Central Squamish Estuary Restoration Project: Year 2
C1-PAC-02-A3 (17-HPAC-01341-A4)
2019 – 2020
FINAL REPORT

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Executive Summary

The Central Squamish Estuary Restoration Project (CERP) is the culmination of meetings, planning sessions, and discussions over the past twenty years to explore restoration opportunities to improve fish passage between the Squamish River and the central Squamish estuary. Over the last 100 years the estuary has been dramatically impacted with the creation of the townsite, logging, industrial development, the construction in the 1950s of a 5 km rail line to service the Squamish Terminals deep sea port (what is now referred to as the CN Spur line), and the construction from 1970 to 1972 of a road to train the Squamish River to the western side (the “Training Berm”) for a coal port development. While the coal port development ultimately was denied the Training Berm remained in place, all but restricting any fish passage between the Squamish River and estuary.

From 2001 onwards, the Squamish River Watershed Society, in partnership with the provincial government, Federal Fisheries, and Squamish Nation, has explored restoration opportunities within the estuary to improve habitat for salmon and salmonids. Funding and support from Fish and Wildlife Compensation Program (and the former Bridge Coastal Restoration Fund) factored heavily in those restoration projects as BC Hydro recognized the importance of functional estuarine habitats for the overall health of salmon on a watershed scale.

The development of the project included numerous meetings, facilitated workshops, and discussions around the potential large-scale upgrades in the Squamish estuary that would improve overall fish passage and habitat between the river and estuary with a focus on restoring Chinook salmon populations (SRWS 2018). The result of those initial meetings and workshops opened the door to develop a three phased approach toward restoration: improvements along the Training Berm to upgrade or replace the existing culverts (Phase 1: Culvert Upgrades); realign or modify the lower end of the Training Berm known as the Spit (Phase 2: Spit Realignment); and install flow control structures across the CN Spur Line to re-establish fish habitat in the Bridge Pond (Phase 3: Bridge Pond Rewatering).

Work on Phase 1 commenced during the 2018/2019 fiscal year and carried into the 2019/2020 field season resulting in the replacement of a former twin 1.2m diameter corrugated steel pipe (CSP) at Location #3 with a 3m x 3m concrete box culvert. Additional shoreline stabilization (armouring), riparian planting, and installation of signage continued at Location #3 into the 2019/2020 fiscal year.

The goals and objectives completed in the 2019/2020 fiscal included:

- Monitoring fish (juvenile Chinook salmon and other salmonids) movement between the Squamish River and the central estuary with a focus on fish passage through the newly upgraded culvert at Location #3.
- Biophysical monitoring of water quality (including dissolved oxygen, pH, salinity / conductivity, and temperature) in the Squamish River, central estuary, Bridge Pond, and Cattermole Slough, as well as sediment drift and transport and vegetation surveys.
- Two modelling reports including wave modelling and modelling for the removal of the Spit for two scenarios including the removal of the lower 1 km and the lower 2 km of the Training Berm.
- Engaging with the community and government stakeholders including all levels of government, First Nation, industry, recreation, and community representatives.
- Delivering educational programming including Rivers Day events, self-guided walks, and school programs.
- Planting riparian vegetation in disturbed areas around culvert crossings at Locations #2 and #3.
- Addition of armour and rip-rap rock along intake channel at culvert Location #3 and clearing out woody debris and sediment build up from the intake of the culverts at Location #1 and #2 to improve water flows and fish passage.

To further the Phase 2: Spit Realignment component of the project, meetings, discussions, and workshops were held with decision makers, government, First Nations, and the community over the course of the year. The biggest factor affecting the Spit realignment centered around access to the southern tip by the wind sport recreation user groups. Another major factor to Phase 2 was the potential impact of sediment build-up along the western berth of the Squamish Terminals.

The work in the 2019/2020 fiscal also included plans to establish flows across the CN Spur line to improve salmon habitat in Phase 3: Bridge Pond Rewatering. To better understand how tidal flow function on either side of the CN Spur Line the SRWS implemented a biophysical monitoring program by deploying data loggers (level loggers, temperature loggers, and photo-point monitoring stations) to collect data. Several on-site meetings with the District of Squamish (DOS) staff were held to discuss the optimum locations in which flow-control structures could be installed, whether manual or automatic structures would be required to manage the flows, and who would be responsible for any long-term management of any new structures.

Contents

Abbreviations

CERP – Central Estuary Restoration Project
CSEB – Canadian Society for Environmental Biologists
CSP – Corrugated steel pipe
DFO – Fisheries and Oceans Canada
DOS – District of Squamish
FWCP – Fish and Wildlife Compensation Program
IFR – InStream Fisheries Research
MOE – Ministry of Forests, Lands, and Natural Resources, Development and Operations
PIT – Passive Integrated Transponder
SNC-L – SNC Lavalin
SRWS – Squamish River Watershed Society
SWS – Squamish Windsports Society
WMA – Wildlife Management Area

1.0 Introduction and Project Description

The Central Estuary Restoration Project (CERP) is a multi-year project focused on improving fish access for salmonids between the Squamish River and the central estuary. The focus is to restore declining Chinook salmon populations by improving spawning and rearing habitat within the estuary. In order to achieve this objective, the scope of the project includes three phases:

- Phase 1: Culvert Upgrades - replace culverts at key locations along Training Berm (Culvert Upgrades)
- Phase 2: Spit Realignment - realign or modify the southern end of the Training Berm, also referred to as the Spit
- Phase 3: Bridge Pond Rewatering - install flow control structures across CN Spur Line to improve water quality between the Bridge Pond/Cattermole Slough and Pretty Slough in the central estuary (in the area managed by Squamish Nation referred to as Site “A”)

The Squamish Estuary, located approximately 52 km north of Vancouver, is situated at the head of Howe Sound where the Squamish River discharges a drainage area of over 3,650 square km. The Squamish estuary encompasses the tidal waters of upper Howe Sound, from the confluence of the Squamish River upstream to the Mamquam River, the Mamquam Blind Channel, and Stawamus River. The project site is located within the Skwelwil’em Squamish Estuary Wildlife Management Area (WMA) which is Crown land managed by the provincial government (MOE 2007). Access along the Training Berm Road is maintained by the DOS in agreement with the provincial government in order to provide access at the south end for wind sports activities between May and September annually. The site is within the territorial lands of Squamish Nation.

The Training Berm, an antiquated structure which was constructed in the early 1970s by BC Rail, was originally intended to “train” the Squamish River along the western edge in order to facilitate the construction of a coal port in the estuary. However, even though the federal government of the day shut this operation down the 5 km road remained in place, effectively cutting all access from the Squamish River to the central estuary for river flows and fish access. In 1994 twin CSP culverts were installed by Fisheries and Oceans Canada (DFO) at the site referred to as Location #3 (Figure 2). From 2001 until 2013 the SRWS, in partnership with DFO, installed an additional eight more culvert crossings to improve tidal exchange and provide fish access between the river and estuary. From 2013 until 2017 the SRWS commissioned a study to determine how the juvenile salmonids were utilizing the culverts. The result of the study determined that salmonids were not able to access the culverts and was likely resulting in the loss of a certain percentage of survival of salmonids as they were flushed down the Squamish River into Howe Sound (Lingard 2018).

Alignment with Priority Issues[1]

The CERP project is consistent with the main priority areas identified in the Cheakamus River Watershed Action Plan (FWCP 2017) and Squamish Salmon Recovery Plan (Golder 2005) including:

Key factors the CERP project addresses are:

I. Restore access to estuary for juvenile salmonids, focus on providing rearing habitat for Chinook salmon. Estuary channels provide excellent rearing habitat for Chinook fry. Over 95% of the juvenile Chinook salmon captured migrating out of the Cheakamus River in the spring of 2000 were first year fry (Lingard 2018). These Chinook fry require a period of residency in estuarine waters during their first spring prior to entry into saltwater. The Squamish River estuary and its tidal channels provide a significant amount of this critical Chinook salmon rearing habitat for the Cheakamus River Chinook salmon populations. Without adequate connections between the Squamish River and the inner estuary delta the access is severely limited for fish passage, and thus the habitat is underutilized.

