COL-VA	**Water**							
Batch R3232386								
WG2136101-2 CRM		**VA-ALKL-CONTROL**						
Alkalinity, Total (as CaCO3)			107.0		%		85-115	24-JUL-15
WG2136101-5 CRM		**VA-ALKM-CONTROL**						
Alkalinity, Total (as CaCO3)			101.9		%		85-115	24-JUL-15
WG2136101-8 CRM		**VA-ALKH-CONTROL**						
Alkalinity, Total (as CaCO3)			102.8		%		85-115	24-JUL-15
WG2136101-1 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUL-15
WG2136101-10 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUL-15
WG2136101-4 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUL-15
WG2136101-7 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	24-JUL-15
EC-PCT-VA	**Water**							
Batch R3232599								
WG2136079-17 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.5		%		90-110	25-JUL-15
WG2136079-18 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			98.2		%		90-110	25-JUL-15
WG2136079-19 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.3		%		90-110	25-JUL-15
WG2136079-20 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			100.3		%		90-110	25-JUL-15
WG2136079-21 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.0		%		90-110	25-JUL-15
WG2136079-22 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.0		%		90-110	25-JUL-15
WG2136079-1 MB								
Conductivity			<2.0		uS/cm		2	25-JUL-15
WG2136079-2 MB								
Conductivity			<2.0		uS/cm		2	25-JUL-15
WG2136079-3 MB								
Conductivity			<2.0		uS/cm		2	25-JUL-15
WG2136079-4 MB								
Conductivity			<2.0		uS/cm		2	25-JUL-15
WG2136079-5 MB								
Conductivity			<2.0		uS/cm		2	25-JUL-15
WG2136079-6 MB								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
EC-PCT-VA	**Water**							
Batch R3232599								
WG2136079-6 MB								
Conductivity			<2.0		uS/cm		2	25-JUL-15
NH3-F-VA	**Water**							
Batch R3234326								
WG2137561-2 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			103.8		%		85-115	28-JUL-15
WG2137561-4 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			99.4		%		85-115	28-JUL-15
WG2137561-6 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			103.8		%		85-115	28-JUL-15
WG2137561-8 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			99.8		%		85-115	28-JUL-15
WG2137561-9 DUP		**L1647348-2**						
Ammonia, Total (as N)		<0.0050	<0.0050	RPD-NA	mg/L	N/A	20	28-JUL-15
WG2137561-1 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	28-JUL-15
WG2137561-3 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	28-JUL-15
WG2137561-5 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	28-JUL-15
WG2137561-7 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	28-JUL-15
WG2137561-10 MS		**L1647348-2**						
Ammonia, Total (as N)			103.1		%		75-125	28-JUL-15
NO2-L-IC-N-VA	**Water**							
Batch R3233253								
WG2135645-14 LCS								
Nitrite (as N)			100.6		%		90-110	24-JUL-15
WG2135645-2 LCS								
Nitrite (as N)			100.8		%		90-110	24-JUL-15
WG2135645-1 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	24-JUL-15
WG2135645-10 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	24-JUL-15
WG2135645-13 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	24-JUL-15
WG2135645-4 MB								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO2-L-IC-N-VA	**Water**							
Batch R3233253								
WG2135645-4 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	24-JUL-15
WG2135645-7 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	24-JUL-15
NO3-L-IC-N-VA	**Water**							
Batch R3233253								
WG2135645-14 LCS								
Nitrate (as N)			101.3		%		90-110	24-JUL-15
WG2135645-2 LCS								
Nitrate (as N)			101.8		%		90-110	24-JUL-15
WG2135645-1 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	24-JUL-15
WG2135645-10 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	24-JUL-15
WG2135645-13 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	24-JUL-15
WG2135645-4 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	24-JUL-15
WG2135645-7 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	24-JUL-15
P-T-PRES-COL-VA	**Water**							
Batch R3232560								
WG2136402-10 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			107.0		%		80-120	25-JUL-15
WG2136402-2 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			105.5		%		80-120	25-JUL-15
WG2136402-6 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			108.4		%		80-120	25-JUL-15
WG2136402-1 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	25-JUL-15
WG2136402-5 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	25-JUL-15
WG2136402-9 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	25-JUL-15
PH-PCT-VA	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PH-PCT-VA	**Water**							
Batch R3232599								
WG2136079-25 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	25-JUL-15
WG2136079-26 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	25-JUL-15
WG2136079-27 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	25-JUL-15
WG2136079-28 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	25-JUL-15
WG2136079-29 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	25-JUL-15
WG2136079-30 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	25-JUL-15
PO4-DO-COL-VA	**Water**							
Batch R3231660								
WG2135501-10 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			108.0		%		80-120	24-JUL-15
WG2135501-14 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			107.8		%		80-120	24-JUL-15
WG2135501-2 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			101.6		%		80-120	24-JUL-15
WG2135501-6 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			101.8		%		80-120	24-JUL-15
WG2135501-1 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	24-JUL-15
WG2135501-13 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	24-JUL-15
WG2135501-5 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	24-JUL-15
WG2135501-9 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	24-JUL-15
TDS-VA	**Water**							
Batch R3235882								
WG2138692-2 LCS								
Total Dissolved Solids			101.6		%		85-115	29-JUL-15
WG2138692-5 LCS								
Total Dissolved Solids			106.0		%		85-115	29-JUL-15
WG2138692-8 LCS								
Total Dissolved Solids			100.8		%		85-115	29-JUL-15

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
TDS-VA	**Water**							
Batch R3235882								
WG2138692-1 MB								
Total Dissolved Solids			<10		mg/L		10	29-JUL-15
WG2138692-4 MB								
Total Dissolved Solids			<10		mg/L		10	29-JUL-15
WG2138692-7 MB								
Total Dissolved Solids			<10		mg/L		10	29-JUL-15
TSS-LOW-VA	**Water**							
Batch R3234835								
WG2138218-2 LCS								
Total Suspended Solids			101.9		%		85-115	28-JUL-15
WG2138218-4 LCS								
Total Suspended Solids			104.7		%		85-115	28-JUL-15
WG2138218-6 LCS								
Total Suspended Solids			102.3		%		85-115	28-JUL-15
WG2138218-1 MB								
Total Suspended Solids			<1.0		mg/L		1	28-JUL-15
WG2138218-3 MB								
Total Suspended Solids			<1.0		mg/L		1	28-JUL-15
WG2138218-5 MB								
Total Suspended Solids			<1.0		mg/L		1	28-JUL-15
TURBIDITY-VA	**Water**							
Batch R3232313								
WG2136075-11 CRM		**VA-FORM-40**						
Turbidity			99.3		%		85-115	24-JUL-15
WG2136075-2 CRM		**VA-FORM-40**						
Turbidity			99.3		%		85-115	24-JUL-15
WG2136075-5 CRM		**VA-FORM-40**						
Turbidity			97.5		%		85-115	24-JUL-15
WG2136075-8 CRM		**VA-FORM-40**						
Turbidity			98.8		%		85-115	24-JUL-15
WG2136075-1 MB								
Turbidity			<0.10		NTU		0.1	24-JUL-15
WG2136075-10 MB								
Turbidity			<0.10		NTU		0.1	24-JUL-15
WG2136075-4 MB								
Turbidity			<0.10		NTU		0.1	24-JUL-15
WG2136075-7 MB								
Turbidity			<0.10		NTU		0.1	24-JUL-15

