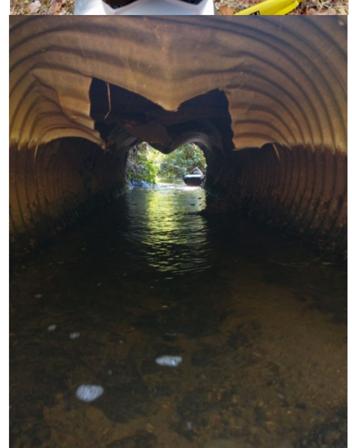
Fish Passage Restoration and Habitat Enhancement

Anadromous fish passage assessment and remediation in the Annapolis and Cornwallis River Watersheds



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Fisheries and Oceans Canada
Nova Scotia Salmon Association
Adopt A Stream

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List of Acronyms

AAS	Adopt A Stream
ACAD	Aquatic Connectivity Analytical Database
CARP	Clean Annapolis River Project
cm	Centimetre
DFO	Fisheries and Oceans Canada
eDNA	Environmental DNA
HWY	Highway
iBoF	Inner Bay of Fundy
JWA	Jijuktu'kwejk Watershed Alliance
km	Kilometre
km^2	Kilometre squared
l	Litre
m	Meter
m^2	Meters squared
μm	Micron
ml	Millilitre
mm	Millimeter
NSE	Nova Scotia Environment
RFA	Recreational Fishing Area

Acknowledgements

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Executive Summary

Habitat fragmentation caused by barriers within a watercourse (e.g. culverts) can impede the upstream and downstream movements of fish through a river system. Insufficient water depths, incorrect sizing, steep slopes, and large outflow drops are potential problems that can characterize a culvert as a barrier. When fish migration is restricted, populations can be negatively impacted. In 2007, the Clean Annapolis River Project (CARP) initiated the Broken Brooks program (renamed the Fish Passage Restoration and Habitat Enhancement Project in 2015) to assess aquatic habitat and fish connectivity within the Annapolis River watershed.

Building upon this work, the primary objective of this two-year project was to assess fish habitat connectivity at private and public watercourse crossings for multiple target species in the Annapolis and Cornwallis River watersheds. Since the inception of the Broken Brooks program, CARP has visited over 700 watercourse crossing sites, with 415 identified as culverts on fish-bearing streams, receiving detailed watercourse crossing assessments. To expand these efforts, CARP partnered with the Jijuktu'kwejk Watershed Alliance (JWA) to assess aquatic connectivity in the Cornwallis River watershed and support the establishment of their Aquatic Habitat Program.

During the first year of the project, the focus was on assessing watercourse crossings within both watersheds, particularly those never assessed before, located near the main stem, or with high potential for upstream habitat gain. In the second year, assessments continued in the Cornwallis River watershed at sites lacking previous data, while in the Annapolis River watershed, the focus shifted to re-assessing sites previously restored by CARP to evaluate the durability and effectiveness of commonly used remediation techniques. Overall, 72 watercourse crossings were assessed during the project's duration, with detailed information entered into an online database determining the barrier status of each culvert and suggesting remediation options.

The second objective was to restore fish habitat connectivity in fragmented sub-watersheds. Throughout the project, 20 sites underwent restoration work, resulting in 15 debris removals, 3 tailwater control structure installations, one low-flow barrier installation, and one fish chute installation. These remediation activities are expected to benefit target fish species by expanding the area of aquatic habitat available for the spawning and rearing of salmonids and other native fish species. In total, these remediation activities re-established access to 35.67 km of upstream habitat.

The project's third objective was to assess species composition and abundance within sub-watersheds where crossing sites were identified to receive remediation actions. Fish sampling surveys were conducted to collect data on species presence and absence, composition, and abundance before and after remediation activities took place. Fish sampling surveys took place within 9 of the sub-watersheds where watercourse crossing remediation activities were conducted, revealing the presence of native species, non-native species, and species at risk.

Additionally, the project included a comprehensive evaluation of fish passage and tidal flow within a significant culvert situated along the Harvest Moon Trail. The assessment concluded that the culvert did not impede fish passage and therefore did not require immediate restoration efforts. The Nova Scotia Salmon Association compiled a report detailing the assessment outcomes and proposing recommended actions, which was subsequently disseminated to pertinent stakeholders. Moreover, 9 outreach events were organized to educate private land managers and trail groups in both watersheds, urging them to address barriers and prioritize fish passage in future projects.

1.0 Introduction

Fragmentation of aquatic habitats is considered a serious concern and major restoration priority for many watershed groups across Nova Scotia. Infrastructure development and land use changes are often the cause of aquatic habitat fragmentation, and the importance of watercourse connectivity within a watershed is often overlooked during these changes (Woods, 2014). Watercourse crossings causing fragmentation affect ecologically significant processes by altering natural channel morphology and creating physical barriers which directly affect aquatic connectivity to both upstream and downstream habitats. The interruption of free travel of aquatic organisms, specifically anadromous fish species, can limit their access to suitable habitat required for spawning and rearing as well as limit their connectivity with neighbouring populations and ultimately limit the total production of the watershed (AAS, 2018).

Watercourse crossing structures are anthropogenic features often constructed to simplify human travel and include structures such as culverts, bridges, dams, and fords. Often installed improperly or not maintained, these structures can create physical barriers to fish passage. Although bridges are the preferred watercourse crossing structure allowing the most natural stream channel dynamics, culverts are the most commonly installed structure because they are cheap to build and quick to install; they are prefabricated and simply dropped into place and covered (Price *et al.*, 2010; AAS, 2018). If these culverts are not installed properly, are poorly designed or are not maintained, they can block migration routes to suitable habitat that could otherwise be reached naturally by anadromous and freshwater species such as Atlantic salmon and brook trout. Culverts can impede fish migration through a wide variety of barrier types:

- Vertical/perching barrier at the inflow or outflow of the culvert
- Depth barrier resulting from an oversized culvert that is too wide
- Length barrier in long culverts that lack resting pools
- Turbulence barriers in baffled culverts
- Velocity barrier in undersized or high slope culverts
- Debris barrier
- Deterioration barrier as a result of lack of maintenance (Bouska and Paukert, 2009; AAS, 2018)

Loss of habitat in smaller brooks is equally as important as in larger river systems, as these provide significant spawning and rearing habitat for fish species. Land use changes surrounding a watercourse can lead to negative impacts such as erosion and sedimentation that damage aquatic ecosystems. Streams can become straightened and over-widened, which in turn can lead to greater erosion and sedimentation, thus reducing the thermal capacity of the watercourse, in-stream cover, and food availability from vegetation as well as appropriate flows for spawning (NSE, 2018). Remediation actions involve the installation of in-stream structures to help redirect the excess sand and silt while supporting natural stream processes, as well as the direct removal of the fine sediments from the stream bed to reveal the natural cobble and gravel substrate, thus enhancing the aquatic habitat for various species including, but not limited to Atlantic salmon and brook trout.

The Fish Passage Restoration and Habitat Enhancement Project (formerly "Broken Brooks") was conceptualized and initialized by the Clean Annapolis River Project (CARP) in 2007. Field work for the project has been ongoing since 2010 with the purpose of assessing and restoring aquatic habitat and connectivity within the Annapolis River watershed. As part of the Broken Brooks program, CARP has been assessing watercourse crossings within the watershed in an attempt to identify which ones pose barriers to fish and prioritize those which have been found to obstruct access to upstream habitats for remediation. During the span of this two-year project (2022-2024), the primary focus was on assessing culverts within the Annapolis River watershed and restoring crossings that had not previously been remediated. Furthermore, past restoration sites were revisited to assess the durability and effectiveness of commonly used remediation techniques. Additionally, in an effort to broaden the scope of the project, watercourse crossing assessments were conducted for the first time in the Cornwallis River watershed to facilitate the development of the Jijuktu'kwejk Watershed Alliance's (JWA) Aquatic Habitat Program.

2.0 Methodology

The project expanded upon previous initiatives led by CARP staff, which concentrated on identifying, prioritizing, and enhancing fish passage within the Annapolis River watershed. Furthermore, collaborative efforts were directed towards evaluating fish passage within the Cornwallis River watershed in conjunction with JWA.

2.1 Watercourse Crossing Assessments

The protocol for assessing culverts for fish passage was adapted from the Nova Scotia Environment provincial guidelines (to determine non-barrier culverts), and from protocols developed by the British Columbia Ministry of Environment (Parker, 2000), Terra Nova National Park (Cote, 2009), U.S. Department of Agriculture, Forest Service, National Technology and Development Program (Clarkin, 2005), and the Department of Fisheries and Oceans Canada (DFO, 2007). The protocol was then modified to be more specific to the target species of brook trout and Atlantic salmon and the criteria for a passable culvert was updated (Taylor, 2011). In addition, the Adopt A Stream Aquatic Connectivity Program was developed in 2010 in collaboration with several partners, including the Clean Annapolis River Project, which provided the appropriate training and materials to perform culvert assessments. Assessments allow for culverts to be placed into one of three categories (non-barrier, partial barrier, or full barrier) with the intent to prioritize culverts for restoration activities to ensure aquatic connectivity.

Throughout the project's two-year duration, culvert assessments targeted watercourse crossings within the Annapolis and Cornwallis River watersheds that had not previously undergone assessment, were situated in close proximity to the main stems of the rivers, or exhibited high potential for upstream habitat enhancement. Moreover, in the second year of the project, culvert assessments within the Annapolis River watershed primarily focused on crossings previously assessed and restored to evaluate the efficacy and durability of common remediation techniques. Detailed culvert data sheets and information on the data collected during culvert assessments can be found in Appendices 7.1 and 7.2. For a comprehensive overview of the assessment procedure and equipment used, please refer to the Adopt A Stream Aquatic Connectivity Initiative: A Guide to Assessing Culverts for Fish Passage (AAS, 2018).