II. The loss of fundamental estuarine flow processes where fresh water moves in diverse patterns and mixes with marine waters is another factor that is addressed in all three phases of the project.

III. Another limiting factor addressed is the probable decrease in Chinook salmon fry growth rate due to reduced water temperatures in freshwater spawning and early life stage rearing habitat. It is suspected this result is from flow diversion at Daisy Lake and the dominance of Rubble and Culliton Creek in defining summer temperatures in the lower Cheakamus River (Lingard 2016). Decrease in spring and summer water temperatures has presumably reduced the potential growth rates and productivity of Cheakamus River Chinook salmon fry. A large component of the Chinook salmon fry produced from spawning grounds on the Cheakamus River leave the river soon after emergence and rear and feed in the mainstem Squamish River and the estuary channels for some months prior to their migration into Howe Sound. By improving Cheakamus River Chinook fry and smolt access to and use of the warm, nutrient rich waters of the Squamish River estuary their overall productivity and survival would be expected to increase in the hundreds of thousands (Lingard 2018).

IV. Incidental benefits are also expected for other species of interest including steelhead and cutthroat trout, and pink, coho and chum salmon. As well, bull trout and coho salmon from the Cheakamus River watershed may spend varying periods of time in the Squamish River

[1] Priority issues have been outlined in the BC Hydro Cheakamus Action Plan, the Squamish Salmon Recovery Plan, and the Skwelwil'em Squamish Estuary Wildlife Management Plan

estuary during their life cycle. Herring and other marine species will also benefit from this project.

Project Urgency

The importance to restore fish passage across the Training Berm between the Squamish River and the central estuary cannot be overstated. This project is recognized as being of high importance to Squamish Nation, the Provincial government, and Federal Fisheries who all recognize coastal Chinook salmon populations are in decline and the importance of improving habitat for survival. Chinook salmon are recognized for their importance as a source of food and cultural significance to Squamish Nation, a source of revenue for sports and recreation fishing enthusiasts, and as a vital link to the health of the south coast resident Killer Whale (SRKW) populations. In addition, Chinook salmon are considered to be of cultural and ecological importance in British Columbia and of conservation concern (COSEWIC 2019). There is also an importance to restore access between the Squamish River and the central estuary to all life stages of salmonids as it is not fully understood how the Training Berm has impacted the overall ecosystem of the watershed and health of the salmon populations. What is known is that following the construction of the Training Berm in the early 1970s many stocks, including pink salmon runs and Chinook salmon runs all but plummeted.

Benefit to Salmon

The focus of the CERP multi-year project is to improve Chinook salmon (*Oncorhynchus tshawytscha*) populations and overall health. However, the project will also benefit coho salmon (*O. kisutch*), chum salmon (*O. keta*), pink salmon (*O. gorbuscha*), steelhead (*O. mykiss*), as well as other salmonids, char, herring, and marine habitat in general.