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Quality Control Report

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH by Meter (Automated)							
	1	23-JUL-15 09:53	25-JUL-15 10:47	0.25	49	hours	EHTR-FM
	2	23-JUL-15 09:53	25-JUL-15 10:47	0.25	49	hours	EHTR-FM

Legend & Qualifier Definitions:

EHTR-FM:	Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR:	Exceeded ALS recommended hold time prior to sample receipt.
EHTL:	Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT:	Exceeded ALS recommended hold time prior to analysis.
Rec. HT:	ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1647348 were received on 23-JUL-15 17:05.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

L1647348-COFC

Chain of Custody / Analytical Request Form
Canada Toll Free : 1 800 668 9878
www.alsglobal.com

COC #: OL-1635

Report To		Reporting		Service Requested
Company:	ECOFISH RESEARCH LTD	Distribution:	☐Fax ☐Mail ☑Email	◉ Regular (Standard Turnaround Times - Business Days) - R
Contact:	Kevin Ganshorn	☐Criteria on Report (select from Guidelines below)		○ Priority (3 Days) - surcharge will apply - P
Address:	Suite 906 - 595 Howe Street Vancouver, BC Canada, V6C 2T5	Report Type:	☑Excel ☑Digital	○ Priority (2 Days) - surcharge will apply - P2
		Report Format:	CROSSTAB_ALSQC	○ Emergency (1-2 day) – surcharge will apply - E
		Report Email(s):	kganshorn@ecofishresearch.com tkasubuchi@ecofishresearch.com	○ Same Day or Weekend Emergency - surcharge will apply - E2
				○ Specify date required - X
Phone:	604-608-6180 Fax:			

Invoice To	☑Email ☐Mail	EDD Format:	ECF100
Company:	ECOFISH RESEARCH LTD	EDD Email(s):	kganshorn@ecofishresearch.com bbennett@ecofishresearch.com tkasubuchi@ecofishresearch.com
Contact:	Accounts Payable		
Address:	Suite F, 450 - 8th Street Courtenay, BC Canada, V9N 1N5	**Project Info**	
		Job #:	1230 JHT-MON8 1230-08.40
		PO/AFE:	
		LSD:	
Email:	accountspayable@ecofishresearch.com	Quote #:	
Phone:	250-334-3042		
Lab Work Order # (lab use only)		ALS Contact: Ariel Tang, B.Sc.	Sampler: Leah Hull

Analysis Requests (Please indicate below Filtered, Preserved or both(F, P, F/P))

Sample #	Sample Identification (This will appear on the report)	Longitude	Latitude	Date	Time	Sample Type	Number of Containers	Alkalinity by Colourimetric (Automated)	Ammonia in Water by Fluorescence	Conductivity (Automated)	Diss. Orthophosphate in Water by Colour	Nitrate in Water by Ion Chromatography	Nitrite in Water by Ion Chromatography	Total Dissolved Solids by Gravimetric	Total P in Water by Colour	Total Suspended Solids by Grav. (1 mg/L)	Turbidity by Meter	pH by Meter (Automated)			
	~~QUN-FIELD-BLANK~~					~~WATER~~	3	R	R	R	R	R	R	R	R	R	R	R			
	~~QUN-TRIP-BLANK~~					~~WATER~~	3	R	R	R	R	R	R	R	R	R	R	R			
	QUN-WQA			23 July 2015	9:53	WATER	3	R	R	R	R	R	R	R	R	R	R	R			
	QUN-WQB			〃	9:53	WATER	3	R	R	R	R	R	R	R	R	R	R	R			

Short Holding Time

Rush Processing

July 2015 Sampling

Questions below must be answered for water samples (check Yes or No)

Is sample taken from a regulated DW system? ☐Yes ☐No

If yes, please use an authorized drinking water COC

Is the water sampled intended to be potable for human consumption? ☐Yes ☐No

Guidelines

SAMPLE CONDITION (lab use only)

☐Frozen ☐Cold ☐Ambient ☐Cooling Initiated

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by: Leah Hull	Date: 23 July 2015	Time: 13:30	Received by: Shayan	Date: July 23	Time: 15:05	Temperature: 10 °C	Verified by:	Date:	Time:	Observations: ☐Yes If Yes add SIF

ECOFISH RESEARCH LTD
ATTN: Kevin Ganshorn
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5

Date Received: 13-AUG-15
Report Date: 21-AUG-15 14:30 (MT)
Version: FINAL

Client Phone: 250-334-3042

Certificate of Analysis

Lab Work Order #: L1657613

Project P.O. #: 1230-08.40.07
Job Reference: 1230-08.40.07
C of C Numbers: OL-1637
Legal Site Desc:

Ariel Tang, B.Sc.
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1657613-1	L1657613-2			
	Description	WATER	WATER			
	Sampled Date	13-AUG-15	13-AUG-15			
	Sampled Time	10:14	10:14			
	Client ID	QUN-WQA	QUN-WQB			
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	177	173			
	pH (pH)	7.85	7.70			
	Total Suspended Solids (mg/L)	<1.0	<1.0			
	Total Dissolved Solids (mg/L)	120	127			
	Turbidity (NTU)	0.42	0.30			
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	49.6	48.0			
	Ammonia, Total (as N) (mg/L)	<0.0050	<0.0050			
	Nitrate (as N) (mg/L)	0.0413	0.0406			
	Nitrite (as N) (mg/L)	<0.0010	<0.0010			
	Orthophosphate-Dissolved (as P) (mg/L)	<0.0010	<0.0010			
	Phosphorus (P)-Total (mg/L)	<0.0020	<0.0020			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Method Blank	Conductivity	B	L1657613-1, -2
Matrix Spike	Phosphorus (P)-Total	MS-B	L1657613-1, -2

Qualifiers for Individual Parameters Listed:

Qualifier	Description
B	Method Blank exceeds ALS DQO. All associated sample results are at least 5 times greater than blank levels and are considered reliable.
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-COL-VA	Water	Alkalinity by Colourimetric (Automated)	EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	APHA 4500 NH3-NITROGEN (AMMONIA)

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-L-IC-N-VA	Water	Nitrite in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-L-IC-N-VA	Water	Nitrate in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-PRES-COL-VA	Water	Total P in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.