In previous years, culvert data was manually analyzed, and each culvert was placed into one of three categories: non-barrier, partial barrier, or full barrier based on a criteria checklist. Once classified as a barrier type, remediation actions were determined, and restoration was prioritized based on the number of downstream barriers and the potential upstream habitat gain of each culvert. These two variables were subdivided into categories, each with a corresponding score. The culvert with the highest cumulative score was deemed to be the highest-priority culvert. After receiving a prioritization score, culverts were then classified into one of three categories: high, medium or low priority. These prioritization scores would be used to guide restoration work for future field seasons also taking into consideration feasibility, in-stream habitat quality above and below the culvert, and its location within the watershed. For further details and methods for prioritizing culverts used prior to the 2018 and 2019 seasons, refer to Fish Habitat Restoration and Enhancement: A Project to Address Fish Habitat Fragmentation and Degradation in the Annapolis River Watershed (Stoffer, 2016).

In 2019, the Adopt A Stream Aquatic Connectivity Initiative, in partnership with the Clean Annapolis River Project, launched ACAD, the Aquatic Connectivity Analytical Database. This web-based tool was designed to manage assessment data and prioritize water crossings for remediation purposes and could be used by watershed groups across Nova Scotia. All of the assessment data gets entered into the database and each culvert, bridge, dam, ford, or other form of watercourse crossing is given a fish passage ranking along with potential remediation options. The watercourse crossing assessments collected during the project were entered and stored in the database and their barrier status and remediation options were digitally calculated.

2.2 Fish Passage Restoration

Culverts selected for remediation were chosen based on their barrier status, upstream habitat gain, and complexity and cost of the restoration.

2.2.1 Debris Removals

Debris can often accumulate at stream crossings, resulting in blockages to fish passage through portions of a waterbody. Over time, leaf litter, fallen branches, garbage, and silt are transported into a stream directly from streambanks or by erosion. Debris can also be carried into streams indirectly during high-flow events. Such debris can be transported downstream, where it may accumulate at restrictions in the channel such as at the inflow, outflow, or inside of a culvert. Once debris begins to accumulate, a snowball effect is created, where more and more debris will be caught upon existing debris, increasing the size of the blockage. Such blockages have the potential to build to where they can restrict flows through a watercourse crossing and impede fish migration through culverts. Grates, cages, and fences placed at the inflow of culverts to reduce blockages can often have the opposite of the desired effect and exacerbate the accumulation of debris, unless cleaned on a regular basis. Beaver dams can also be a significant source of debris, as beavers often barricade the interior or the inflow of culverts, or construct dams directly upstream or downstream of a watercourse crossing. Such dams can either entirely block movement through a culvert or can affect water levels by altering the water flow through a watercourse crossing.

Debris removals are therefore an important component of restoration work that is needed to maintain fish passage and adequate water flow through culverts. Debris removals were completed by CARP and JWA staff with various hand tools including saws, shovels, and brush clippers.

2.2.2 Tailwater Controls

One of the most common watercourse crossing issues that pose a threat to fish passage are outflow drops. Culvert outflow drops that are too high result in perched culverts that are not accessible to fish, thus closing off upstream habitat. The outflow drop of a culvert is calculated as the height difference between the outflow of the culvert and the tailwater control.

A tailwater control is located downstream of an outflow pool, and is the highest elevation point leading into the natural downstream channel. By increasing the height of an existing tailwater control, or establishing a new one, the depth of water in a culvert's outflow pool can be raised, thereby reducing, or even eliminating an outflow drop. The construction of tailwater controls alone as a remediation for outflow drops is not recommended for drops that exceed 30 cm, as they become less effective, and are more likely to pose another barrier to fish passage. For culverts whose outflow drops exceed 30 cm, tailwater controls are often used in combination with additional weirs constructed downstream, fish chutes, baffles, and/or low flow barriers.

Three tailwater control structures were built in the first year of the project, following a vortex rock weir design. The foundation of the rock weirs consisted of large, flat footer stones, with smaller pebbles and gravel used to fill gaps between the larger stones, following calculations for rock sizing and utilizing materials available at the site. During the second year of the project, maintenance was carried out on one tailwater control structure originally built by CARP staff in 2015. While re-assessing the site in 2023, it was determined that the rock weir required maintenance. The maintenance work involved reinforcing the structure by replacing eroded rock material along the streambanks and edges of the weir to prevent further erosion and washout. For further design information, calculations used, and a detailed description of the rock weir construction, refer to Appendices 7.4 and 7.5.

2.2.3 Low Flow Barriers

In situations where multiple culverts are present at watercourse crossings, it's common for one culvert to handle the majority of the water flow. This is especially noticeable when one culvert sustains damage that restricts water flow or when its entrance is positioned above the water line. During periods of low-flow conditions, the effects of having multiple culvert openings can become more pronounced. To address this issue and enhance water levels for fish, low-flow barriers can be installed at the entrances of culverts to redirect flow and elevate water levels within the primary functioning culvert during low-flow seasons.

In the first year of the project, a low-flow barrier was installed to divert water into one side of a double box culvert. The barrier consisted of untreated 4x4 lumber stacked two high and secured in place to prevent water from flowing under or around it. Installation of the low-flow barrier involved the use of various hand tools, including saws and a cordless power drill.

2.2.4 Fish Chutes

Fish chutes are another feature, often used in addition to other culvert remediation actions, that are added to the outflow of a culvert to assist in reducing the effects of a large outflow drop. In 2016, a fish chute was installed in combination with a tailwater control structure to alleviate an outflow drop of over 50 cm. Culvert measurements were used to calculate the required chute dimensions using a formula for determining baffle notch sizes. Unfortunately, upon re-assessing the site in 2023, the chute had detached from its affixed baffles and was no longer attached to the culvert.

Using the same design as in 2016, a new chute was ordered from RKO Steel Ltd in Dartmouth, NS. The chute was made from 6.35 mm galvanized steel plate, and the length of the chute itself was increased from 540 mm to 750 mm. A wooden frame was constructed around the outflow of the culvert using pressure-treated 4x4 lumber. The fish chute was affixed to the wooden frame using galvanized lag bolts. Stainless steel corner braces were also attached to add additional reinforcement to the structure.

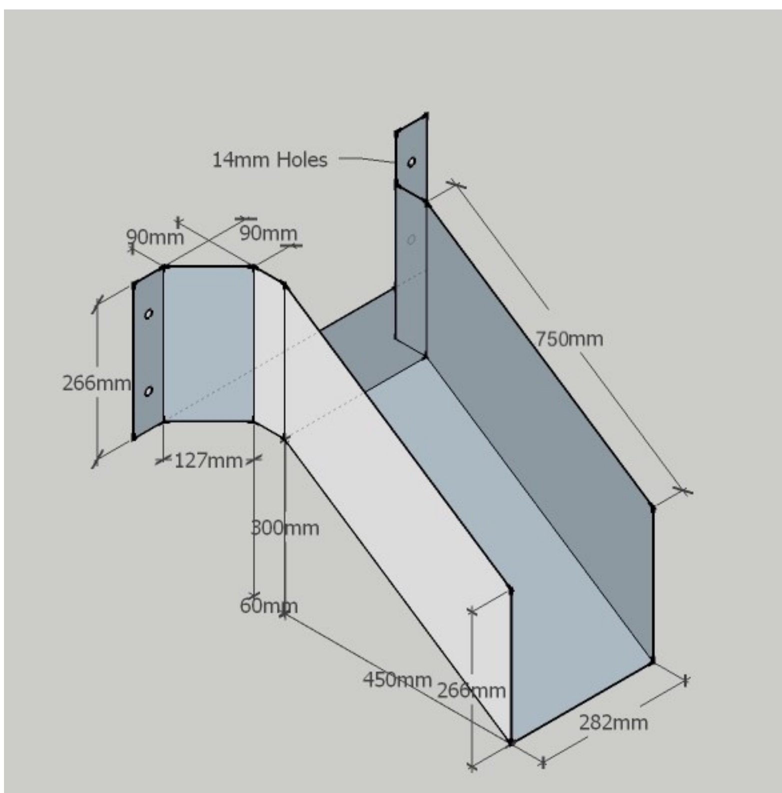

Figure 1. Fish chute design and dimensions.

2.3 Species Composition and Abundance Surveys

Species composition and abundance surveys were conducted using various techniques within the sub-watersheds where crossing sites were identified to receive remediation actions. The survey techniques included electrofishing, fyke net deployment, and environmental DNA (eDNA) sampling to collect data on species presence and absence, composition, and abundance before and after remediation activities took place.

2.3.1 Electrofishing Surveys

Electrofishing is a scientific survey method used to sample fish populations and determine a variety of factors including species' health, abundance, and density within an ecosystem. An electrical current is created between two submerged electrodes - a positive anode and a negative cathode. Galvanotaxis draws the fish towards the anode and once the fish is between the two electrodes, part of a closed circuit is formed and some of the current flows through the fish's body. The fish are then netted and placed in a temporary holding tank where they revive and can be assessed, measured, and sampled to collect various data.

Backpack electrofishing was conducted within 9 of the sub-watersheds where watercourse crossing remediation activities took place. Each site represented an open reach with an average length of approximately 100 m. A single pass was executed at each site, documenting the captured fish species, and recording their fork length. The objective of these surveys was to compile a representative inventory of the fish species inhabiting each sub-watershed. Refer to Appendices 7.6 and 7.7 for an example of an electrofishing data sheet and information on the data that is collected during an electrofishing survey.

2.3.2 eDNA Sampling

Environmental DNA refers to the genetic material shed by organisms into the environment, such as water or soil, which can be extracted to identify the species from which the DNA originated. This genetic material may include fragments of tissue like feces, gametes, scales, and cellular material. In freshwater aquatic systems, eDNA is collected and filtered from water samples (Hobbs, 2017). It's important to emphasize that eDNA sampling can only determine the presence or absence of a species in a watercourse, not its abundance.