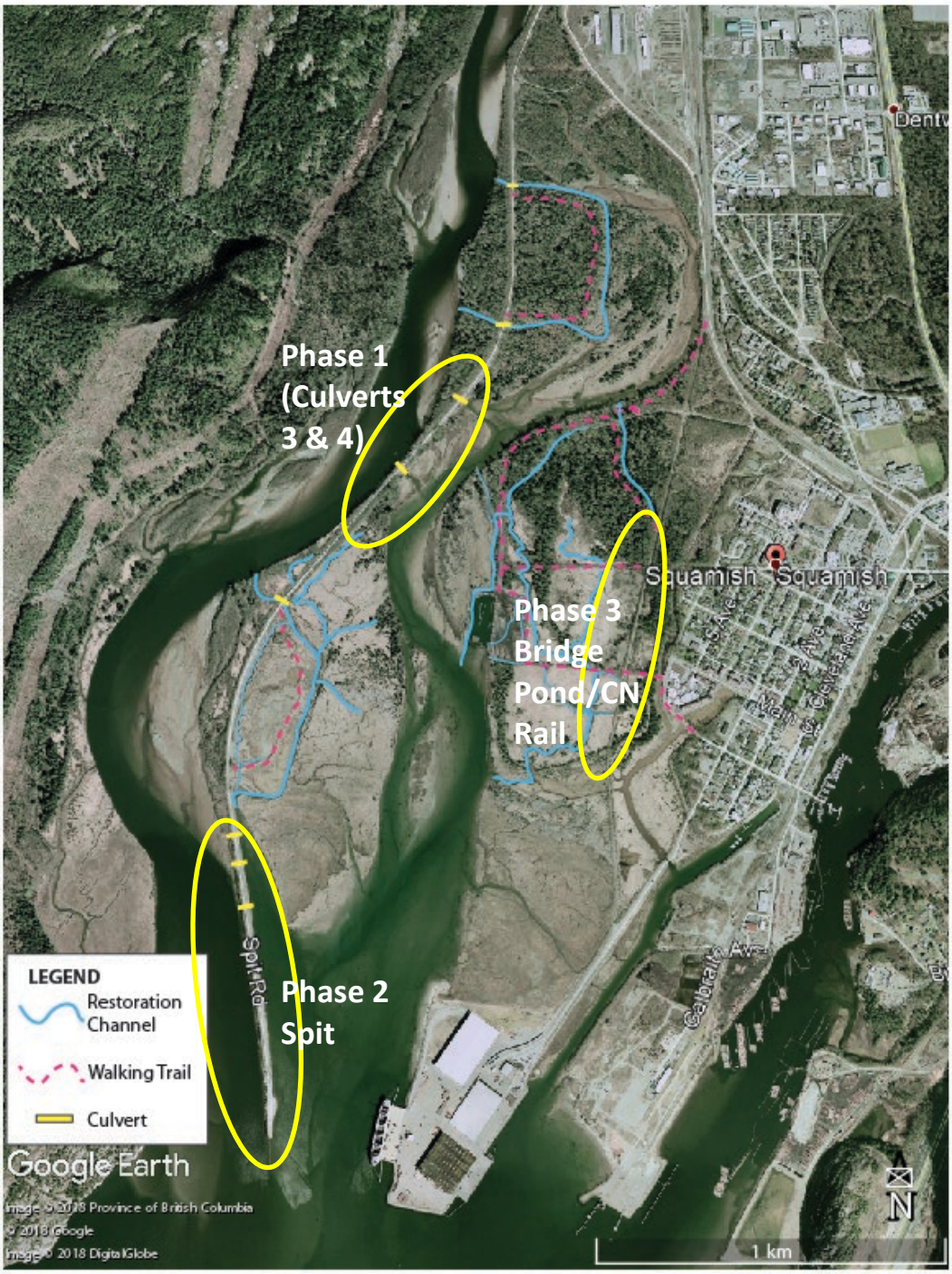


Figure 1. Central Estuary Restoration Project Phases 1 – 3

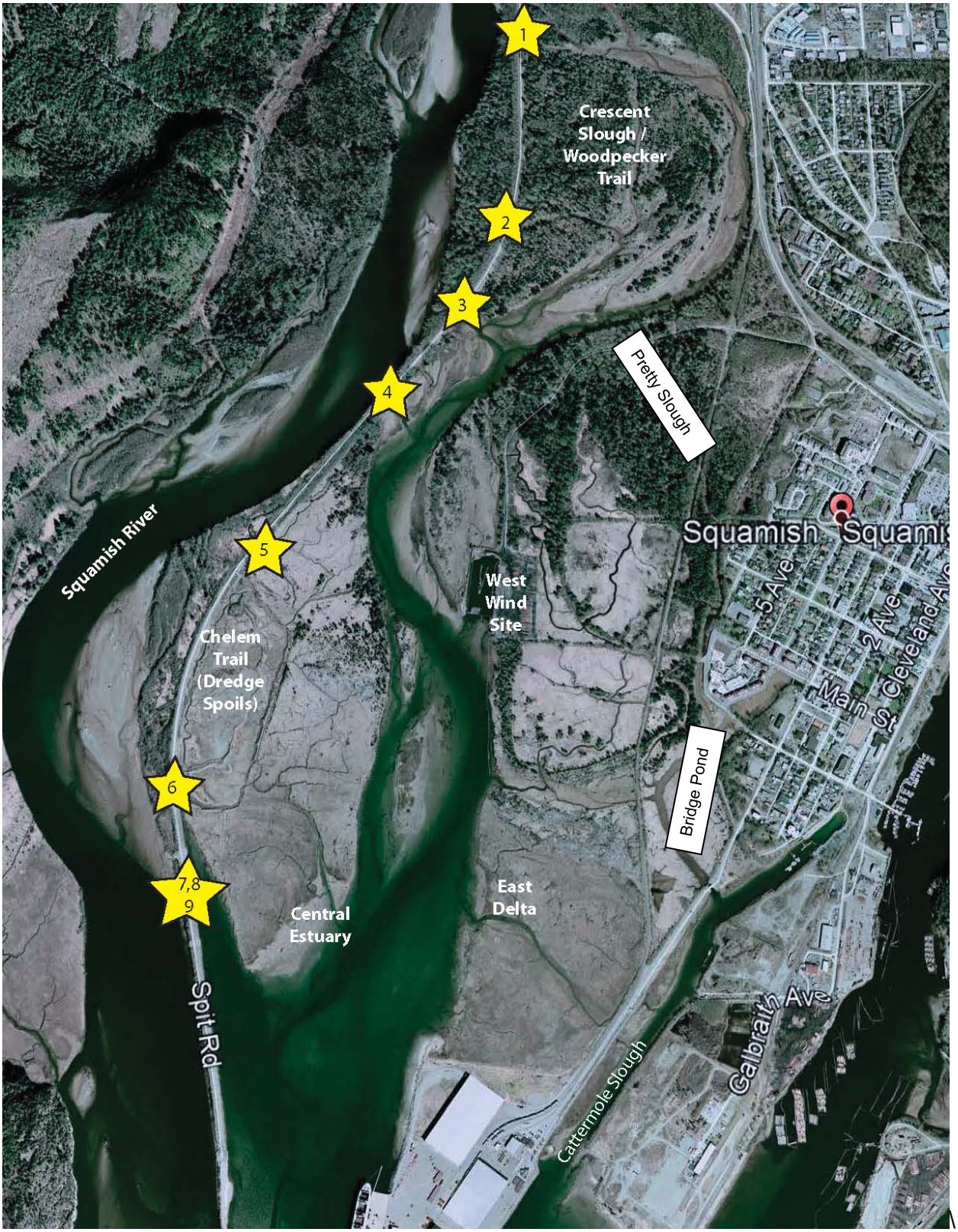


Figure 2. Location map of culvert crossings (1 to 9 in yellow stars) Squamish estuary

2.0 Goals and Objectives

When this application was developed in the fall of 2018, the intention was to be at a stage in which work on Phase 2: Spit Realignment could commence in the 2019/2020 field season. However, over the course of numerous meetings and workshops it became very clear that this ambitious component of the project would require rigorous studies, community support, and a commitment from the District of Squamish and the Province to support the Squamish Windsport Society (SWS) to establish an alternative access for wind sport recreation users to the launch site at the south end of the Spit. While there remains strong support for the CERP program by the community and agencies, the focus over the course of the year shifted more towards fisheries and biophysical monitoring as well as additional wave and spit realignment modelling.

A summary table is provided below outlining the various phases of the project, what components and phases have been completed to date, what is being planned for the upcoming year, and what the plans are for the future as the various restoration works, monitoring programs, and engineering modelling is realized.

Table 1. Summary of Project Phases & Monitoring Programs

Goal	Objective	Details	Date Achieved
Fisheries & Biophysical Monitoring	Establish baseline data followed by consistent monitoring design following physical works associated with Phases 1, 2, and 3	Fisheries monitoring using various techniques including PIT tags, acoustic tags, Gee trapping & seine netting at various locations in the Squamish River and Estuary. Biophysical monitoring for water quality, sediment transport, vegetation colonization and invertebrate populations at various locations in the Squamish River and estuary	2018 2019 2020 (underway) 2021 (pending) 2022 (wrap up)
Phase 1: improve fish accessibility across Training Berm	Replace fish passage obstructing culverts across Squamish Training Berm	Culvert replacement at Location #3	May 2019
		Culvert replacement at Location #4	Pending: August 2020
		Additional culvert replacements (Locations #1, 2, 7 – 9)	Summer 2021 & Summer 2022
Phase 2: remove or realign Spit to reopen lower 77 hectares of habitat	Realign Spit	Wave modelling & Spit Realignment modelling	Reports: 2020
		Meetings & consultation	2018 - present
		Design & Approval	Design: 2021? Approval:2022?
Phase 3: Bridge Pond re-watering	Install a flow control structure across the CN Spur line to provide controlled flows into the Bridge Pond	Fisheries monitoring & Biophysical monitoring	Summer 2018, 2019, & 2020
		Design & Approval	Sept. 2020? Summer 2021?

2.1 Fisheries Monitoring of Juvenile Chinook Salmon Outmigration

A monitoring program was developed in 2018 by InStream Fisheries Resource (IFR) to establish baseline data prior to the culvert upgrade at Location #3 which. This program was implemented in the summer of 2018 and repeated in 2019, following the culvert upgrade. This monitoring program expanded on previous DFO efforts to collect data on salmon usage of the estuary and river including seine netting and Gee trapping. The focus of the IFR monitoring program was on the fish passage limitations at Location #3 and #4 (Figure 2). The monitoring program was intended to capture the largest movement of out-migrating juvenile Chinook salmon based on the historic data regarding the capture of Chinook salmon in the Cheakamus River Rotary Screw Traps (RST) from March to early July. The goal of this program was to recapture tagged fish and thus provide a coarse assessment of distribution of salmonids. To this end 982 Passive Integrated Transponder (PIT) tagged fish were deployed in the 2019 field season along with 100 acoustic tags at various locations in the Squamish River (Figure 3) on both wild and hatchery origin juvenile Chinook salmon. Acoustic receivers were installed in both the Squamish River and at various locations within the estuary. PIT antennas were installed in the new box culvert at Location #3 and in the channel connecting the two upper culverts at Locations #1 and #2 (Figure 2).

Photo image of acoustic array in Culvert #3 to monitor fish passage between Squamish River and estuary