TDS-VA	Water	Total Dissolved Solids by Gravimetric	APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TSS-LOW-VA	Water	Total Suspended Solids by Grav. (1 mg/L)	APHA 2540D

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 Turbidity

Reference Information

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

OL-1637

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

ALS Environmental

Quality Control Report

Workorder: L1657613 Report Date: 21-AUG-15

Client: ECOFISH RESEARCH LTD
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5

Contact: Kevin Ganshorn

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ALK-COL-VA	**Water**							
Batch R3248171								
WG2151173-2 CRM		**VA-ALKL-CONTROL**						
Alkalinity, Total (as CaCO3)			97.9		%		85-115	17-AUG-15
WG2151173-5 CRM		**VA-ALKM-CONTROL**						
Alkalinity, Total (as CaCO3)			96.0		%		85-115	17-AUG-15
WG2151173-8 CRM		**VA-ALKH-CONTROL**						
Alkalinity, Total (as CaCO3)			102.2		%		85-115	17-AUG-15
WG2151173-1 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	17-AUG-15
WG2151173-11 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	17-AUG-15
WG2151173-13 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	17-AUG-15
WG2151173-15 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	17-AUG-15
WG2151173-4 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	17-AUG-15
WG2151173-7 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	17-AUG-15
Batch R3249000								
WG2152397-2 CRM		**VA-ALKL-CONTROL**						
Alkalinity, Total (as CaCO3)			100.0		%		85-115	18-AUG-15
WG2152397-5 CRM		**VA-ALKM-CONTROL**						
Alkalinity, Total (as CaCO3)			99.3		%		85-115	18-AUG-15
WG2152397-8 CRM		**VA-ALKH-CONTROL**						
Alkalinity, Total (as CaCO3)			101.2		%		85-115	18-AUG-15
WG2152397-1 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	18-AUG-15
WG2152397-11 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	18-AUG-15
WG2152397-4 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	18-AUG-15
WG2152397-7 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	18-AUG-15
EC-PCT-VA	**Water**							
Batch R3249050								
WG2151037-17 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.5		%		90-110	18-AUG-15
WG2151037-18 CRM		**VA-EC-PCT-CONTROL**						

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
EC-PCT-VA	**Water**							
Batch R3249050								
WG2151037-18 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.1		%		90-110	18-AUG-15
WG2151037-19 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.5		%		90-110	18-AUG-15
WG2151037-20 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			100.8		%		90-110	18-AUG-15
WG2151037-21 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.5		%		90-110	18-AUG-15
WG2151037-22 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			103.6		%		90-110	18-AUG-15
WG2151037-1 MB								
Conductivity			<2.0		uS/cm		2	18-AUG-15
WG2151037-2 MB								
Conductivity			<2.0		uS/cm		2	18-AUG-15
WG2151037-3 MB								
Conductivity			<2.0		uS/cm		2	18-AUG-15
WG2151037-4 MB								
Conductivity			<2.0		uS/cm		2	18-AUG-15
WG2151037-5 MB								
Conductivity			<2.0		uS/cm		2	18-AUG-15
WG2151037-6 MB								
Conductivity			2.8	B	uS/cm		2	18-AUG-15
NH3-F-VA	**Water**							
Batch R3249735								
WG2152161-2 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			97.3		%		85-115	19-AUG-15
WG2152161-4 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			95.8		%		85-115	19-AUG-15
WG2152161-6 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			96.3		%		85-115	19-AUG-15
WG2152161-8 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			95.3		%		85-115	19-AUG-15
WG2152161-11 DUP		**L1657613-2**						
Ammonia, Total (as N)		<0.0050	<0.0050	RPD-NA	mg/L	N/A	20	19-AUG-15
WG2152161-1 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-AUG-15
WG2152161-3 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-AUG-15
WG2152161-5 MB								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NH3-F-VA	**Water**							
Batch R3249735								
WG2152161-5 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-AUG-15
WG2152161-7 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	19-AUG-15
WG2152161-12 MS		**L1657613-2**						
Ammonia, Total (as N)			102.4		%		75-125	19-AUG-15
NO2-L-IC-N-VA	**Water**							
Batch R3249185								
WG2149422-18 LCS								
Nitrite (as N)			100.2		%		90-110	14-AUG-15
WG2149422-2 LCS								
Nitrite (as N)			100.6		%		90-110	14-AUG-15
WG2149422-1 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	14-AUG-15
WG2149422-10 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	14-AUG-15
WG2149422-13 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	14-AUG-15
WG2149422-16 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	14-AUG-15
WG2149422-4 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	14-AUG-15
WG2149422-7 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	14-AUG-15
NO3-L-IC-N-VA	**Water**							
Batch R3249185								
WG2149422-18 LCS								
Nitrate (as N)			101.4		%		90-110	14-AUG-15
WG2149422-2 LCS								
Nitrate (as N)			101.1		%		90-110	14-AUG-15
WG2149422-1 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	14-AUG-15
WG2149422-10 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	14-AUG-15
WG2149422-13 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	14-AUG-15
WG2149422-16 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	14-AUG-15

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO3-L-IC-N-VA	**Water**							
Batch R3249185								
WG2149422-4 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	14-AUG-15
WG2149422-7 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	14-AUG-15
P-T-PRES-COL-VA	**Water**							
Batch R3247206								
WG2150164-14 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			104.5		%		80-120	15-AUG-15
WG2150164-13 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	15-AUG-15
PH-PCT-VA	**Water**							
Batch R3249050								
WG2151037-25 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	18-AUG-15
WG2151037-26 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	18-AUG-15
WG2151037-27 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	18-AUG-15
WG2151037-28 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	18-AUG-15
WG2151037-29 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	18-AUG-15
WG2151037-30 CRM		**VA-PH7-BUF**						
pH			7.01		pH		6.9-7.1	18-AUG-15
PO4-DO-COL-VA	**Water**							
Batch R3247033								
WG2150137-10 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			99.9		%		80-120	15-AUG-15
WG2150137-14 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			118.3		%		80-120	15-AUG-15
WG2150137-2 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			93.1		%		80-120	15-AUG-15
WG2150137-6 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			104.1		%		80-120	15-AUG-15
WG2150137-1 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	15-AUG-15
WG2150137-13 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	15-AUG-15