During the 2022 season, water samples were gathered from three locations along Sharpe Brook in the Cornwallis River watershed, using sterile 250 ml Nalgene bottles. To prevent contamination, the sites were accessed from the riverbank, ensuring no DNA from waders or boots could influence the samples. Samples were collected both upstream and downstream of two culverts to assess the presence of aquatic invasive species before proceeding with remediation efforts. Triplicate samples were obtained at each site to enhance the likelihood of DNA detection. The samples were stored in a cooler until brought back to the CARP office for filtration. Each water sample underwent filtration through a 0.45 μm cellulose nitrate membrane filter using a Gast vacuum pump. Subsequently, the filters were preserved in silica desiccant beads and shipped to the University of Maine for specific DNA extraction. For detailed information on the complete eDNA sampling and filtration protocol used, please refer to the University of New Hampshire's Estuaries eDNA website.

3.0 Results

The restoration initiatives carried out during the project led to significant enhancements in fish passage. A total of 42 watercourse crossings in the Annapolis River watershed and 30 crossings in the Cornwallis River watershed underwent assessments for fish passage. Of these, 20 crossings underwent restoration work, which comprised 15 debris removals, 3 installations of tailwater control structures, one low-flow barrier installation, and one fish chute installation. These efforts collectively improved access to 35.67 km of upstream habitat.

Table 1. Summary of fish passage restorations.

Restoration Site	Watercourse Name	Latitude	Longitude	Upstream Habitat Gain (km)	Restoration Work Completed
PAR006	Paradise Brook Tributary	44.8396	-65.1793	n/a	Debris removal
BIG002	Big Brook	44.8351	-65.1757	1.30	Debris removal
JOU001	Joudrey Brook	44.7825	-65.2220	0.38	Debris removal & Rock weir construction
NEW001	Newcombe Brook	44.8761	-64.9772	3.50	Debris removal
MAR001	Marshall Lake Tributary	44.9162	-64.8284	0.92	Debris removal
FAL013	Fales River Tributary	44.9192	-64.8969	1.60	Debris removal
EAL001	East Allan Lake Tributary	44.8678	-64.9503	0.87	Debris removal & Rock weir construction
CLO001	Cloud Lake Tributary	44.8575	-64.9144	5.10	Debris removal
RHR064	Round Hill River Tributary	44.7481	-65.3853	0.93	Debris removal
RHR061	Gibsons Brook	44.7181	-65.2944	4.30	Debris removal
SHB005	Sharpe Brook	45.0409	-64.6467	0.89	Low-flow barrier installation
RFB001	Rochford Brook	45.0568	-64.6741	1.40	Rock weir construction
EAS009	East Moose River	44.6392	-65.5326	0.56	Debris removal & Rock weir maintenance
ALL017	Grand Lake Flowage	44.6898	-65.5191	0.26	Debris removal
PET002	Petes Brook	44.8740	-65.1307	2.22	Debris removal
WAT004	Watton Brook	44.9702	-65.0261	1.50	Fish chute installation
TRO010	Troop Brook	44.7636	-65.5015	2.74	Debris removal
BLK004	Black River	44.9452	-65.0248	0.83	Debris removal
SHB006	Sharpe Brook	45.0374	-64.6420	1.92	Debris removal
BWB003	Brandywine Brook	45.0924	-64.5984	4.45	Debris removal

3.1 Watercourse Crossing Assessments

Over the course of the project's two-year duration, a total of 72 watercourse crossing sites underwent assessment in the Annapolis River and Cornwallis River watersheds. In the initial year, efforts were concentrated on evaluating crossings that had not been previously assessed in detail. In the subsequent year, assessments in the Cornwallis River watershed persisted at sites lacking prior data, while attention shifted in the Annapolis River watershed to re-assessing sites previously restored by CARP. This aimed to gauge the durability and effectiveness of commonly employed remediation techniques.

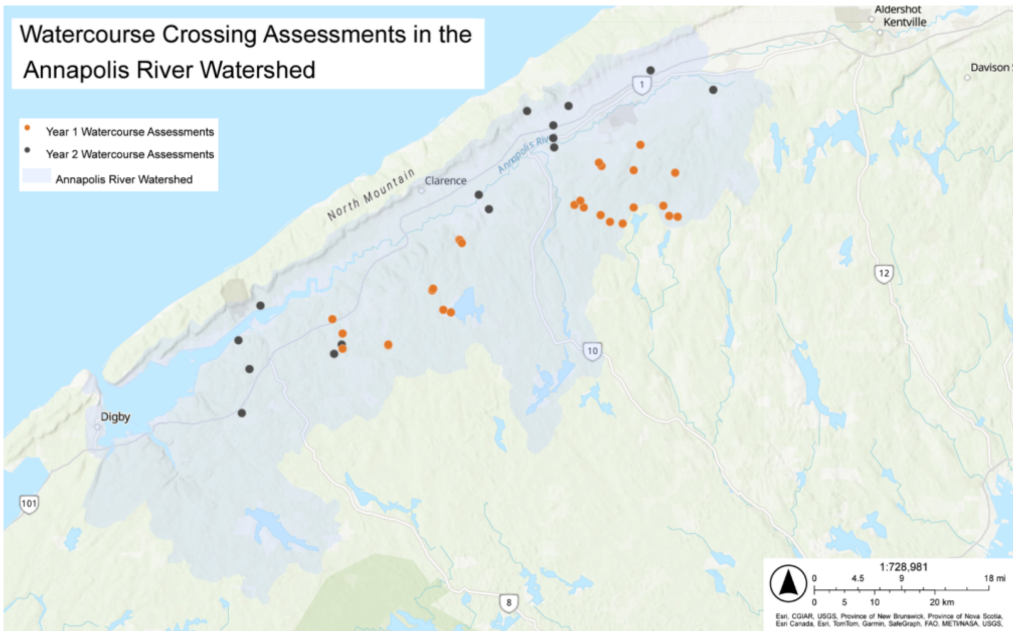

Figure 2. Map of watercourse crossings assessed in the Annapolis River watershed.

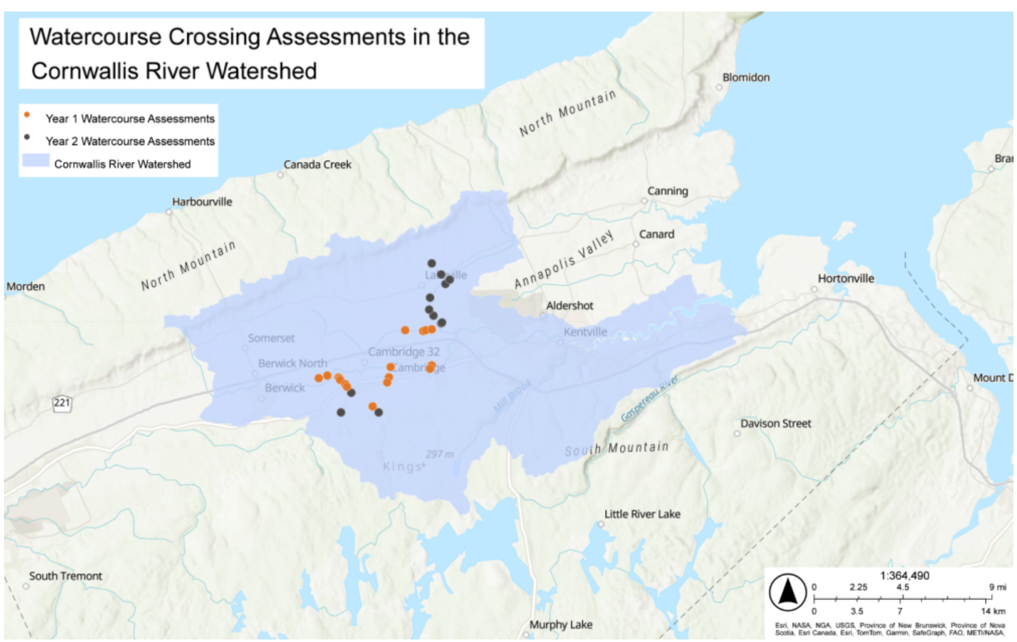

Figure 3. Map of watercourse crossings assessed in the Cornwallis River watershed.

Of the 72 watercourse crossings that were assessed, 32 were bridges, while 40 were found to be a type of culvert. Table 2 shows the number of culverts that were found to have a visible outflow drop, water depth less than 15 cm anywhere in the culvert, no backwatering, a noticeable difference in the stream width above and below the culvert or a debris blockage present. Culverts that were initially found upon visual inspection to have any of these variables were theoretically posing an immediate form of barrier to fish passage and required a full, detailed assessment. However, the substantial rainfall experienced throughout the spring and summer of 2023 (year 2 of the project) limited the number of full culvert assessments that could be conducted. The majority of the sites visited featured high-water levels and swift currents, creating unsafe conditions for performing a thorough assessment.

Of the 40 culverts assessed over the project duration, nearly half (18 culverts, or 45%) have more than one contributing issue resulting in the restriction of fish passage. The watercourse crossings determined to be partial and full barriers to fish passage according to the AAS ACAD webpage were prioritized and received suggested remediation actions based on complexity and cost efficiency. It's worth noting that 6 of the sites with visible outflow drops had fish chutes affixed, and were equipped with tailwater control structures, which were previously installed by CARP. Further details of all watercourse crossing assessments can be found in Appendix 7.3.

Table 2. Rapid assessment results.