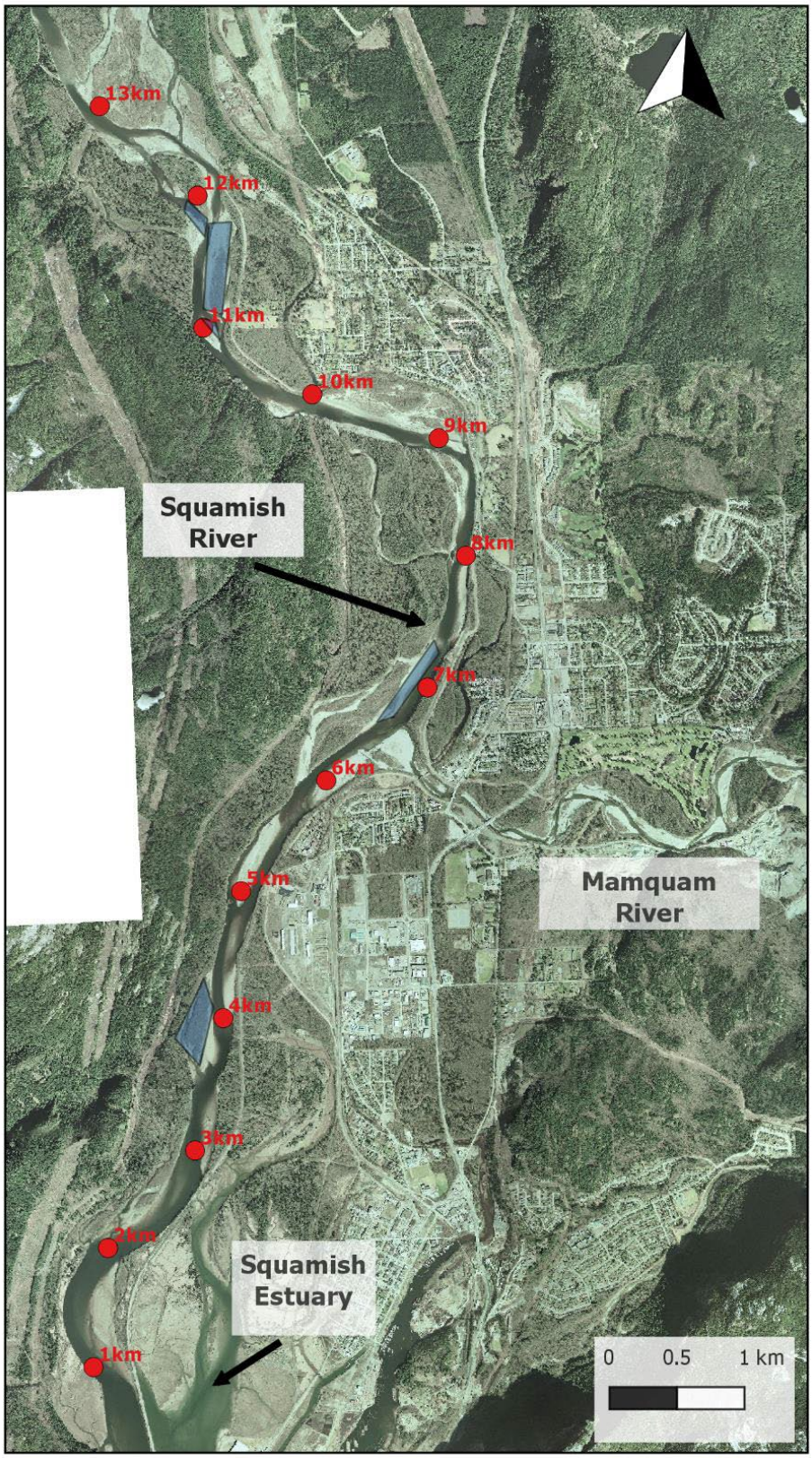


Figure 3. Fish collection locations on Squamish River (blue)

2.2 Biophysical Monitoring

Lake Trail Consulting was hired in 2018 to develop a baseline biophysical program by which to assess changes in the estuary to water quality (dissolved oxygen, pH, salinity / conductivity, and temperature), sediment transport, invertebrate assemblages, and changes in vegetation in association with Phases 1, 2, and 3 (culvert upgrades along the Training Berm and future Spit realignment, and water flow upgrades into Bridge Pond). They were able to implement the program in the summer of 2018 and repeat the methodology with additional monitoring stations in 2019 following the replacement of the box culvert.

Biophysical monitoring was an important component of the project as it provides a measure by which to evaluate the success of the restoration efforts to meet the project goal of improving fish accessibility to the Squamish estuary from the Squamish River and associated habitat improvements.

2.3 Modelling Scenarios: Wave and Spit Removal

In order to better understand potential impacts associated with the removal or realignment of the Spit as part of Phase 2 of the project, SNC Lavalin was engaged to undertake two modelling scenarios this year which included: “Wave Impact Assessment” and “Squamish Training Berm Removal”. The objective of these modelling exercises was to provide information by which to assess what, if any, impacts the realignment or removal of the Spit would have on flood impacts on the downtown, sediment accumulation that could affect operations of the Squamish Terminals, and other potential adverse effects.

2.4 Engaging with the Community, Government, and Stakeholders

The development of the Central Estuary Restoration Project is the result of over a decade of discussion and planning with the community and project partners (Squamish Nation and Fisheries and Oceans Canada). The goal of this year was to meet with the stakeholders and various parties to provide updates on the progress of the various phases of the project and to hold workshops and meetings to further along Phase 2: Spit Realignment. To this end, several meetings, workshops, media releases, and web blogs were held or posted throughout the year. The project partners, Fisheries and Oceans Canada and Squamish Nation, were central to all these meetings and workshops and engaged at all levels of discussion.

2.5 Educational Outreach Programming

The goal and objective of the educational program for this year was to provide fun and innovative experiential learning opportunities to students and the community to learn about the work the SRWS was undertaking and to engage in activities associated with the CERP.

Several events were held over the course of the year including Rivers Day (September 22, 2019). The theme of 2019 was “Year of the Salmon” and the SRWS partook in numerous guided tours and events that helped to celebrate salmon. Students and community were invited to help plant up the riparian zone at the newly replaced culvert at Location #3.

2.6 Riparian Planting

The goal of planting riparian vegetation in the areas disturbed from the culvert replacement at Location #3 and the cleaning out of the upper culverts at Locations #1 and #2 was to stabilize the embankments, prevent the spread of invasive plants, discourage public access on newly exposed areas, and to replace any disturbed vegetation. Approximately 875 native trees and shrubs were reestablished at these locations and included over 25 hours of volunteer time and support.

2.7 Armouring of River Intake at Culvert #3 and Maintenance of Upper Culverts

The goal was to clean out the upper two culverts at Locations #1 and #2 and restore fish access across these culverts to improve overall water flows between the Squamish River and the Crescent Slough (upper estuary). Over the winter months several storms resulted in an accumulation of woody debris that plugged up the trash racks and the culverts themselves. Maintenance and cleaning out these culverts occur every three to seven years on average, although the culvert at Location #2 has only had to be cleaned out once before in the 20 years since it was installed. The two upper culverts may be the location of potential upgrades with either arch culverts or larger box culverts as a continuation of Phase 1.

The goal of adding additional armour to the river side of the newly upgraded box culvert at Location #3 was to stabilize the banks and prevent erosion. There was an excess of rock left over from the installation of the culvert and the probability of erosion was considered significant. The additional rock is intended reduce future maintenance at this location.

3.0 Study Area

The Squamish Training Dike is a 5 km structure that extends from the confluence of the Mamquam River downstream to Howe Sound and confines the Squamish River to the western bank. The focus of this phase of the project was to improve fish passage across Culvert #3 located at latitude 49.707275 longitude -123.170656 (Figure 1).

4.0 Methods

The focus of the year was to continue monitoring the changes and improvements along the river and estuary following the replacement of the culvert at location #3 (Figure 2) and to undertake any additional modelling as required.

4.1 Fisheries Monitoring[2]

A total of 982 PIT tags were implanted into both wild and hatchery origin Chinook salmon juveniles captured in-river. As well, 100 acoustic tags were implanted into wild and hatchery raised juvenile Chinook salmon. Acoustic receivers were installed in both the Squamish River and at various locations within the estuary. PIT antennas were also installed in the new box culvert and in a channel connecting the two northern culverts to the Central Estuary.

The program was delayed by the construction of the culvert in early May 2019, resulting in a shorter monitoring season.

Additional areas were also fished to collect baseline species assemblage data along Pretty Slough, Bridge Pond, and Cattermole Slough (Figure 2) through the use of Gee trapping.

For a detailed summary of the fisheries monitoring methodology, results, and recommendations please refer to the report prepared by InStream Fisheries "Squamish River Central Estuary Restoration Effectiveness Monitoring; Implementation Year 2019" (IFR 2020).

4.2 Biophysical Monitoring[3]

Monitoring of water quality and biophysical components in the estuary was for carried out during the two-year period from 2018 to 2019 to establish a baseline of habitat conditions for Chinook salmon and a post culvert upgrade study. Metrics on water quality, sediment dynamics, vegetation, soils, and channel morphology were collected to reflect the current status of fish habitat in the estuary and to capture changes associated with the restoration works.

4.2.1 Water quality monitoring methodology

1. Conductivity
    - Type: automatic using a conductivity logger
    - Objective: To detect changes in the physico-chemical environment as a result of restoration activities.
    - Rationale: Conductivity can be used to evaluate the degree of mixing of freshwater and salt water that is expected to increase as a result of restoration.
2. Dissolved Oxygen
    - Type: Instantaneous measures taken manually with a YSI meter
    - Objective: To detect changes in the physio-chemical environment as a result of restoration activities.