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PO4-DO-COL-VA	**Water**							
Batch R3247033								
WG2150137-5 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	15-AUG-15
WG2150137-9 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	15-AUG-15
TDS-VA	**Water**							
Batch R3250426								
WG2152618-11 LCS								
Total Dissolved Solids			95.1		%		85-115	19-AUG-15
WG2152618-2 LCS								
Total Dissolved Solids			102.1		%		85-115	19-AUG-15
WG2152618-5 LCS								
Total Dissolved Solids			100.9		%		85-115	19-AUG-15
WG2152618-8 LCS								
Total Dissolved Solids			104.9		%		85-115	19-AUG-15
WG2152618-1 MB								
Total Dissolved Solids			<10		mg/L		10	19-AUG-15
WG2152618-10 MB								
Total Dissolved Solids			<10		mg/L		10	19-AUG-15
WG2152618-4 MB								
Total Dissolved Solids			<10		mg/L		10	19-AUG-15
WG2152618-7 MB								
Total Dissolved Solids			<10		mg/L		10	19-AUG-15
TSS-LOW-VA	**Water**							
Batch R3249331								
WG2151556-4 LCS								
Total Suspended Solids			102.9		%		85-115	18-AUG-15
WG2151556-3 MB								
Total Suspended Solids			<1.0		mg/L		1	18-AUG-15
TURBIDITY-VA	**Water**							
Batch R3246255								
WG2149341-2 CRM		**VA-FORM-40**						
Turbidity			95.0		%		85-115	14-AUG-15
WG2149341-5 CRM		**VA-FORM-40**						
Turbidity			94.8		%		85-115	14-AUG-15
WG2149341-1 MB								
Turbidity			<0.10		NTU		0.1	14-AUG-15
WG2149341-4 MB								
Turbidity			<0.10		NTU		0.1	14-AUG-15

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
B	Method Blank exceeds ALS DQO. All associated sample results are at least 5 times greater than blank levels and are considered reliable.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH by Meter (Automated)							
	1	13-AUG-15 10:14	18-AUG-15 06:11	0.25	116	hours	EHTR-FM
	2	13-AUG-15 10:14	18-AUG-15 06:11	0.25	116	hours	EHTR-FM

Legend & Qualifier Definitions:

EHTR-FM: Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR: Exceeded ALS recommended hold time prior to sample receipt.
EHTL: Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT: Exceeded ALS recommended hold time prior to analysis.
Rec. HT: ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1657613 were received on 13-AUG-15 18:00.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

ALS Environmental

Chain of Custody / Analytical Request Form
Canada Toll Free : 1 800 668 9878
www.alsglobal.com

COC #: OL-1637

Report To

Company:	ECOFISH RESEARCH LTD
Contact:	Kevin Ganshorn
Address:	Suite 906 - 595 Howe Street Vancouver, BC Canada, V6C 2T5
Phone:	604-608-6180
Fax:	

Invoice To ☑Email ☐Mail

Company:	ECOFISH RESEARCH LTD
Contact:	Accounts Payable
Address:	Suite F, 450 - 8th Street Courtenay, BC Canada, V9N 1N5
Email:	accountspayable@ecofishresearch.com
Phone:	250-334-3042

Lab Work Order # (lab use only)

Reporting

Distribution:	☐Fax ☐Mail ☑Email
☐Criteria on Report (select from Guidelines below)	
Report Type:	☑Excel ☑Digital
Report Format:	CROSSTAB_ALSQC
Report Email(s):	kganshorn@ecofishresearch.com tkasubuchi@ecofishresearch.com
EDD Format:	ECF100
EDD Email(s):	kganshorn@ecofishresearch.com bbennett@ecofishresearch.com tkasubuchi@ecofishresearch.com

Project Info

Job #:	~~1230-JHT-MON8~~
PO/AFE:	1230-08.40.08
LSD:	
Quote #:	
ALS Contact:	Ariel Tang, B.Sc.
Sampler:	Leah Hull

Service Requested

- ⦿ Regular (Standard Turnaround Times - Business Days) - R
- ○ Priority (3 Days) - surcharge will apply - P
- ○ Priority (2 Days) - surcharge will apply - P2
- ○ Emergency (1-2 day) – surcharge will apply - E
- ○ Same Day or Weekend Emergency - surcharge will apply - E2
- ○ Specify date required - X

Analysis Requests

Please indicate below Filtered, Preserved or both(F, P, F/P)

Sample #	Sample Identification (This will appear on the report)	Longitude	Latitude	Date	Time	Sample Type	Number of Containers	Alkalinity by Colourimetric (Automated)	Ammonia in Water by Fluorescence	Conductivity (Automated)	Diss. Orthophosphate in Water by Colour	Nitrate in Water by Ion Chromatography	Nitrite in Water by Ion Chromatography	Total Dissolved Solids by Gravimetric	Total P in Water by Colour	Total Suspended Solids by Grav. (1 mg/L)	Turbidity by Meter	pH by Meter (Automated)
	~~QUN-FIELD BLANK~~			~~13-Aug-2015~~		WATER	3	R	R	R	R	R	R	R	R	R	R	R
	~~QUN-TRIP BLANK~~					WATER	3	R	R	R	R	R	R	R	R	R	R	R
	QUN-WQA			13-Aug-2015	10:14	WATER	3	R	R	R	R	R	R	R	R	R	R	R
	QUN-WQB			13-Aug-2015	10:14	WATER	3	R	R	R	R	R	R	R	R	R	R	R

Short Holding Time

Rush Processing

L1657613-COFC

Guidelin

August 2015 Sampling

The questions below must be answered for water samples (check Yes or No)

Are any sample taken from a regulated DW system? ☐Yes ☐No

If yes, please use an authorized drinking water COC

Is the water sampled intended to be potable for human consumption? ☐Yes ☐No

SAMPLE CONDITION (lab use only)

☐Frozen ☐Cold ☐Ambient ☐Cooling Initiated

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by: Leah Hull	Date: 13-Aug 2015	Time: 14:00	Received by: Shayan	Date: Aug 13	Time: 18:00	Temperature: 7.1 °C	Verified by:	Date:	Time:	Observations: ☐Yes If Yes add SIF

ECOFISH RESEARCH LTD
ATTN: Kevin Ganshorn
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5