	Visible Outflow Drop	Water Depth Less than 15 cm Anywhere in the Culvert	Culvert is Backwatered Only Part of the Way or Not at All	Stream Width is Noticeably Different Above and Below the Culvert	Debris Blockage Present
Count	14	13	14	7	14
Percentage (%)	35	32.5	35	17.5	35

3.2 Fish Passage Restorations

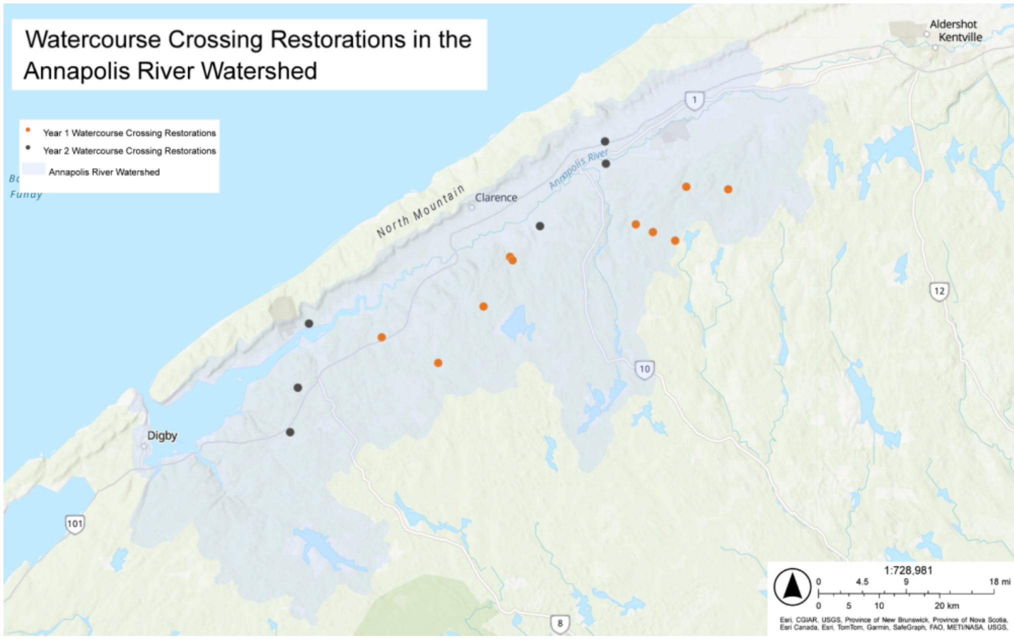

Figure 4. Map of watercourse crossing restorations in the Annapolis River watershed.

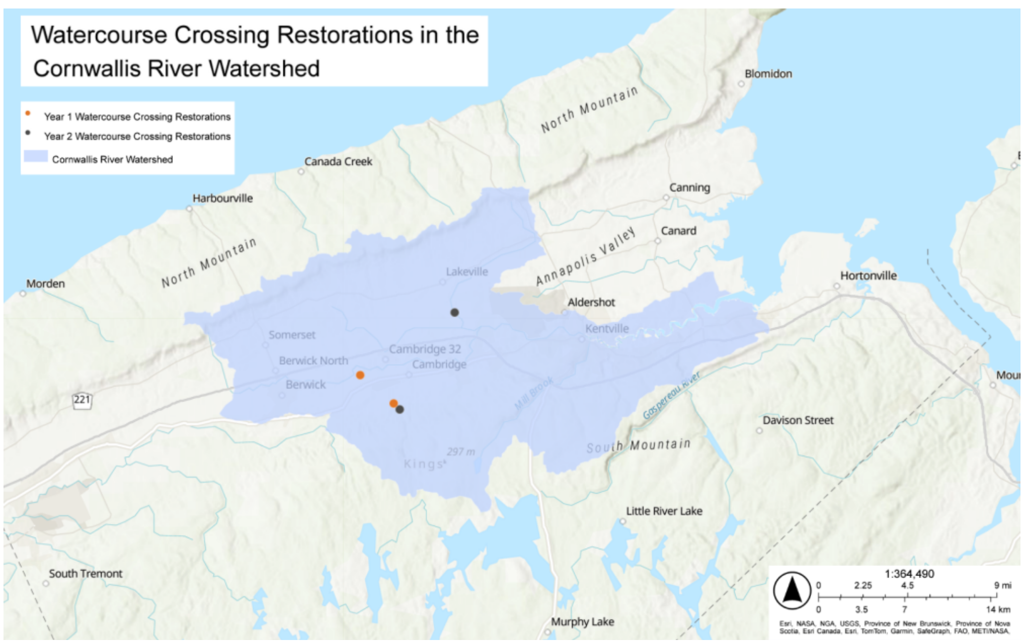

Figure 5. Map of watercourse crossing restorations in the Cornwallis River watershed.

3.2.1 PAR006

Location: Roxbury Road
Stream Name: Paradise Brook Tributary
Watershed: Annapolis
Remediation: Debris Removal
Upstream Habitat Gain: N/a
Comments: PAR006, situated along a tributary to Paradise Brook within the Roxbury Brook sub-watershed, was a corrugated plastic culvert. The culvert faced significant obstruction caused by debris and organic matter. As a result, a debris removal was conducted at both the inflow and outflow of the culvert in the summer of 2022.

Figure 6. Before (left) and after (right) the culvert inflow debris removal.

Figure 7. Before (left) and after (right) of the culvert outflow debris removal.

3.2.2 BIG002

Location: Resource/Rec Road off Roxbury Road
Stream Name: Big Brook
Watershed: Annapolis
Remediation: Debris Removal
Upstream Habitat Gain: 1.3 km
Comments: BIG002, positioned along Big Brook within the Roxbury Brook sub-watershed, was a bridge crossing. The bridge was constructed atop previously collapsed bridges, leading to the buildup of woody debris, leaf litter, and sediment at the structure's base. In the summer of 2022, a debris removal was carried out at BIG002. Subsequently, in October 2022, the site was revisited to confirm the absence of any new debris blockages.

Figure 8. BIG002 before (left) and after (right) debris removal.

Figure 9. BIG002 upon revisiting the site in October 2022.

3.2.3 NEW001

Location: Allen Lake Road
Stream Name: Newcombe Brook
Watershed: Annapolis
Remediation: Debris Removal
Upstream Habitat Gain: 3.5 km
Comments: NEW001, located on Newcombe Brook within the Black River sub-watershed, functioned as a bridge crossing. Downstream of the structure, an accumulation of sticks and woody debris caused a blockage. This obstruction was cleared during the summer of 2022, restoring access to 3.5 km of upstream habitat. However, upon revisiting the site the following summer, an active beaver dam was noticed downstream of the bridge. Since the dam was active, it was left undisturbed.


Figure 10. NEW001 before (left) and after (right) debris removal.

Figure 11. Active beaver dam downstream of NEW001.

3.2.4 MAR001

Location: Resource/Rec Road Off Aylesford Road (Route 99)
Stream Name: Marshall Lake Tributary
Watershed: Annapolis
Remediation: Debris Removal
Upstream Habitat Gain: 0.92 km
Comments: MAR001 was a bridge crossing located within the Cloud Lake Wilderness Area. Leaf litter, woody debris, and sediment had accumulated underneath the structure. Upon the removal of the debris, access to 0.92 km of upstream habitat was restored. Upon returning to the site the next summer, an active beaver dam was spotted upstream of the bridge. As the dam was still in use, no action was taken.

Figure 12. MAR001 before (left) and after (right) debris removal.

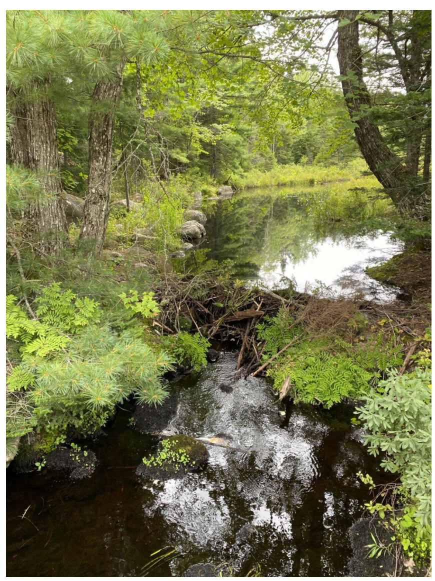

Figure 13. Active beaver dam downstream of MAR001.

3.2.5 FAL013

Location: Resource/Rec Road Off East Torbrook Road
Stream Name: Fales River Tributary
Watershed: Annapolis
Remediation: Debris Removal
Upstream Habitat Gain: 1.6 km
Comments: FAL013 was a corrugated plastic culvert located within the Fales River sub-watershed. Woody debris had accumulated at the inflow as well as inside of the culvert. The debris blockage was removed during the summer of 2022, restoring access to 1.6 km of upstream habitat.

Figure 14. FAL013 before (left) and after (right) debris removal.

3.2.6 RHR064

Location: Spurr Road
Stream Name: Round Hill River Tributary
Watershed: Annapolis
Remediation: Debris Removal
Upstream Habitat Gain: 0.93 km
Comments: RHR064 consisted of two corrugated metal culverts positioned in the Round Hill River sub-watershed. The right side of the culverts' inflow was obstructed by a buildup of debris. Clearance of the debris enabled the restoration of access to 0.93 km of upstream habitat.

Figure 15. RHR064 before (left) and after (right) debris removal.

3.2.7 CLO001

Location: Fire Lane (Route 90)
Stream Name: Cloud Lake Tributary
Watershed: Annapolis
Remediation: Debris Removal
Upstream Habitat Gain: 5.10 km
Comments: CLO001, positioned within the Cloud Lake Wilderness Area, served as a corrugated metal culvert crossing. The inflow of the culvert was obstructed by woody debris and leaf litter, hindering fish passage. Upon removal of the debris blockage, access to 5.1 km of upstream habitat was restored. A follow-up visit to the crossing in October 2022 confirmed the absence of any additional debris accumulation.

Figure 16. CLO001 before (left) and after (right) debris removal.

Figure 17. CLO001 upon revisiting the site in October 2022.

3.2.8 RHR061

Location: West Dalhousie Road
Stream Name: Gibsons Brook
Watershed: Annapolis
Remediation: Debris Removal
Upstream Habitat Gain: 4.30 km
Comments: RHR061, situated in the Round Hill River sub-watershed, functioned as a culvert equipped with a metal grate designed to prevent debris from obstructing the culvert interior. However, the grate was prone to accumulating debris during periods of high-water flow (see Figure 19). To address this issue, both the grate and any remaining debris were removed during the summer of 2022.