[2] Cook, K., et.al. "Squamish River Central Estuary Restoration Effectiveness Monitoring; Implementation Year #1 (2019)". October 15, 2019.
[3] Tryon, L., Alyssa Togado. "Central Estuary Monitoring Program: 2018 – 2019 Interim Report" March 31, 2020.

- Rationale: This will evaluate if restoration activities prolong the duration of acceptable DO levels for Chinook rearing during the summer period

3. Temperature
    - Type: automatic with tidbit loggers and level loggers
    - Type: Instantaneous when D.O. measures collected
    - Objective: To detect changes in the physio-chemical environment as a result of restoration activities.
    - Rationale: This will evaluate if improved mixing from restoration will prolong the duration of acceptable temperatures for Chinook rearing during the summer period
4. Nutrients
    - Type: Water sample sent in for laboratory analysis (Phosphorus and Nitrogen)
    - Objective: To detect changes in the physio-chemical environment as a result of restoration activities.
    - Rationale: Nutrients in estuaries are important for production and are often cited as a key factor in supporting critical life stages for salmon. However, studies indicated the Squamish estuary in poor in nutrients. Monitoring dissolved phosphorus, nitrogen and will evaluate if improved mixing from restoration actions will result in nutrient concentrations beneficial for salmon productivity.

4.2.2 Physical Habitat (flows, channel dimensions)

Monitoring of physical habitat for critical estuarine life stages of Chinook salmon (smolting and upstream migration) to include:

1. Tidal channel dimensions
    - Type: Rod and level survey of channel dimensions prior to and following restoration activities.
    - Objective: To detect changes in the physical environment as a result of restoration activities.
    - Rationale: This will evaluate if restoration activities result in improvements (e.g. increased pools) or degradations (increased widening, decreased pools) in tidal channel morphology as it relates to chinook salmon habitat.
2. Flows through channels and culverts
    - Type: Direct measurements of water flow velocities through culverts and tidal channels using a flow meter
    - Type: Indirect measurements of flow velocities through culverts by measuring water depth and relating to culvert dimensions and slope
    - Objective: To assess range in flow velocities against known flow thresholds for critical life stages of Chinook:
        i. smolting - for culverts and tidal channels
        ii. adult migration - for culverts only

Table 2: Sites for permanent monitoring stations

Site	Site Name	Location Description	UTM[1]	Water Level	Conductivity	Temperature	Sediment	Channel	Soils	Vegetation
A	River Station	Logger station installed along left bank of Squamish River 600m upstream of Culvert 1	10U 487884 E 5507607 N	X		X				
B	Culvert 1	Monitoring site is ~300m downstream (east side) of culvert 1. Includes logger station in tidal channel, 2 sediment stations in marsh, 2 channel cross sections, and 4 soil/veg transects adjacent to tidal channel	10U 488177 E 5506994 N	X		X	X	X	X	X
C	Bailey Street	Area adjacent to Wilson Slough Intake. Logger Station in Crescent Slough adjacent to Bailey Street and 330m downstream (south) of intake. Two sediment stations and one channel cross section station across main channel.	10U 488530 E 5506410 N		X	X	X	X		
D	Culvert 2	No longer a monitoring station - loss of staff gauge. Possible future monitoring.	10U 487895 E 5506375 N							
E	Culvert 3	Area east of Culvert 3. Includes logger station 70m upstream main tidal channel from where culvert 3 tidal channel enters. Logger station removed for winter season and re-set in spring. Also includes 4 sediment stations-2 in marsh (2018 install), 2 in mudflat (2019 install), and one cross section across culvert 3 tidal channel. 4 veg/soil transects perpendicular to and east of Spit road.	10U 487901 E 5505991 N	X	X	X	X	X	X	X
F	Culvert 4	Area east of Culvert 4. Logger station in Culvert 4 pool. Culvert 4 tidal channel has 2 cross-sections and main channel has 1 cross section 70m downstream (south) of culvert 4 tidal channel confluence. Also includes 4 sediment stations-2 in marsh (2018 install), 2 in mudflat (2019 install). One vegetation transect north and perpendicular to C4 tidal channel.	10U 487530 E 5505810 N	X		X	X	X	X	X
	Culvert 7	Hobo tidbit loggers installed on either side of culvert	10U 486995 E 5504561 N			X				
	Culvert 9	Hobo tidbit loggers installed on either side of culvert	10U 487038 E 5504352 N			X				
G	Lower Estuary	Logger station installed on a piling complex (dolphin) in lower estuary approximately 500m east of Culvert 8. 4 sediment stations: 2 in marsh (2018 install) and 2 in mudflats (2019 install), all on northeast side of main tidal channel in vicinity of logger station.	10U 487516 E 5504466 N	X	X	X	X		X	
H	Cattermole Slough	Logger station installed June 2019 in Cattermole Slough below stinky pond.	10U 488382 E 5504457 N	X	X	X				

1 UTM location is central to all stations at monitoring site.

A detailed summary of the methodology deployed can be found in greater detail in the report prepared by Lora Tryon, Lake Trail Environmental Consulting (Tryon 2020).

It is expected with increasing connectivity between the river and the estuary, there will be greater flushing of estuarine habitats and improved water quality within preferred ranges for smolting Chinook salmon. Seven stations, including one in the river and six in the central estuary, were established to monitor temperature with automatic data loggers. Of those stations, six also collect water level data and five collected conductivity data (for calculation of salinity).

Greater periods of marsh inundation and increased area of marsh coverage are also expected to be improved in association with the culvert upgrades as the pathways for sediment to enter the estuary from the river are opened. Sediment, vegetation, and soil surveys will provide a measure by which to monitor changes in marsh communities and coverage, as well as changes in soil carbon and sediment accretion rates. In 2018 and 2019, metrics were collected at 17 sediment stations, 10 vegetation transects, 39 vegetation plots, and 20 soil plots (Figure 4).

Greater flows from the river into the estuary are expected to deepen tidal channels, resulting in more wetted habitat available during low tide periods for Chinook salmon.