Date Received: 17-SEP-15
Report Date: 28-SEP-15 12:15 (MT)
Version: FINAL

Client Phone: 250-334-3042

Certificate of Analysis

Lab Work Order #: L1674881

Project P.O. #: NOT SUBMITTED
Job Reference: 1230-08.40.07
C of C Numbers: OL-1641
Legal Site Desc:

Ariel Tang, B.Sc.
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1674881-1	L1674881-2			
	Description	Water	Water			
	Sampled Date	16-SEP-15	16-SEP-15			
	Sampled Time	11:00	11:00			
	Client ID	QUN-WQA	QUN-WQB			
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	177	179			
	pH (pH)	7.94	7.94			
	Total Suspended Solids (mg/L)	<1.0	<1.0			
	Total Dissolved Solids (mg/L)	116	173			
	Turbidity (NTU)	0.42	0.38			
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	46.0	46.3			
	Ammonia, Total (as N) (mg/L)	<0.0050	<0.0050			
	Nitrate (as N) (mg/L)	0.0141	0.0139			
	Nitrite (as N) (mg/L)	<0.0010	<0.0010			
	Orthophosphate-Dissolved (as P) (mg/L)	<0.0010	<0.0010			
	Phosphorus (P)-Total (mg/L)	0.0023	<0.0020			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Duplicate	Nitrite (as N)	DLM	L1674881-1, -2
Matrix Spike	Phosphorus (P)-Total	MS-B	L1674881-1, -2

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLM	Detection Limit Adjusted due to sample matrix effects.
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-COL-VA	Water	Alkalinity by Colourimetric (Automated)	EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	APHA 4500 NH3-NITROGEN (AMMONIA)

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-L-IC-N-VA	Water	Nitrite in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-L-IC-N-VA	Water	Nitrate in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-PRES-COL-VA	Water	Total P in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.

TDS-VA	Water	Total Dissolved Solids by Gravimetric	APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TSS-LOW-VA	Water	Total Suspended Solids by Grav. (1 mg/L)	APHA 2540D

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

Reference Information

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

OL-1641

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Client: ECOFISH RESEARCH LTD
Suite F, 450 - 8th Street
Courtenay BC V9N 1N5

Contact: Kevin Ganshorn

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ALK-COL-VA	**Water**							
Batch R3272690								
WG2174165-2 CRM		**VA-ALKL-CONTROL**						
Alkalinity, Total (as CaCO3)			101.0		%		85-115	18-SEP-15
WG2174165-5 CRM		**VA-ALKM-CONTROL**						
Alkalinity, Total (as CaCO3)			106.1		%		85-115	18-SEP-15
WG2174165-8 CRM		**VA-ALKH-CONTROL**						
Alkalinity, Total (as CaCO3)			103.5		%		85-115	18-SEP-15
WG2174165-1 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	18-SEP-15
WG2174165-10 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	18-SEP-15
WG2174165-4 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	18-SEP-15
WG2174165-7 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	18-SEP-15
EC-PCT-VA	**Water**							
Batch R3273719								
WG2175534-17 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.1		%		90-110	22-SEP-15
WG2175534-18 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			100.3		%		90-110	22-SEP-15
WG2175534-19 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.3		%		90-110	22-SEP-15
WG2175534-20 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			100.1		%		90-110	22-SEP-15
WG2175534-21 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			100.1		%		90-110	23-SEP-15
WG2175534-22 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.0		%		90-110	23-SEP-15
WG2175534-1 MB								
Conductivity			<2.0		uS/cm		2	22-SEP-15
WG2175534-2 MB								
Conductivity			<2.0		uS/cm		2	22-SEP-15
WG2175534-4 MB								
Conductivity			<2.0		uS/cm		2	22-SEP-15
WG2175534-5 MB								
Conductivity			<2.0		uS/cm		2	23-SEP-15
WG2175534-6 MB								
Conductivity			<2.0		uS/cm		2	23-SEP-15

ALS Environmental

Quality Control Report

Workorder: L1674881 Report Date: 28-SEP-15

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NH3-F-VA	**Water**							
Batch R3276144								
WG2179116-2 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			99.2		%		85-115	25-SEP-15
WG2179116-4 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			100.3		%		85-115	25-SEP-15
WG2179116-6 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			101.1		%		85-115	25-SEP-15
WG2179116-8 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			99.0		%		85-115	25-SEP-15
WG2179116-13 DUP		**L1674881-1**						
Ammonia, Total (as N)		<0.0050	<0.0050	RPD-NA	mg/L	N/A	20	25-SEP-15
WG2179116-1 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	25-SEP-15
WG2179116-3 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	25-SEP-15
WG2179116-5 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	25-SEP-15
WG2179116-7 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	25-SEP-15
WG2179116-14 MS		**L1674881-1**						
Ammonia, Total (as N)			101.4		%		75-125	25-SEP-15
NO2-L-IC-N-VA	**Water**							
Batch R3271790								
WG2174219-18 LCS								
Nitrite (as N)			98.5		%		90-110	18-SEP-15
WG2174219-2 LCS								
Nitrite (as N)			99.4		%		90-110	18-SEP-15
WG2174219-1 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	18-SEP-15
WG2174219-10 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	18-SEP-15
WG2174219-13 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	18-SEP-15
WG2174219-16 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	18-SEP-15
WG2174219-4 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	18-SEP-15
WG2174219-7 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	18-SEP-15