Figure 18. RHR061 before (left) and after (right) debris removal.

Figure 19. Culvert grate blocked with debris.

3.2.9 JOU001

Location: Resource/Rec Road off Morse Road
Stream Name: Joudrey Brook
Watershed: Annapolis
Remediation: Tailwater Control Weir Construction
Upstream Habitat Gain: 0.38 km
Comments: At JOU001, a tailwater control weir was built to elevate the water level in the culvert's outflow pool, aiming to decrease or eliminate an outflow drop of 19.5 cm. Following specific vortex rock weir formulas, the weir was meticulously constructed by manually relocating rocks collected from the site.

Figure 20. JOU001 before rock weir construction.

Figure 21. Rock weir built on Joudrey Brook.

3.2.10 EAL001

Location: Resource/Rec Road Off Fire Lane
Stream Name: East Allen Lake Tributary
Watershed: Annapolis
Remediation: Tailwater Control Weir Construction
Upstream Habitat Gain: 0.87 km
Comments: At EAL001, a tailwater control weir was built to elevate the water level in the culvert's outflow pool, aiming to decrease or eliminate an outflow drop of 13.5 cm. Following specific vortex rock weir formulas, the weir was meticulously constructed by manually relocating rocks collected from the site.

Figure 22. EAL001 before rock weir construction.

Figure 23. Rock weir built at EAL001.

3.2.11 RFB001

Location: Dykens Lane
Stream Name: Rochford Brook
Watershed: Cornwallis
Remediation: Tailwater Control Weir Construction
Upstream Habitat Gain: 1.4 km
Comments: At RFB001, a tailwater control weir was constructed by JWA to elevate the water level in the culvert's outflow pool, aiming to decrease or even eliminate an outflow drop of 11 cm. Following specific vortex rock weir formulas, the weir was meticulously constructed by manually relocating rocks delivered to the site. However, upon revisiting RFB001 the following summer, it was observed that the weir did not remain intact and required additional rock to rebuild it properly.

Figure 24. RFB001 before (left) and during (right) rock weir installation.

Figure 25. The rock weir at RFB001 no longer intact.

3.2.12 SHB005

Location: Randolph Road
Stream Name: Sharpe Brook
Watershed: Cornwallis
Remediation: Low-flow Barrier Installation
Upstream Habitat Gain: 0.89 km
Comments: A low-flow barrier was installed by JWA at SHB005 to redirect water into one side of a double box culvert. The barrier was made out of untreated 4x4 lumber and installed using various hand tools.

Figure 26. SHB005 before (left) and after (right) the low-flow barrier installation.

3.2.13 EAS009

Location: Fraser Road
Stream Name: East Moose River
Watershed: Annapolis
Remediation: Debris Removal and Tailwater Control Structure Maintenance
Upstream Habitat Gain: 0.56 km
Comments: EAS009 was a corrugated metal culvert positioned along the East Moose River. In 2015, a fish chute and tailwater control structure were installed at this location. Maintenance work on the tailwater control structure and a debris removal were conducted in the summer of 2023, restoring access to 0.56 km of upstream habitat.

Figure 27. EAS009 before (left) and after (right) the culvert inflow debris removal.

Figure 28. Before (left) and after (right) the tailwater control structure maintenance.

3.2.14 ALL017

Location: Clementsvale Road
Stream Name: Grand Lake Flowage
Watershed: Annapolis
Remediation: Debris Removal
Upstream Habitat Gain: 0.26 km
Comments: ALL017 consisted of a pair of corrugated metal culverts. In 2015, a fish chute and tailwater control structure were installed at the site. When the site was revisited in 2023, obstructions from debris were observed at the inflow and outflow of the culverts, resulting in flooding conditions upstream. A debris removal was undertaken to clear blockages from the culvert and accumulated debris downstream, restoring access to 0.26 km of upstream habitat.

Figure 29. ALL017 inflow (left) and outflow (right) blocked with debris.

Figure 30. ALL017 inflow (left) and outflow (right) after the debris removal.

3.2.15 PET002

Location: HWY 201
Stream Name: Petes Brook
Watershed: Annapolis
Remediation: Debris Removal
Upstream Habitat Gain: 2.22 km
Comments: PET002 was a concrete culvert situated on Petes Brook. In 2018, CARP installed a fish chute and tailwater control structure at this location. Fortunately, those structures required no maintenance; however, there was an accumulation of sticks and woody debris observed at the culvert's inflow. A debris removal was conducted, restoring access to 2.22 km of upstream habitat.

Figure 31. PET002 before (left) and after (right) debris removal.

3.2.16 WAT004

Location: McColough Road
Stream Name: Watton Brook
Watershed: Annapolis
Remediation: Fish Chute Installation
Upstream Habitat Gain: 1.50 km
Comments: WAT004, located on Watton Brook, consisted of a double wooden box culvert. In 2016, several enhancements were made to the site, including the installation of baffles, a low-flow barrier, a fish chute, and a tailwater control structure. However, during the 2023 site revisit, it was discovered that the fish chute had detached from the culvert and couldn't be located. A replacement chute was ordered and successfully installed in September 2023 to rectify the culvert's excessive outflow drop of more than 50 cm.

Figure 32. WAT004 before (left) and after (right) the fish chute installation.

Figure 33. CARP staff, Levi Cliche and Shauna Forrestall installing the fish chute.

3.2.17 TRO010

Location: Post Road
Stream Name: Troop Brook
Watershed: Annapolis
Remediation: Debris Removal
Upstream Habitat Gain: 2.74 km
Comments: TRO010 was a pair of corrugated metal culverts located on Troop Brook. Woody debris and other organic matter had accumulated at the inflow gates of both culverts. The debris was removed during the summer of 2023, re-establishing access to 2.74 km of upstream habitat.

Figure 34. TRO010 inflow before the debris removal.

Figure 35. TRO010 inflow after the debris removal.

3.2.18 BLK004

Location: HWY 201
Stream Name: Black River
Watershed: Annapolis
Remediation: Debris Removal
Upstream Habitat Gain: 0.83 km
Comments: BLK004, located on the Black River, was a corrugated metal culvert. Downstream of the culvert, a significant accumulation of debris had formed, acting as a barrier to fish passage. The obstruction was successfully cleared, reopening access to 0.83 km of upstream habitat.

Figure 36. Downstream of BLK004 before (left) and after (right) debris removal.

3.2.19 SHB006

Location: Jodrey Mountain Road
Stream Name: Sharpe Brook
Watershed: Cornwallis
Remediation: Debris Removal
Upstream Habitat Gain: 1.92 km
Comments: SHB006 was a set of 3 corrugated metal culverts along Sharpe Brook. Two out of the three culverts had severe accumulations of trash and woody debris, restricting water flow. A debris removal was conducted by the JWA field team, restoring access to 1.92 km of upstream habitat.

Figure 37. SHB006 before (left) and during (right) the debris removal.

3.2.20 BWB003

Location: North Bishop Road
Stream Name: Brandywine Brook
Watershed: Cornwallis
Remediation: Debris Removal
Upstream Habitat Gain: 4.45 km
Comments: BWB003 was a set of 3 corrugated metal culverts underlying a concrete crossing on an agricultural property. An accumulation of woody debris was observed at the inflow of all culverts. A debris removal was conducted by the JWA field team, restoring access to 4.45 km of upstream habitat.

Figure 38. BWB003 before (left) the debris removal and JWA staff (right) with the debris removed from the site.

Figure 39. BWB003 after the debris removal.

3.3 Species Composition and Abundance Surveys

Species composition and abundance surveys were conducted within 9 of the sub-watersheds where crossing sites were identified to receive remediation actions.

3.3.1 Electrofishing Surveys

During the first year of the project, electrofishing surveys were conducted at three sites within the Fales River, Black River, Roxbury Brook, and Round Hill River sub-watersheds and two sites within the Sharpe Brook sub-watershed. Seven native and non-invasive fish species were found, including brook trout, brown trout, white sucker, creek chub, three-spined stickleback, American eel, and brook lamprey. Additionally, Atlantic salmon parr were found in the Fales River and Roxbury Brook.

During the second year of the project, electrofishing surveys were carried out at two locations on the Fales River and one site on the Round Hill River, revealing the presence of four native fish species: white sucker, creek chub, three-spined stickleback, and American eel. Electrofishing surveys were also conducted at the following culvert restoration sites: PET002, TRO010, EAS009, SHB006, and RFB001 (Y1 restoration site).

Due to the substantial summer rainfall in 2023, elevated water levels posed significant challenges for safe entry into the rivers for electrofishing. Moreover, during periods of safe water levels, high velocity and poor visibility made netting extremely difficult. Given that electrofishing is restricted to the period between June 1 and September 30, limited efforts could be conducted under favourable conditions. To compensate for the shortfall in electrofishing efforts, fyke nets were deployed. Two fyke nets were set in the Round Hill River and Roxbury Brook on October 17, 2023. Deployed for approximately 20 hours, the nets were checked and retrieved on October 18. Unfortunately, the nets accumulated fallen autumn leaves, resulting in no fish being caught or observed. Refer to Appendix 7.8 for detailed electrofishing results including pass and species information.

3.3.2 eDNA Sampling

During the first year of the project, eDNA water samples were obtained from three sites along Sharpe Brook in the Cornwallis River watershed. These samples were taken from both upstream and downstream of two culverts to assess the potential presence of aquatic invasive species prior to any remediation efforts. Fortunately, the results indicated no presence of aquatic invasive species across all sampling locations. However, it's worth noting that one of the triplicate samples taken at site SHB007 tested positive for Atlantic salmon. Nevertheless, this singular positive result was considered inconclusive due to the lack of consistent findings across multiple samples. Refer to Appendix 7.9 for detailed eDNA results.