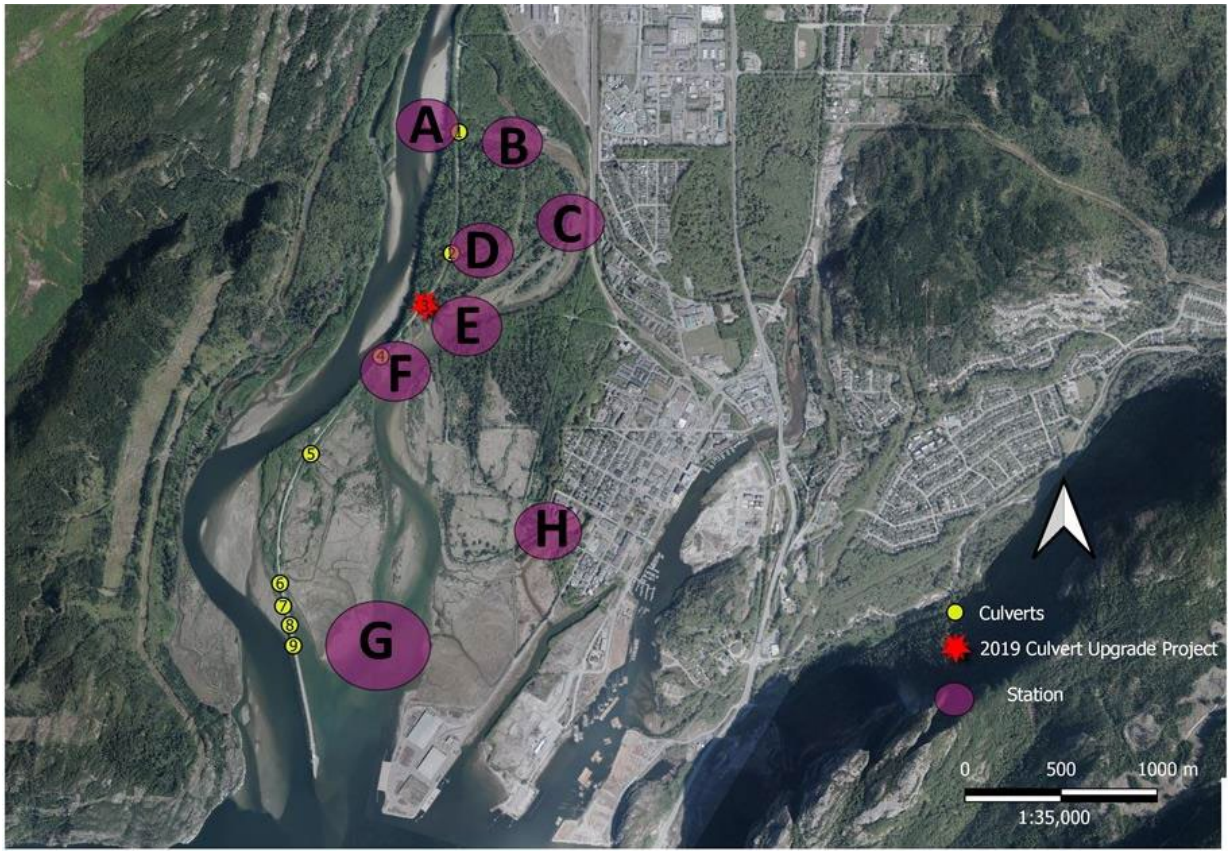


Figure 4. Monitoring Stations Site Locations

4.3 Wave Modelling and Spit Removal Modelling

Additional modelling for the year included: wave modelling to identify how the existing Spit functions and what role, if any, it performs to deflect wave action that could result in flood risk to the downtown; and modelling for the Spit removal. SNC Lavalin was hired to undertake both modelling scenarios and a summary of the methodology can be found in the respective reports: “Squamish Training Berm Realignment Wave Impact Assessment” (SNC-L February 2020) and the draft report “Squamish Training Berm Removal Progress Report” (SNC-L June 2020).

4.4 Engagement with the Public, Stakeholders, and Community

Numerous meetings were held throughout the year, along with stakeholder workshops, blog postings, and media releases.

4.4.1 Meetings

- December 18, 2019: DOS – SWS Interim Access Engagement Plan (District of Squamish)
- January 31, 2020: Windsports Access Interim Options Workshop, Meeting Summary Report (District of Squamish)
- February 26, 2020: Squamish Training Berm Realignment Wave Impact Assessment (SNC-Lavalin)
- February 28, 2020: Facilitated Stakeholder Workshop (CERP Stakeholder Meeting #3 appended)
- March 4, 2020: Squamish Training Berm Realignment Technical Proposal (WSP)
- March 31, 2020: Central Estuary Monitoring Program 2018-2019 Interim Report (Lake Trail)
- March 31, 2020: Squamish River Central Estuary Restoration Effectiveness Monitoring (InStream)

4.4.2 Media Releases

- March 13, 2020: District of Squamish weekly newsletter: https://squamish.ca/yourgovernment/news/collaborative-effort-to-achieve-long-term-balance-of-environmental-economic-and-recreation-interests-in-the-squamish-estuary-and-spit-is-underway/
- March 18, 2020: Salmon News

4.5 Education Outreach Programming

Several programs were held throughout the year in celebration of the 2019 “Year of the Salmon” with a focus on the work being undertaken as part of the CERP. Over 25 students and a dozen volunteers came out to help with the riparian planting and keeping the newly planted sites watered and cared for. Events, such as Rivers Day, helped to raise awareness in the community on the importance of estuary restoration and provided an opportunity for the community to learn more about this exciting project and the plans for the coming year.

Rivers Day Poster

Matt Foy leading Year of the Salmon tour, Dec 2019

Wild for Salmon Outreach program, May 2019

4.6 Riparian Planting

Over 800 native riparian plants were established around Culvert #3. Much of the planting took place in September 2019 with the assistance of volunteer support from the BC Institute of Technology Ecological Restoration program. An additional 75 native riparian vegetation were planted around Culvert #2 in April 2020 following the cleaning out of woody debris buildup.

The estuary facing east slope of Culvert #3 was predominantly planted up with sword fern and a mix of various riparian plants were placed along the disturbed areas on the west side (river facing) of Culvert #3.

Table 3: Riparian Species Planted at Culverts #2 & #3

Plant Description for	**Culverts #2 & #3**		
Plant Name	Common Name	# plants	size
Cornus stolonifera	Red osier dogwood	25	1 gal pots
Mahonia nervosa	Dull Oregon grape	100	1 gal pots
Myrica gale	Sweet gale	50	1 gal pots
Polystichum munitum	Sword ferns	300	1 gal pots
Rosa nutkana	Nootka rose	25	1 gal pots
Rubus parviflorum	Thimbleberry	100	1 gal pots
Rubus spectabilis	Salmonberry	100	1 gal pots
Salix sitchensis	Sitka willow	25	1 gal pots
Spirea douglasii	Purple spirea/hardhack	100	1 gal pots
Thuja plicata	Western red cedar	50	1 gal pots
Total		875	

4.7 Armouring of River Intake at Culvert #3 and Culvert Maintenance

In October 2019, the extra stockpile of armour rock left over from the installation of the box culvert at Location #3 was placed along the river intake channel to stabilize the banks and prevent future erosion. The equipment used for this work included two 300 series excavators (one excavator used to load the rock into the truck and the other to place the rock material) along with a rock truck provided by John Hunter and Company. Each piece of armour rock was carefully placed into the embankment in a layered manner that would be able to withstand storm events or large woody debris collisions. The work took place over a 9-day period.

During low flow conditions in May 2020 a 300 series excavator was used (John Hunter and Company) to physically remove woody debris build up along the trash racks and plugged up the culverts at Locations #1 and #2. The river intake channels were also deepened out to the Squamish River, and sediment was removed and side cast along the embankment to restore unobstructed river flows through to the culverts. The work took place over three days and was restricted to low-tide periods on each day. The temporary access road was blocked off (in order to prevent pedestrian access) and planted up with native riparian vegetation. Additional signage is intended to be placed at each of the two culverts to acknowledge funding support and provide information on the purpose of the culverts and their importance in conveying water and fish passage between the Squamish River and the Crescent Slough (upper estuary).

The outcomes of adding the additional armour rock at Culvert #3 resulted in stabilizing 250 square metres of habitat. The outcomes of cleaning out woody debris build up at Culverts #1 and #2 resulted in restoring 250 linear meters of channel flows and over 700 square meters of habitat for the passage of salmonids between the Squamish River and the upper estuary.

5.0 Results and Outcomes

The outcomes for this fiscal year varied from the original plans due to the need for additional studies and community engagement. The plans to move forward with Phase 2 still need more details worked out but in the interim the focus for the coming field season will be to replace a second culvert (Location #4) as part of Phase 1 and develop detailed engineering plans and surveys to install an intake structure across the CN Spur Line (Phase 3). The outcomes from the year included meetings, reports, engineering and hydraulic modelling, educational programming, and ongoing networking and outreach.

5.1 Fisheries Monitoring[4]

Telemetry data from the PIT antennas installed in the new box culvert and at various locations in the central estuary (Figure 5) showed seven juvenile Chinook salmon passed through the new box culvert at Location #3. Another thirteen of the 100 fish implanted with acoustic tags, and two PIT-tagged fish (one wild and one hatchery) were also observed to have accessed the estuary, presumably by migrating around the Spit (IFR 2019).

Tagged hatchery fish accessing the estuary were detected for several weeks making use of the estuary, confirming the use and importance of the estuary for juvenile Chinook salmon. The remaining 86% of the hatchery Chinook salmon implanted with acoustic tags were never detected on receivers in the estuary and were assumed to have migrated directly into Howe Sound. There was no way to determine the survival of the either the juvenile salmonids that had a residency time in the estuary versus those that migrated directly into Howe Sound.