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO3-L-IC-N-VA	**Water**							
Batch R3271790								
WG2174219-18 LCS								
Nitrate (as N)			101.4		%		90-110	18-SEP-15
WG2174219-2 LCS								
Nitrate (as N)			101.1		%		90-110	18-SEP-15
WG2174219-1 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	18-SEP-15
WG2174219-10 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	18-SEP-15
WG2174219-13 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	18-SEP-15
WG2174219-16 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	18-SEP-15
WG2174219-4 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	18-SEP-15
WG2174219-7 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	18-SEP-15
P-T-PRES-COL-VA	**Water**							
Batch R3273189								
WG2175937-2 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			103.4		%		80-120	22-SEP-15
WG2175937-1 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	22-SEP-15
PH-PCT-VA	**Water**							
Batch R3273719								
WG2175534-25 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	22-SEP-15
WG2175534-26 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	22-SEP-15
WG2175534-27 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	22-SEP-15
WG2175534-28 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	22-SEP-15
WG2175534-29 CRM		**VA-PH7-BUF**						
pH			7.04		pH		6.9-7.1	23-SEP-15
WG2175534-30 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	23-SEP-15
PO4-DO-COL-VA	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PO4-DO-COL-VA	**Water**							
Batch R3270161								
WG2174416-10 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			103.7		%		80-120	18-SEP-15
WG2174416-2 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			105.0		%		80-120	18-SEP-15
WG2174416-6 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			102.6		%		80-120	18-SEP-15
WG2174416-1 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	18-SEP-15
WG2174416-5 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	18-SEP-15
WG2174416-9 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	18-SEP-15
TDS-VA	**Water**							
Batch R3274726								
WG2176811-2 LCS								
Total Dissolved Solids			102.5		%		85-115	23-SEP-15
WG2176811-5 LCS								
Total Dissolved Solids			103.6		%		85-115	23-SEP-15
WG2176811-1 MB								
Total Dissolved Solids			<10		mg/L		10	23-SEP-15
WG2176811-4 MB								
Total Dissolved Solids			<10		mg/L		10	23-SEP-15
TSS-LOW-VA	**Water**							
Batch R3273676								
WG2176577-2 LCS								
Total Suspended Solids			97.5		%		85-115	22-SEP-15
WG2176577-1 MB								
Total Suspended Solids			<1.0		mg/L		1	22-SEP-15
TURBIDITY-VA	**Water**							
Batch R3269755								
WG2173882-2 CRM		**VA-FORM-40**						
Turbidity			95.5		%		85-115	18-SEP-15
WG2173882-5 CRM		**VA-FORM-40**						
Turbidity			95.5		%		85-115	18-SEP-15
WG2173882-1 MB								
Turbidity			<0.10		NTU		0.1	18-SEP-15
WG2173882-4 MB								
Turbidity			<0.10		NTU		0.1	18-SEP-15

Quality Control Report

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Quality Control Report

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH by Meter (Automated)							
	1	16-SEP-15 11:00	22-SEP-15 10:51	0.25	144	hours	EHTR-FM
	2	16-SEP-15 11:00	22-SEP-15 10:51	0.25	144	hours	EHTR-FM

Legend & Qualifier Definitions:

EHTR-FM: Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR: Exceeded ALS recommended hold time prior to sample receipt.
EHTL: Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT: Exceeded ALS recommended hold time prior to analysis.
Rec. HT: ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1674881 were received on 17-SEP-15 19:55.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

L1674881-COFC

Chain of Custody / Analytical Request Form

Canada Toll Free : 1 800 668 9878

www.alsglobal.com

COC #: OL-1641

Report To

Company: ECOFISH RESEARCH LTD

Contact: Kevin Ganshorn

Address: Suite 906 - 595 Howe Street
Vancouver, BC
Canada, V6C 2T5

Phone: 604-608-6180 Fax:

Invoice To ☑Email ☐Mail

Company: ECOFISH RESEARCH LTD

Contact: Accounts Payable

Address: Suite F, 450 - 8th Street
Courtenay, BC
Canada, V9N 1N5

Email: accountspayable@ecofishresearch.com

Phone: 250-334-3042

Lab Work Order # (lab use only)

Reporting

Distribution: ☐Fax ☐Mail ☑Email

☐Criteria on Report (select from Guidelines below)

Report Type: ☑Excel ☑Digital

Report Format: CROSSTAB_ALSQC

Report Email(s): kganshorn@ecofishresearch.com
tkasubuchi@ecofishresearch.com

EDD Format: ECF100

EDD Email(s): kganshorn@ecofishresearch.com
bbennett@ecofishresearch.com
tkasubuchi@ecofishresearch.com

Project Info 1230-08.40.07

Job #: ~~1230 JHT-MON8~~

PO/AFE:

LSD:

Quote #:

ALS Contact: Ariel Tang, B.Sc. Sampler: Leah Hull

Service Requested

⊙ Regular (Standard Turnaround Times - Business Days) - R

○ Priority (3 Days) - surcharge will apply - P

○ Priority (2 Days) - surcharge will apply - P2

○ Emergency (1-2 day) – surcharge will apply - E

○ Same Day or Weekend Emergency - surcharge will apply - E2

○ Specify date required - X

Analysis Requests (Please indicate below Filtered, Preserved or both (F, P, F/P))

Sample #	Sample Identification (This will appear on the report)	Longitude	Latitude	Date	Time	Sample Type	Number of Containers	Alkalinity by Colourimetric (Automated)	Ammonia in Water by Fluorescence	Conductivity (Automated)	Diss. Orthophosphate in Water by Colour	Nitrate in Water by Ion Chromatography	Nitrite in Water by Ion Chromatography	Total Dissolved Solids by Gravimetric	Total P in Water by Colour	Total Suspended Solids by Grav. (1 mg/L)	Turbidity by Meter	pH by Meter (Automated)
	QUN-FIELD BLANK			~~16-Sept 2015~~		WATER	3	R	R	R	R	R	R	R	R	R	R	R
	QUN-TRIP BLANK					WATER	3	R	R	R	R	R	R	R	R	R	R	R
	QUN-WQA			16-Sept 2015	11:00	WATER	3	R	R	R	R	R	R	R	R	R	R	R
	QUN-WQB			16-Sept 2015	11:00	WATER	3	R	R	R	R	R	R	R	R	R	R	R

Short Holding Time

Rush Processing

Special Instructions/Comments

October 2015 Sampling

The questions below must be answered for water samples (check Yes or No)

Are any sample taken from a regulated DW system? ☐Yes ☒No

If yes, please use an authorized drinking water COC

Is the water sampled intended to be potable for human consumption? ☐Yes ☒No

Guidelines

SAMPLE CONDITION (lab use only)

☐Frozen ☐Cold ☐Ambient ☐Cooling Initiated

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by: Leah Hull	Date: 17 Sept 2015	Time: 16:00	Received by: ISAAC	Date: Sept 17	Time: 19:55	Temperature: 5 °C	Verified by:	Date:	Time:	Observations: ☐Yes If Yes add SIF

ECOFISH RESEARCH LTD
ATTN: Kevin Ganshorn
Suite 906 - 595 Howe Street
Vancouver BC V6C 2T5

Date Received: 16-OCT-15
Report Date: 23-OCT-15 13:38 (MT)
Version: FINAL

Client Phone: 604-608-6180

Certificate of Analysis

Lab Work Order #: L1689157

Project P.O. #: 1230-08.40.07
Job Reference: 1230-08.40.07
C of C Numbers: OL-1639
Legal Site Desc:

Ariel Tang, B.Sc.
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1689157-1	L1689157-2			
	Description	Water	Water			
	Sampled Date	14-OCT-15	14-OCT-15			
	Sampled Time	11:44	11:44			
	Client ID	QUN-WQA	QUN-WQB			
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	131	129			
	pH (pH)	7.52	7.58			
	Total Suspended Solids (mg/L)	1.6	<1.0			
	Total Dissolved Solids (mg/L)	92	96			
	Turbidity (NTU)	0.53	0.40			
Anions and Nutrients	Alkalinity, Total (as CaCO3) (mg/L)	34.1	33.9			
	Ammonia, Total (as N) (mg/L)	0.0092	0.0088			
	Nitrate (as N) (mg/L)	0.0356	0.0363			
	Nitrite (as N) (mg/L)	<0.0010	<0.0010			
	Orthophosphate-Dissolved (as P) (mg/L)	<0.0010	<0.0010			
	Phosphorus (P)-Total (mg/L)	0.0048	0.0044			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Matrix Spike	Phosphorus (P)-Total	MS-B	L1689157-1, -2

Qualifiers for Individual Parameters Listed:

Qualifier	Description
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-COL-VA	Water	Alkalinity by Colourimetric (Automated)	EPA 310.2

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	APHA 4500 NH3-NITROGEN (AMMONIA)

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-L-IC-N-VA	Water	Nitrite in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-L-IC-N-VA	Water	Nitrate in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-PRES-COL-VA	Water	Total P in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H "pH Value"

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.

TDS-VA	Water	Total Dissolved Solids by Gravimetric	APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TSS-LOW-VA	Water	Total Suspended Solids by Grav. (1 mg/L)	APHA 2540D

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 "Turbidity"

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

Reference Information

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

OL-1639

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

ALS Environmental

Quality Control Report

Client: ECOFISH RESEARCH LTD
Suite 906 - 595 Howe Street
Vancouver BC V6C 2T5

Contact: Kevin Ganshorn

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ALK-COL-VA	**Water**							
Batch R3293958								
WG2196845-2 CRM		**VA-ALKL-CONTROL**						
Alkalinity, Total (as CaCO3)			96.8		%		85-115	20-OCT-15
WG2196845-5 CRM		**VA-ALKM-CONTROL**						
Alkalinity, Total (as CaCO3)			97.3		%		85-115	20-OCT-15
WG2196845-8 CRM		**VA-ALKH-CONTROL**						
Alkalinity, Total (as CaCO3)			102.0		%		85-115	20-OCT-15
WG2196845-1 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-OCT-15
WG2196845-11 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-OCT-15
WG2196845-13 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-OCT-15
WG2196845-15 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-OCT-15
WG2196845-17 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-OCT-15
WG2196845-19 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-OCT-15
WG2196845-4 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-OCT-15
WG2196845-7 MB								
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	20-OCT-15
EC-PCT-VA	**Water**							
Batch R3293078								
WG2195702-17 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.3		%		90-110	20-OCT-15
WG2195702-18 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			101.1		%		90-110	20-OCT-15
WG2195702-19 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.0		%		90-110	20-OCT-15
WG2195702-20 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			100.4		%		90-110	20-OCT-15
WG2195702-21 CRM		**VA-EC-PCT-CONTROL**						
Conductivity			102.5		%		90-110	20-OCT-15
WG2195702-37 DUP		**L1689157-2**						
Conductivity		129	129		uS/cm	0.1	10	20-OCT-15
WG2195702-1 MB								
Conductivity			<2.0		uS/cm		2	20-OCT-15
WG2195702-2 MB								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
EC-PCT-VA	**Water**							
Batch R3293078								
WG2195702-2 MB								
Conductivity			<2.0		uS/cm		2	20-OCT-15
WG2195702-3 MB								
Conductivity			<2.0		uS/cm		2	20-OCT-15
WG2195702-4 MB								
Conductivity			<2.0		uS/cm		2	20-OCT-15
WG2195702-5 MB								
Conductivity			<2.0		uS/cm		2	20-OCT-15
NH3-F-VA	**Water**							
Batch R3294890								
WG2197838-10 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			109.1		%		85-115	22-OCT-15
WG2197838-2 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			103.0		%		85-115	22-OCT-15
WG2197838-4 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			113.4		%		85-115	22-OCT-15
WG2197838-6 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			105.2		%		85-115	22-OCT-15
WG2197838-8 CRM		**VA-NH3-F**						
Ammonia, Total (as N)			105.4		%		85-115	22-OCT-15
WG2197838-15 DUP		**L1689157-2**						
Ammonia, Total (as N)		0.0088	0.0089		mg/L	0.3	20	22-OCT-15
WG2197838-1 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	22-OCT-15
WG2197838-3 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	22-OCT-15
WG2197838-5 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	22-OCT-15
WG2197838-7 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	22-OCT-15
WG2197838-9 MB								
Ammonia, Total (as N)			<0.0050		mg/L		0.005	22-OCT-15
WG2197838-16 MS		**L1689157-2**						
Ammonia, Total (as N)			103.1		%		75-125	22-OCT-15
NO2-L-IC-N-VA	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO2-L-IC-N-VA	**Water**							
Batch R3291993								
WG2194852-16 LCS								
Nitrite (as N)			99.4		%		90-110	17-OCT-15
WG2194852-2 LCS								
Nitrite (as N)			99.3		%		90-110	17-OCT-15
WG2194852-1 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-OCT-15
WG2194852-11 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-OCT-15
WG2194852-14 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-OCT-15
WG2194852-3 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-OCT-15
WG2194852-5 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-OCT-15
WG2194852-8 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	17-OCT-15
NO3-L-IC-N-VA	**Water**							
Batch R3291993								
WG2194852-16 LCS								
Nitrate (as N)			101.1		%		90-110	17-OCT-15
WG2194852-2 LCS								
Nitrate (as N)			101.0		%		90-110	17-OCT-15
WG2194852-1 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-OCT-15
WG2194852-11 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-OCT-15
WG2194852-14 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-OCT-15
WG2194852-3 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-OCT-15
WG2194852-5 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-OCT-15
WG2194852-8 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	17-OCT-15
P-T-PRES-COL-VA	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
P-T-PRES-COL-VA	**Water**							
Batch R3291332								
WG2194764-6 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			106.0		%		80-120	17-OCT-15
WG2194764-5 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	17-OCT-15
PH-PCT-VA	**Water**							
Batch R3293078								
WG2195702-25 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	20-OCT-15
WG2195702-26 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	20-OCT-15
WG2195702-27 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	20-OCT-15
WG2195702-28 CRM		**VA-PH7-BUF**						
pH			7.03		pH		6.9-7.1	20-OCT-15
WG2195702-29 CRM		**VA-PH7-BUF**						
pH			7.02		pH		6.9-7.1	20-OCT-15
WG2195702-37 DUP		**L1689157-2**						
pH		7.58	7.58	J	pH	0.00	0.3	20-OCT-15
PO4-DO-COL-VA	**Water**							
Batch R3291158								
WG2194704-10 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			100.2		%		80-120	16-OCT-15
WG2194704-14 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			97.1		%		80-120	16-OCT-15
WG2194704-18 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			92.9		%		80-120	16-OCT-15
WG2194704-2 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			95.4		%		80-120	16-OCT-15
WG2194704-22 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			92.2		%		80-120	16-OCT-15
WG2194704-6 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			97.9		%		80-120	16-OCT-15
WG2194704-8 DUP		**L1689157-2**						
Orthophosphate-Dissolved (as P)		<0.0010	<0.0010	RPD-NA	mg/L	N/A	20	16-OCT-15
WG2194704-1 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-OCT-15
WG2194704-13 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-OCT-15