4.0 Additional Activities

4.1 Education and Outreach Initiatives

Education and outreach initiatives were conducted to promote future action in remediating barriers and prioritizing fish habitat connectivity. In total, 9 outreach initiatives took place over the two years of the project, reaching over 1000 individuals.

On August 13, 2022, the Jijuktu'kwejk Watershed Alliance set up an education booth at the Wolfville Farmers' Market. The booth showcased information on aquatic connectivity and its benefits to anadromous species, along with culvert assessment photographs from the field season. The booth attracted interest from over 35 individuals.

Figure 40. JWA summer staff and booth at the Wolfville Farmers' Market.

On August 23, 2022, CARP participated and presented at the Connectivity Partner Engagement Symposium hosted by the Canadian Wildlife Federation. The virtual Symposium brought together 17 participants from 10 organizations specializing in aquatic connectivity across the province. CARP delivered a 15-minute presentation on habitat fragmentation in the Annapolis River watershed due to barriers to aquatic connectivity and provided a brief overview of CARP's ongoing work to improve fish passage. A poster presentation on the same topic was prepared for the Atlantic Society of Fish and Wildlife Biologists Conference held in Fredericton, New Brunswick, on October 15, 2022. Over 30 academia and industry partners participated in the 2-day conference, presenting findings from various research projects.

Additionally, a presentation was delivered at the Recreational Fishing Advisory Council Meeting for RFA 5, which includes both the Annapolis and Cornwallis River watersheds. The virtual meeting, held on December 7, 2022, saw 20 participants including anglers, industry partners, and academia in attendance. CARP's presentation included project updates as well as the threats of barriers to connectivity on iBoF Atlantic salmon.

CARP held its Annual General Meeting on June 27, 2023, open to organizational members and the public. Approximately 40 attendees were present, where a poster presentation on aquatic connectivity and CARP's efforts to enhance fish passage in the Annapolis River watershed was delivered. Additionally, two editions of CARP's quarterly newsletter, The Waterstrider, were disseminated to 982 mailing list members. The summer 2023 edition highlighted CARP's recent fish habitat work, while the October 2023 edition focused on the proper identification and habitat requirements for Atlantic salmon.

On May 17, 2023, the JWA team participated in the Kentville Farmer's Market to raise funds for their annual canoe raffle and increase awareness about JWA's ongoing projects and objectives. Approximately 30 community members engaged in discussions about iBoF Atlantic salmon and JWA's endeavours to restore viable habitat for anadromous fish in the watershed.

On July 15, 2023, the JWA team attended the Annapolis River Fest in Bridgetown and operated a booth featuring information on the JWA's collaboration with CARP, routine water quality and E. Coli monitoring, species at risk in the watershed, and JWA's restoration projects, including iBoF Atlantic salmon recovery. With an estimated 1847 attendees, the event aimed to reach a broader audience beyond the Jijuktu'kwejk Watershed, attracting individuals unfamiliar with the watershed and the JWA's initiatives.

On September 9, 2023, JWA participated in the Kentville Rotary Club's Environment Day. JWA a table showcasing an informational poster on the various projects conducted each year, including habitat connectivity assessment and enhancement. Engaging with an estimated 150 community members, discussions revolved around JWA's habitat restoration efforts, including its partnership with CARP.

4.2 Fish Passage and Tidal Flow Assessment on Sawmill Creek

In the first year of the project, the Nova Scotia Salmon Association conducted watercourse crossing assessments on the culvert located at the junction of Sawmill Creek and its confluence with the lower tidal section of the Annapolis River. Both freshwater and tidal watercourse crossing assessment protocols were utilized. The assessment concluded that the culvert does not present a barrier to fish passage and therefore does not necessitate immediate restoration action.

Subsequently, the Nova Scotia Salmon Association developed a report encompassing the assessment results and recommended remediation actions for the culvert. This report was disseminated to various relevant stakeholders, including the landowner who initially raised concerns about the culvert impeding fish passage.

The report was shared with the following stakeholders:

- The landowner
- The Department of Natural Resources and Renewables
- The Department of Public Works
- The Municipality of the County of Annapolis
- The Annapolis Valley Trails Coalition

Feedback and comments on the report were provided by the landowner. Despite the report's conclusion that the culvert does not obstruct fish passage, he and his family have observed declines in various species that were once abundant in Sawmill Creek. His primary concern, however, pertains to the deteriorated state of the culvert, which he fears may collapse and result in upstream flooding on his agricultural property. Consequently, he advocates for the installation of a bridge in place of the culvert.

5.0 Recommendations

Recommendations are based on the project itself, as well as previous work through the Fish Passage Restoration and Habitat Enhancement Program.

A) Watercourse Crossing Assessments

I. Re-evaluate the barrier status of all watercourse crossing sites assessed throughout the project under low-flow conditions to enhance accuracy.

II. Assessments should be continued during future field seasons with a focus on priority sub-watersheds that lack detailed assessment data. These could include updating assessments that were completed prior to 2022/23 – different events may have occurred surrounding the crossing site leading to a change in the barrier status of previously assessed culverts during the past five or more years.

B) Fish Passage Restorations

I. Revisit all sites that have received restoration work throughout the project to ensure installed structures' functionality and to monitor debris accumulation.

II. Revisit WAT004 to ensure the fish chute is secure and still affixed to the culvert.

III. Rebuilt the rock weir at RFB001. As the site’s substrate is predominately sand and gravel, more rock will need to be ordered to reconstruct the weir.

C) Outreach Initiatives

I. Continue to deliver targeted outreach initiatives to various industry partners and stakeholder groups.

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7.0 Appendices

7.1 Watercourse Crossing Data Sheet

NSLC adopt a stream

Aquatic Connectivity Program Crossing Assessment

SALMON

Site Information			
Crossing ID		Watershed Group Name	
Crossing Type	☐Culvert ☐Bridge* ☐Dam ☐Ford ☐Other	# of Culverts	
Field Crew		Date (dd/mm/yyyy)	
Stream Name		Time	
Road Name		Projection	☐ WGS 84 ☐ NAD 83
Ownership of Crossing	☐ Public Road ROW ☐ Rail Bed ROW ☐Private	Lat (deg, min, sec)	
Debris Blockage Present	☐Yes ☐No	Long (deg, min, sec)	
Description of Debris		Fish Habitat**	☐Yes ☐No

*If crossing is a bridge or other open bottomed structure, complete bridge section
**If crossing is identified as being on a fish bearing stream, then proceed with further data collection

Photo Files			
Upstream	File Name	**Downstream**	File Name
Toward Inflow		Toward Outflow	
Through Culvert		Through Culvert	
Looking Upstream		Looking Downstream	
Other		Other	

Bridge Dimensions			
Span (m)		Wetted Width Under Bridge (m)	
Rise (m)		Average Water Depth Under Bridge (m)	
Bridge Width (m)		Stream Width Ratio	

Rapid Assessment	
There is a visible outflow drop.	☐True ☐False
Water depth is less than 15cm in at least one location inside the culvert.	☐True ☐False
The culvert is not fully backwatered.	☐True ☐False
The stream width noticeably different above and below the culvert?	☐True ☐False

If the response to any of these questions is TRUE then continue with the full assessment.

Stream Characteristics

Water Quality					
Air Temp (°C)		pH		DO (mg/L)	
Water Temp (°C)		Conductivity (µS/cm)		TDS (mg/L)	

Substrate Sizes (taken upstream of culvert in percent composition)

Fines (<0.2cm)		Cobble (6.4-25.6cm)		Bedrock	
Gravel (0.2-6.4cm)		Boulder (>25.6cm)			

Channel Measurements (taken upstream)

	Pool	Riffle	Run	Average
Wetted Width (m)				
Bankfull Width (m)				
Stream Width Ratio				

Culvert Information							
Culvert Material	☐ Concrete ☐ Corrugated Metal Pipe (Spiral) ☐ Corrugated Metal Pipe (Annular) ☐ Corrugated Plastic ☐ Wood ☐ Other	Culvert Shape	☐ Circular ☐ Box ☐ Pipe Arch ☐ Open Arch ☐ Other	Entrance Type	☐ Projecting ☐ Headwall ☐ Mitered ☐ Wingwall ☐ Other		
		Is Culvert Deformed?	☐ Yes ☐ No	Deterioration	☐None ☐Moderate ☐Severe	Baffles	☐ Present ☐ Absent
Culvert Bottom	☐ Closed ☐ Open If Open, Dominant Substrate:____			Variable Slope in Culvert	☐ Yes ☐ No		

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Culvert Dimensions					
Culvert Measurements (m)	WIDTH	HEIGHT	Corrugation (cm)	WIDTH	HEIGHT

Additional Information			
Inflow Habitat Type	☐ Pool ☐ Riffle ☐ Run ☐ Drop	Beaver Dam Present	☐ Yes ☐ No
Backwatered	☐ 0% ☐ 25% ☐ 50% ☐ 75% ☐ 100%	Fish Observed	☐ Upstream ☐ Downstream
Embedment	☐ Embedded from Upstream ☐ No Embedment ☐ Embedded from Downstream ☐ Fully Embedded	X-Sectional Degree of Embedment	☐ 0% ☐ <20% ☐ >20%
Length of Culvert with Embedment	☐ 0% ☐ 25% ☐ 50% ☐ 75% ☐ 100%		

Upstream of Culvert

Elevations				Measurements		
	HI (m) (10 + change in tripod height)	FS (m) (survey rod reading)	Elevation (m) (HI - FS)	Water Depth at Inflow (cm)		Velocity (m/s)
				Stagnation Depth at Inflow (cm)		
Crest of Riffle Upstream				Upstream Riffle to Inflow Invert (m)		
Inflow				Culvert Length (m)		
Upstream Channel Slope (%)						