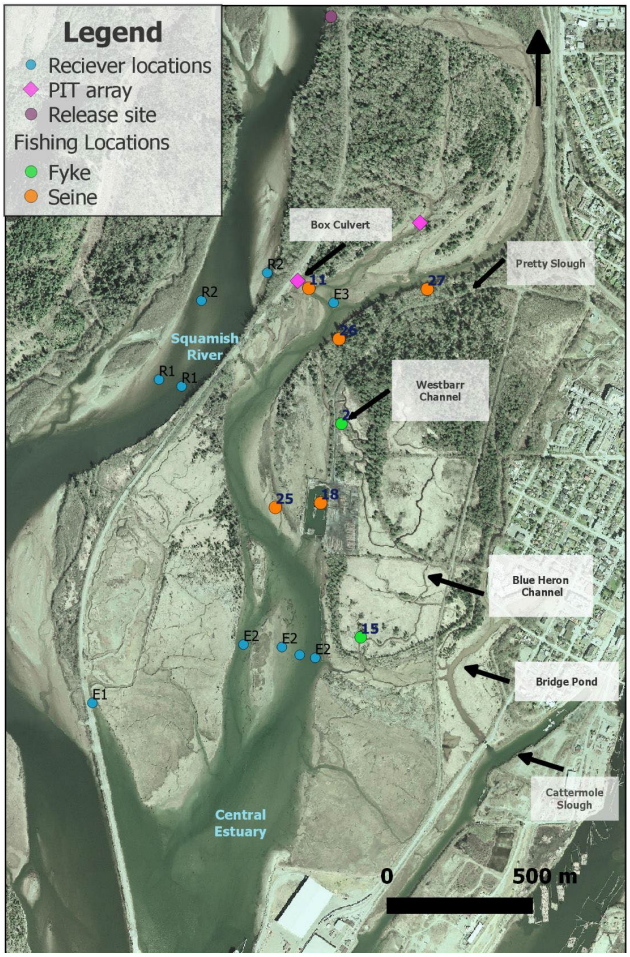


Figure 5: Map of CERP fisheries monitoring project locations

Use of estuarine habitat was also assessed through a capture program in the estuary using seine nets and traps. The goal was to recapture tagged fish and to provide a coarse assessment of distributions of salmonids. Juvenile Chinook salmon were primarily captured in the southern portions of the estuary and no PIT tagged fish were recaptured[5]. Additionally, specific areas of interest for future restoration activities (Pretty Slough, Bridge Pond, and Cattermole Slough) were also fished to collect baseline species assemblage data. The result of this additional trapping was salmonids were only observed in Cattermole Slough. These results, combined with previous years of capture data from the estuary, suggested that improvements to estuarine habitat access are still needed. However,

[4] Cook, K., et.al. "Squamish River Central Estuary Restoration Effectiveness Monitoring; Implementation Year #1 (2019)". October 15, 2019.
[5] It should be noted that the field season only started at the end of May 2019, after the culvert upgrade had been completed, which was likely the cause of no PIT tagged fish being captured.

it should be noted that less fishing effort was allotted to the estuary in the 2019 field season relative to the effort dedicated to the Squamish River around the culverts.

The results from the 2019 field program were inherently biased due to delays in the culvert construction (delayed from March to May due to the change in plans from designing of a bridge to a box culvert). It should also be noted that most of the fish tagged were hatchery raised fish which may be more motivated to migrate directly to marine environments than wild fish. As such, the recommendation for the 2020 field season is to tag wild fish at the start of the migratory season in early March.

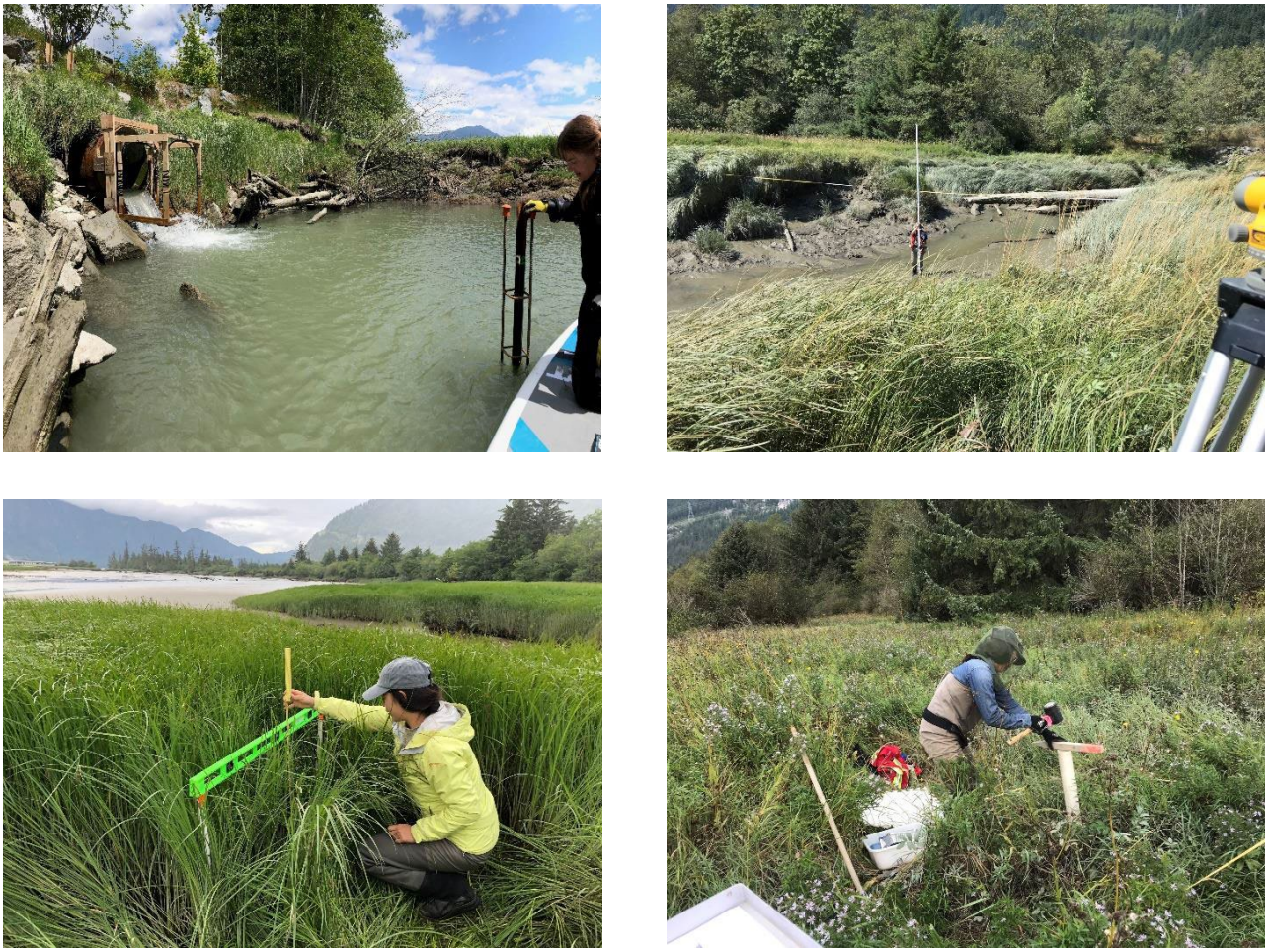
Overall, the 2019 monitoring program indicated the installation of the box culvert was a successful step in restoration activities to improve fish passage along the Squamish River into the estuary.

5.2 Biophysical Monitoring[6]

Monitoring stations were established at several locations throughout the estuary to capture various parameters. These parameters included the deployment of temperature loggers at 7 sites and conductivity loggers at 5 sites (Figure 4). To study physical habitat, 6 tidal channel cross sections were surveyed at 4 sites (Figure 4). Six level loggers were deployed along the Squamish River and the central estuary to establish tidal variations. In order to study sediment dynamics, a total of 17 sediment stations were established at 5 locations. To assess vegetation and soils, a total of 10 vegetation transects, and 39 vegetation plots were established, along with 20 soil plots. Invertebrate populations were studied at several locations with the use of Hester Dendy's. A total of 23 photo-points were established to study changes in vegetation. The summary results of these monitoring stations are still being assembled and will be shared in a later report.