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PO4-DO-COL-VA	**Water**							
Batch R3291158								
WG2194704-17 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-OCT-15
WG2194704-21 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-OCT-15
WG2194704-5 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-OCT-15
WG2194704-9 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	16-OCT-15
WG2194704-7 MS		**L1689157-1**						
Orthophosphate-Dissolved (as P)			96.3		%		70-130	16-OCT-15
TDS-VA	**Water**							
Batch R3291930								
WG2194751-2 LCS								
Total Dissolved Solids			101.4		%		85-115	17-OCT-15
WG2194751-1 MB								
Total Dissolved Solids			<10		mg/L		10	17-OCT-15
TSS-LOW-VA	**Water**							
Batch R3292340								
WG2194728-4 LCS								
Total Suspended Solids			105.0		%		85-115	17-OCT-15
WG2194728-3 MB								
Total Suspended Solids			<1.0		mg/L		1	17-OCT-15
TURBIDITY-VA	**Water**							
Batch R3291165								
WG2194745-2 CRM		**VA-FORM-40**						
Turbidity			94.8		%		85-115	17-OCT-15
WG2194745-5 CRM		**VA-FORM-40**						
Turbidity			95.0		%		85-115	17-OCT-15
WG2194745-1 MB								
Turbidity			<0.10		NTU		0.1	17-OCT-15
WG2194745-4 MB								
Turbidity			<0.10		NTU		0.1	17-OCT-15

Quality Control Report

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
J	Duplicate results and limits are expressed in terms of absolute difference.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Quality Control Report

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH by Meter (Automated)							
	1	14-OCT-15 11:44	20-OCT-15 08:36	0.25	141	hours	EHTR-FM
	2	14-OCT-15 11:44	20-OCT-15 08:36	0.25	141	hours	EHTR-FM

Legend & Qualifier Definitions:

EHTR-FM: Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR: Exceeded ALS recommended hold time prior to sample receipt.
EHTL: Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT: Exceeded ALS recommended hold time prior to analysis.
Rec. HT: ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1689157 were received on 16-OCT-15 11:15.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

COC #: OL-1639

ALS Environmental

Chain of Custody / Analytical Request Form
Canada Toll Free : 1 800 668 9878
www.alsglobal.com

Report To		Reporting		Service Requested
Company:	ECOFISH RESEARCH LTD	Distribution:	☐Fax ☐Mail ☑Email	⊙ Regular (Standard Turnaround Times - Business Days) - R
Contact:	Kevin Ganshorn	☐Criteria on Report (select from Guidelines below)		O Priority (3 Days) - surcharge will apply - P
Address:	Suite 906 - 595 Howe Street Vancouver, BC Canada, V6C 2T5	Report Type:	☑Excel ☑Digital	O Priority (2 Days) - surcharge will apply - P2
		Report Format:	CROSSTAB_ALSQC	O Emergency (1-2 day) – surcharge will apply - E
		Report Email(s):	kganshorn@ecofishresearch.com tkasubuchi@ecofishresearch.com	O Same Day or Weekend Emergency - surcharge will apply - E2
				O Specify date required - X
Phone:	604-608-6180 Fax:			
Invoice To	☑Email ☐Mail	EDD Format:	ECF100	
Company:	ECOFISH RESEARCH LTD	EDD Email(s):	kganshorn@ecofishresearch.com bbennett@ecofishresearch.com tkasubuchi@ecofishresearch.com	
Contact:	Accounts Payable			
Address:	Suite F, 450 - 8th Street Courtenay, BC Canada, V9N 1N5	Project Info		
		Job #:	~~1230-IFT-MON8~~ 1230-08.40.07	
		PO/AFE:		
Email:	accountspayable@ecofishresearch.com	LSD:		
Phone:	250-334-3042	Quote #:		
Lab Work Order # (lab use only)		ALS Contact:	Ariel Tang, B.Sc. Sampler: Leah Hull	

Analysis Requests (Please indicate below Filtered, Preserved or both (F, P, F/P))

Sample #	Sample Identification (This will appear on the report)	Longitude	Latitude	Date	Time	Sample Type	Number of Containers	Alkalinity by Colourimetric (Automated)	Ammonia in Water by Fluorescence	Conductivity (Automated)	Diss. Orthophosphate in Water by Colour	Nitrate in Water by Ion Chromatography	Nitrite in Water by Ion Chromatography	Total Dissolved Solids by Gravimetric	Total P in Water by Colour	Total Suspended Solids by Grav. (1 mg/L)	Turbidity by Meter	pH by Meter (Automated)
	~~QUN-FIELD BLANK~~					~~WATER~~	3	R	R	R	R	R	R	R	R	R	R	R
	~~QUN-TRIP BLANK~~					~~WATER~~	3	R	R	R	R	R	R	R	R	R	R	R
	QUN-WQA			14-Oct-2015	11:44	WATER	3	R	R	R	R	R	R	R	R	R	R	R
	QUN-WQB			14-Oct-2015	11:44	WATER	3	R	R	R	R	R	R	R	R	R	R	R

L1689157-COFC

~~September~~ Oct 2015 Sampling

The questions below must be answered for water samples (check Yes or No)

Are any sample taken from a regulated DW system? ☐Yes ☒No

If yes, please use an authorized drinking water COC

Is the water sampled intended to be potable for human consumption? ☐Yes ☒No

Guidelines

SAMPLE CONDITION (lab use only)

☐Frozen ☐Cold ☐Ambient ☐Cooling Initiated

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by: Leah Hull	Date: 15-Oct 2015	Time: 18:00	Received by:	Date:	Time:	Temperature: 7 °C	Verified by: Edwin	OCT 16 2015	Time: 1115	Observations: ☐Yes If Yes add SIF