Downstream of Culvert

Elevations				Measurements		
	HI (m) (10 + change in tripod height)	FS (m) (survey rod reading)	Elevation (m) (HI - FS)	Water Depth at Outflow (cm)		Velocity (m/s)
				Stagnation Depth at Outflow (cm)		
				Plunge Pool Bankfull Width (m)		
Outflow						
Plunge Pool Bottom				Outflow to Tailwater Control (m)		
Tailwater Control				Tailwater Control to 2nd Riffle Downstream (m)		
Crest of 2nd Riffle				Culvert Slope		
Pool Surface Elevation				Outflow Drop (cm)		
Downstream Channel Slope						

Tailwater Cross Section

Widths	Elevations				Measurements
	Station	HI (m) (10 + change in tripod height)	FS (m) (survey rod reading)	Elevation (m) (HI - FS)	Water Depth (m)
Wetted Width (m)	1 (Left Bankfull)				
	2 (1/5 Bankfull Width)				
Bankfull Width (m)	3 (1/5 Bankfull Width)				
	4 (1/5 Bankfull Width)				
Bankfull Width / 5	5 (1/5 Bankfull Width)				
	6 (Right Bankfull)				

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Baffle Information (Complete if culvert is baffled)					
Baffle Height (cm)		Baffle Material	☐ Concrete ☐ Metal ☐ Wood ☐ Other		
Notch Depth (cm)		Baffle Type	☐ Straight ☐ Diagonal ☐ Right Angled ☐ Other		
Notch Width (cm)		Notch Chutes	☐ Yes ☐ No		
Number of Baffles		Notch Chute Material	☐ Concrete ☐ Metal ☐ Wood ☐ Other		
Distance Between Baffles (m)		Elevations	HI (m) (10 + change in tripod height)	FS (m) (survey rod reading)	Elevation (m) (HI - FS)
Distance from Bottom Baffle to Outflow (m)		Most D/S Baffle			
		Adjacent U/S Baffle			
Drop Between Baffles (m)					

Notes

Sketch

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7.2 Watercourse Crossing Assessment Parameters

Table 3. Variables assessed during watercourse crossing assessments.

Variable	Units	Description
Air Temperature	Celcius	The temperature of the air on the day of the survey
Average Water Depth Under Bridge	m	The water depth underneath the bridge taken in a location that is representative of the average depth
Backwatered	%	The surface of the outflow pool extending back into the culvert Is recorded as 25%, 50%, 75% or 100% backwatered
Baffle Height	cm	Height (highest point) of the baffle
Baffle Material		The material that the baffle is made of (wood, concrete, other)
Baffle Type		The shape of the baffles that are present (straight, diagonal, etc)
Bankfull Width	m	Horizontal distance between banks on opposite sides of the stream
Bridge Width		
Channel Measurements	m	Both wetted and bankfull measured taken at representative locations upstream of a structure. A measurement in metres of the width of the water course and bankfull width which best represents the true character of the watercourse
Conductivity	μS/cm	The ability of a solution (water) to carry an electrical current
Corrugation	m	The height and spacing between corrugations of a steel or plastic culvert
Crest of Riffle Upstream	M	An elevation measurement taken the first riffle of an identified location upstream
Crossing ID		An identification code unique to each crossing. This is a six-digit code; the first three digits are letters. These letters relate to the watercourse name or geographical location of the crossing. The last three digits are numbers, which relate to the crossings identification within the watercourse or geographical area.
Crossing Type		The type of crossing being assessed: culvert, bridge, dam, ford, other
Culvert Bottom Material		Material found in the bottom of the culvert (ie natural bottom, metal, etc)
Culvert Length	m	The length of the culvert being assessed
Culvert Material		The material that the culvert is made of (wood, steel, cement, stone)
Culvert Measurements	m	The width and height of the culvert measured at the outflow
Culvert Shape		The shape of the culvert being surveyed (box, round, etc)
Culvert Slope	%	The slope of the culvert calculated by: [(Elevation at Inflow - Elevation at Outflow)/Culvert Length] x 100
Culvert Width	m	The width of the culvert
Date		The date on which the culvert assessment was completed
Distance from Bottom Baffle to Outflow Invert	m	Distance measured in meters between the farthest downstream baffle and the culvert outflow
DO	mg/L	The amount of oxygen dissolved in the water
Downstream Baffle Elevation	m	Elevation measurement taken from the top of the baffle located farthest to the downstream end of the culvert
Downstream Channel Slope	%	The natural slope of the streambed calculated by :
(Elevation at Tailwater Control - Elevation at 2nd Riffle) x 100		

Drop Between Baffles	m	The difference in height between the upstream baffle elevation and the downstream baffle elevation
Elevation at Crest of 2nd Riffle	m	Elevation of the second riffle downstream of the outflow pool
Elevation at Inflow	m	An elevation measurement taken at the bottom of the inflow of a structure
Elevation at Outflow	m	An elevation measurement taken at the bottom of the outflow of a structure
Elevation Tailwater Control	m	An elevation measurement taken in the thalweg at the end of the outflow pool or at an identified location downstream of the structure
Depth of Embedment	cm	The depth to which the culvert is embedded within the substrate of the watercourse
Entrance Type		The design of the culvert inflow (projecting, wingwall, headwall)
Field Crew		The assessors collecting the data
Fish Habitat		The ability of the watercourse to support fish
Fish Observed		The observation of fish upstream and/or downstream of the culvert
Inflow Habitat Type	m	The stream characteristic immediately upstream of the culvert (pool, riffle, run, or drop)
Length of Culvert With Embedment	%	Proportion of the culvert that is embedded within the streambed, taken as a percentage either from upstream or downstream
Notch Depth	cm	The depth of the baffles notch, taken from the lowest portion of the baffle to the top
Notch Width	cm	The width of the lowest portion of the baffle
Outflow Drop	cm	The difference in height between the bottom of the outflow invert and the thalweg of the tailwater control. It is calculated by subtracting the tailwater elevation from the outflow elevation
Outflow Invert to Tailwater Control	m	Distance measured in metres from the culvert outflow to the 1st riffle located downstream
Ownership of Crossing		The person or entity responsible for the crossing
pH		The acidity of the water in the watercourse
Photos		The photos taken of the watercourse crossing site
Pool Bottom Elevation	m	An elevation measurement taken at the deepest part of the outflow pool
Pool Surface Elevation	m	An elevation measurement taken at the surface of the water in the outflow pool
Road Name		The name of the road that the crossing is located on
Rise	m	The height of the bridge across the road
Span	m	The width of the bridge from abutment to abutment
Station	m	The distance, starting from the left floodplain at the tailwater cross section, where elevation and water depth are measured. Stations between stream banks are determined based on Bankfull Width /5
Stream Name		The name of the watercourse where the structure is located
Stream Width Ratio		The value derived from dividing the average upstream channel width by the culvert width
Substrate Size		The proportion of each type of substrate found upstream of the culvert inflow
Tailwater Control to 2nd Riffle Downstream	m	Distance from the downstream tailwater control (1st riffle) to the 2nd riffle
Tailwater Cross Section		Based on the bankfull width, the cross section is divided into segments and measured for height and water depth

Time		The time that the culvert assessment began
TDS	mg/l	Total dissolved solids, the measurement of the combined content of all inorganic and organic substances in its suspended form
Upstream Baffle Elevation	m	Elevation measurement taken from the top of the baffle located farthest to the upstream end of the culvert
Upstream Channel Slope	%	The natural slope of the streambed calculated by : (Elevation at 1st Riffle - Elevation at Inflow) x 100
Upstream Riffle to Inflow Invert	m	Distance from the first upstream riffle to the culvert inflow
UTM Coordinates		GPS position of the watercourse crossing location, described with Northings and Eastings, using a NAD83 projection
Velocity Head	cm	A measurement of water velocity taken as the centimeter difference from the front to the back of a meter stick when placed in the stream
Water Temperature	Celcius	Downstream water temperature
Wetted Width	m	The width of the water taken at various stations
Wetted Width Under Bridge	m	The width of the water column under the bridge.

7.3 Details of Watercourse Crossing Assessments

Table 4. Watercourse crossing detailed assessment results.

								Rapid Assessment			
Culvert ID	Stream Name	Watershed	Road Name	Latitude	Longitude	Crossing Type	Debris Blockage	Is there a visible outflow drop?	Is the water depth less than 15 cm anywhere in the culvert?	Is the culvert backwatered only part of the way or not at all?	Is the stream width noticeably different above or below the culvert?
PAR006	Paradise Brook Tributary	Annapolis River	Roxbury Road	44.8396	-65.1793	Culvert	Yes	Yes	No	No	Yes
BIG001	Big Brook	Annapolis River	Roxbury Road	44.8381	-65.1784	Bridge	No	N/a	N/a	N/a	N/a
BIG002	Big Brook	Annapolis River	Resource/Rec Road off Roxbury Road	44.8351	-65.1757	Bridge	Yes	N/a	N/a	N/a	N/a
JOU002	Joudrey Brook Tributary	Annapolis River	Resource/Rec Road off Morse Road	44.7813	-65.2224	Culvert	No	No	No	No	No
PAR007	Paradise Brook	Annapolis River	Thorne Road	44.7559	-65.1928	Bridge	No	N/a	N/a	N/a	N/a
PAR008	Paradise Brook	Annapolis River	Thorne Road	44.7587	-65.2047	Bridge	No	N/a	N/a	N/a	N/a
JOU001	Joudrey Brook	Annapolis River	Resourse/Rec Road off Morse Road	44.7825	-65.222	Culvert	Yes	Yes	Yes	Yes	No
BLK014	Black River	Annapolis River	Allen Lake Road	44.8794	-64.9917	Bridge	No	N/a	N/a	N/a	N/a
NEW001	Newcombe Brook	Annapolis River	Allen Lake Road	44.8761	-64.9772	Bridge	Yes	N/a	N/a	N/a	N/a