Some preliminary findings from comparing the baseline monitoring undertaken in 2018 and 2019 (pre culvert replacement) and contrasted with the post culvert upgrade suggest that greater flows from the river into the estuary are expected to deepen tidal channels resulting in more wetted habitat available during low tide periods for Chinook salmon. Furthermore, greater periods of marsh inundation and increased area of marsh coverage are also expected to be improved upon as a result of the culvert upgrades which will provide pathways for sediment to enter the estuary from the river. Monitoring the changes in sediment, vegetation, and soil through surveys will help to determine the extent which marsh communities and coverage, as well as change in soil carbon and sediment accretion rates, are improved upon by the culvert upgrades along with the resultant improvements for outmigrating juvenile Chinook salmon.

[6] Tryon, L., Alyssa Togado. "Central Estuary Monitoring Program: 2018 – 2019 Interim Report" March 31, 2020.



Photos of various monitoring and surveying. Upper left: station on estuary side of Culvert #4. Upper right: station at southern end of Crescent Slough downstream of Culvert #2. Lower left: Alyssa Togado measures vegetation growth. Lower right: Lora Tryon installing biophysical station

6.0 Discussion

This project has been developed in partnership with Fisheries and Oceans Canada and Squamish Nation and is of importance to improve the overall health of Chinook salmon stocks and restore the estuary to previous pre-development conditions. Support has also been recognized from the local sports fish advisory board, recreation fishing groups, Ministry of Forests, Lands, and Natural Resource Operations, and other community stewards. Squamish Nation manages portions within the estuary, Site “A”, adjacent to the Bridge Pond, that will directly benefit from improved water quality and tidal flows resulting from this project. This in turn will add to Squamish Nation’s ability to harvest local salmonids, as well as provide educational programming. The project allows for engagement with local universities, technical institutes, and local schools in hands-on experiential learning opportunities including tree planting, mapping, monitoring, and the development of long-term post-graduate research

studies. In addition to allowing community and student engagement, the SRWS has been able to sponsor a University of British Columbia Master's student to study Chinook salmon behaviour associated with the restoration efforts. Students from School District #48 regularly participate in special events, programs, and activities directly associated to this project including studying wildlife and fish movement, planting native riparian vegetation, undertaking tree and bird surveys, and learning about the natural habitat and environment (for more on these programs check our website: https://www.squamishwatershed.com/outreach-program.html).

The project restoration completed in the 2019 field season was published in the Fall 2019 issue of the Canadian Society of Environmental Biologists[7] (CSEB 2019).

7.0 Recommendations

There were numerous challenges to face in the 2019/2020 fiscal year regarding strategic planning and modelling requirements. The better part of the fall of 2019 was spent in discussions between the project partners (SRWS, DFO, and Squamish Nation) and the Squamish Windsports Society (SWS), the District of Squamish (DOS), and the Squamish Terminals around Phase 2 Spit realignment. The DOS required modelling of wind impacts and Spit removal to better understand if any modifications to the Spit would impact flood levels or sediment accretion issues, the result of which SNC-L was engaged to provide two engineering modelling reports: "Squamish Training Berm Realignment Wave Impact Assessment" (SNC-L February 2020) and the "Squamish Training Berm Realignment Model Progress Report" (SNC-L June 2020). The District of Squamish flood gauges at the Third Avenue flood gate (which would have provided valuable information on tidal flows for Phase 3 of the project to install flow control structures across the CN Spur Line) were not in operation, resulting in the SRWS having to set up level-loggers and monitoring stations on either side of the CN Spur Line.

While the year was extremely important in moving the project forward, the intended work on Phase 2 had to be deferred for a later date and remains indefinite as the scope of the realignment of the Spit needs to include alternate access for the SWS, which is beyond the ability of the SRWS to achieve alone. Physical works for this year were refocused on providing additional armour stabilizing along the river intake at Culvert #3 and the maintenance of Culverts #1 and #2 that were blocked with woody debris buildup. The plans moving forward for the 2020 field season are to focus on additional culvert upgrades as part of Phase 1 of the project while continuing to have discussion and planning for Phase 2: Spit Realignment and Phase 3: Bridge Pond Rewatering.

[7] CSEB Fall 2019 issue: https://cseb-scbe.org/wpmarine/wp-content/uploads/2019/11/CSEB_Vol76-3-Fall-2019-Email-Final.pdf

8.0 Acknowledgement

We would like to thank our project partners Fisheries and Oceans Canada and Squamish Nation and Fish and Wildlife Compensation Program for funding and supporting this project.

Project Team:

- Edith Tobe, Project Manager, Squamish River Watershed Society
- Kimberly Armour, Assistant Project Manager, Squamish River Watershed Society
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- Dave Nanson, Restoration Biologist, Fisheries and Oceans Canada
- Murray Manson, Fisheries Protection Biologist, Fisheries and Oceans Canada
- Katrina Cook, Stephanie Lingard, and Cole Martin, InStream Fisheries Research Inc
- Lora Tryon, Lake Trail Environmental Consulting

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- DOS engineering department
- Judith Cullington, JCA and Associates
- Squamish Windsports Society
- Squamish Environment Society, and
- Squamish Streamkeepers

9.0 References

Canadian Society of Environmental Biologists. “Restoration in the Squamish Estuary to Improve Chinook Salmon Populations”. Volume 76 (3) pp 4 – 10. Fall 2019

COSEWIC 2019. COSEWIC assessment and status report on the Chinook Salmon *Oncorhynchus tshawytscha*, Designable Units in Southern British Columbia (Part One – Designable Units with no or low levels of artificial releases in the last 12 years), in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xxxi + 283 pp. (Species at Risk Public Registry).

Fish and Wildlife Compensation Program. “Cheakamus River Watershed Action Plan”. November 14, 2017

Golder Associates. “Squamish Salmon Recovery Plan”. Prepared for Pacific Salmon Foundation. May 2005.

InStream Fisheries Resource Inc. “Squamish River Central Estuary Restoration Effectiveness Monitoring; Implementation Year 1 (2019)”. October 15, 2019.

Kerr Wood Leidal. “Squamish Estuary Flood Modelling Training Berm Bridge Opening”. Prepared for Squamish River Watershed Society. November 26, 2018.

Kerr Wood Leidal. “Squamish River Estuary Enhancement – Draft Squamish Estuary Qualitative Sediment Transport Assessment. Prepared for Squamish River Watershed Society. March 2, 2018.

Lingard, S., et.al. “Squamish Estuary Juvenile Chinook Salmon Habitat Usage Survey” Prepared by InStream Fisheries for Squamish River Watershed Society. August 20, 2018.

Ministry of Environment, Environmental Stewardship Division. “Skwelwil’em Squamish Estuary Wildlife Management Area Management Plan”. August 2007.

SNC-Lavalin. “Squamish Training Berm Realignment – Wave Impact Assessment”. February 26, 2020.

SNC-Lavalin. “Squamish Training Berm Removal; Model Criteria and Progress Report”. June 11, 2020.

Squamish River Watershed Society. “Squamish River Estuary Training Dike Fish Passage Feasibility Study Report – March 2018”. Prepared by E. B. Tobe Enterprises and the Squamish River Watershed Society. March 31, 2018.

Tryon, L. and Alyssa Togado “Central Estuary Monitoring Program: 2018 – 2019 Interim Report”. March 31, 2020. Prepared by Lake Trail Environmental Consulting

10.0 Photos

Culvert #1 Clean-up

Before

After

Facing twin culverts from west side of Training Berm (river side): note build up on left photo

Trash rack at river confluence; note build-up of sediment and woody debris before then after

Clean-out of intake channel at river; note build-up before and clean-up after

Culvert #2 Clean-up

Facing upstream towards Squamish River from Training Berm

Culvert #3

Facing east from river side towards Training Berm

March 15, 2020. Facing west from Training Berm (towards Squamish River intake); note placement of additional rip rap along banks leading towards river to provide erosion protection

September 21, 2019 volunteer support with riparian planting from BCIT Ecological Restoration program:

Students from BCIT ER program after a full afternoon of planting riparian vegetation

Signage warning water sport users to use caution if moving through culvert (signage installed at both sides of the culvert)

Information signage on kiosk/bench

Detail of signage