BLK049	Black River Tributary	Annapolis River	Resource/Rec Road off Allen Lake Road	44.8839	-64.9831	Culvert	No	No	Yes	No	No
SPI002	Spinney Brook	Annapolis River	Spinney Mountain Road	44.9244	-64.9489	Bridge	No	N/a	N/a	N/a	N/a
SPI001	Spinney Brook	Annapolis River	Spinney Mountain Road	44.9278	-64.9522	Bridge	No	N/a	N/a	N/a	N/a
FAL012	Fales River	Annapolis River	Fire Lane (Route 90)	44.8594	-64.9343	Bridge	No	N/a	N/a	N/a	N/a
BOO001	Boot Lake Tributary	Annapolis River	Alton Road (Route 90)	44.867	-64.8379	Bridge	No	N/a	N/a	N/a	N/a
FOX001	Fox Lake Tributary	Annapolis River	Resource/Rec Road off Alton Road (Route 95)	44.866	-64.8251	Bridge	No	N/a	N/a	N/a	N/a
MAR001	Marshall Lake Tributary	Annapolis River	Resource/Red Road off Aylesford Road (Route 99)	44.9162	-64.8284	Bridge	Yes	N/a	N/a	N/a	N/a
BIR001	Birch Lake Tributary	Annapolis River	Alton Road (Route 90)	44.8787	-64.8488	Bridge	No	N/a	N/a	N/a	N/a
FAL013	Fales River Tributary	Annapolis River	Resource/Rec Road off East Torbrook Road	44.9192	-64.8969	Culvert	Yes	No	Yes	No	No
EAL001	East Allen Lake Tributary	Annapolis River	Resource/Rec Road off Fire Lane	44.8678	-64.9503	Culvert	Yes	Yes	Yes	Yes	No
CLO001	Cloud Lake Tributary	Annapolis River	Fire Lane (Route 90)	44.8575	-64.9144	Culvert	Yes	No	Yes	Yes	No
FAL014	Fales River Tributary	Annapolis River	Alton Road (Route 90)	44.8767	-64.8964	Culvert	No	No	Yes	No	No

FAL015	Fales River Tributary	Annapolis River	Crystal Falls Trail	44.9482	-64.8856	Culvert	No	Yes	Yes	Yes	No
RHR058A	Upper Wrights Lake Tributary	Annapolis River	Wright Lake Road	44.7309	-65.3684	Culvert	No	No	Yes	No	No
RHR037	East Branch Round Hill River	Annapolis River	Spurr Road	44.7139	-65.3686	Bridge	No	N/a	N/a	N/a	N/a
RHR064	Round Hill River Tributary	Annapolis River	Spurr Road	44.7481	-65.3853	Culvert	Yes	No	No	Yes	No
RHR065	Gibsons Brook	Annapolis River	West Dalhousie Road	44.7178	-65.2947	Culvert	No	Yes	No	No	No
RHR061	Gibsons Brook	Annapolis River	West Dalhousie Road	44.7181	-65.2944	Culvert	Yes	Yes	Yes	Yes	No
CMB001	Coleman Brook	Cornwallis River	North Bishop Road	45.0847	-64.5994	Bridge	No	N/a	N/a	N/a	N/a
CMB002	Coleman Brook	Cornwallis River	Unknown (Farm Access Road)	45.0840	-64.6044	Culvert	No	No	No	No	No
CMB003	Coleman Brook	Cornwallis River	Unknown (Farm Access Road)	45.0835	-64.6068	Bridge	No	N/a	N/a	N/a	N/a
CMB004	Coleman Brook	Cornwallis River	Unknown (Farm Access Road)	45.0840	-64.6207	Culvert	No	No	No	No	No
FWB001	Fishwick Brook	Cornwallis River	Black Rock Road	45.0586	-64.6831	Culvert	No	No	No	No	No
FWB002	Fishwick Brook	Cornwallis River	Unknown (Farm Access Road)	45.0570	-64.6900	Culvert	No	No	No	Yes	Yes
RFB001	Rochford Brook	Cornwallis River	Dykens Lane	45.0568	-64.6741	Culvert	No	No	No	Yes	No
RFB002	Rochford Brook	Cornwallis River	Dykens Lane	45.0576	-64.6742	Culvert	No	No	No	Yes	No
RFB003	Rochford Brook	Cornwallis River	County Home Road	45.0560	-64.6734	Bridge	No	N/a	N/a	N/a	N/a

RFB004	Rochford Brook	Cornwallis River	Harvest Moon Trail	45.0537	-64.6689	Culvert	No	No	No	No	No
RFB005	Rochford Brook	Cornwallis River	HWY 1	45.0521	-64.6677	Culvert	No	No	No	No	No
SHB001	Sharpe Brook	Cornwallis River	Harvest Moon Trail	45.0632	-64.6324	Bridge	No	N/a	N/a	N/a	N/a
SHB002	Sharpe Brook	Cornwallis River	Unknown (Farm Access Road)	45.0631	-64.6324	Bridge	No	N/a	N/a	N/a	N/a
SHB003	Sharpe Brook	Cornwallis River	HWY 1	45.0574	-64.6337	Culvert	No	No	No	No	No
SHB004	Sharpe Brook	Cornwallis River	Cambridge Mountain Road	45.0546	-64.6350	Culvert	Yes	Yes	Yes	Yes	No
SHB005	Sharpe Brook	Cornwallis River	Randolph Road	45.0409	-64.6467	Culvert	No	Yes	Yes	Yes	Yes
STB001	Spittal Brook	Cornwallis River	South Bishop Road	45.0641	-64.5999	Bridge	No	N/a	N/a	N/a	N/a
STB002	Spittal Brook	Cornwallis River	Harvest Moon Trail	45.0626	-64.6007	Culvert	No	No	No	No	No
EAS009	East Moose River	Annapolis River	Fraser Road	44.6392	-65.5326	Culvert	Yes	Yes	No	No	No
ALL017	Grand Lake Flowage	Annapolis River	Clementsvale Road	44.6898	-65.5191	Culvert	Yes	Yes	No	No	Yes
RHR023	Eight Mile Brook	Annapolis River	West Dalhousie Road	44.7082	-65.3829	Bridge	No	N/a	N/a	N/a	N/a
RHR036	East Branch Round Hill River	Annapolis River	Spurr Road	44.7180	-65.3698	Culvert	No	No	No	No	No
BAL001	Balcom Brook	Annapolis River	HWY 1	44.7236	-65.5376	Culvert	No	No	No	No	No

PET002	Petes Brook	Annapolis River	HWY 201	44.8740	-65.1307	Culvert	Yes	Yes	No	No	No
WIS010	Wiswal Brook	Annapolis River	Vault Road	44.9930	-65.0017	Bridge	No	N/a	N/a	N/a	N/a
WAT004	Watton Brook	Annapolis River	McColough Road	44.9702	-65.0261	Culvert	No	Yes	No	Yes	No
HUT004	Hutchinson Brook	Annapolis River	Hall Road	45.0118	-64.7670	Culvert	No	Yes	No	No	No
WAT002	Watton Brook	Annapolis River	Harvest Moon Trail	44.9560	-65.0268	Culvert	No	No	No	No	No
OHB001	Oak Hollow Brook	Annapolis River	Harvest Moon Trail	44.8907	-65.1474	Culvert	Yes	No	Yes	No	Yes
TRO010	Troop Brook	Annapolis River	Post Road	44.7636	-65.5015	Culvert	Yes	No	Yes	Yes	Yes
BLK004	Black River	Annapolis River	Hwy 201	44.9452	-65.0248	Culvert	Yes	No	No	Yes	No
MOR008	Morton Brook	Annapolis River	HWY 362	44.9867	-65.0688	Culvert	No	Yes	No	No	Yes
MCG009	McGee Brook	Annapolis River	Brooklyn Street	45.0338	-64.8684	Bridge	No	N/a	N/a	N/a	N/a
SHB006	Sharpe Brook	Cornwallis River	Jodrey Mountain Road	45.0374	-64.6420	Culvert	Yes	No	No	No	No
BWB001	Brandywine Brook	Cornwallis River	Brooklyn Street	45.0879	-64.5922	Bridge	No	N/a	N/a	N/a	N/a
BWB002	Brandywine Brook	Cornwallis River	Brooklyn Street	45.0885	-64.5916	Bridge	No	N/a	N/a	N/a	N/a
BWB003	Brandywine Brook	Cornwallis River	North Bishop Road	45.0924	-64.5984	Culvert	Yes	No	No	No	No
BWB004	Brandywine Brook	Cornwallis River	North Bishop Road	45.0957	-64.6014	Bridge	No	N/a	N/a	N/a	N/a
BWB005	Brandywine Brook	Cornwallis River	North Bishop Road	45.1025	-64.6009	Bridge	No	N/a	N/a	N/a	N/a

BWB006	Brandywine Brook	Cornwallis River	Green Road	45.1105	-64.5884	Bridge	No	N/a	N/a	N/a	N/a
BWB007	Brandywine Brook	Cornwallis River	Lakewood Road	45.1130	-64.5853	Bridge	No	N/a	N/a	N/a	N/a
BWB008	Brandywine Brook	Cornwallis River	HWY 221	45.1155	-64.5923	Bridge	No	N/a	N/a	N/a	N/a
BWB009	Brandywine Brook	Cornwallis River	Lamont Road	45.1219	-64.5995	Culvert	No	No	No	No	No
RFB006	Rochford Brook	Cornwallis River	Waterville Mountain Road	45.0488	-64.6643	Bridge	No	N/a	N/a	N/a	N/a
RFB007	Rochford Brook	Cornwallis River	Thompson Road	45.0376	-64.6724	Bridge	No	N/a	N/a	N/a	N/a

7.4 Rock Weir Design (Taylor, 2010)

The vortex rock weir is a U-shaped design, where the apex points upstream. The weir is designed to be either on 20º or 30 º angles from the base of the weir. For our design, a 30º angle from the base of the weir was used (Figure 26). The location of the vortex rock weir is determined based on the ideal location of a tailwater control determined by the size of the outflow pool. The recommended length of an outflow pool is three times the culvert's diameter.

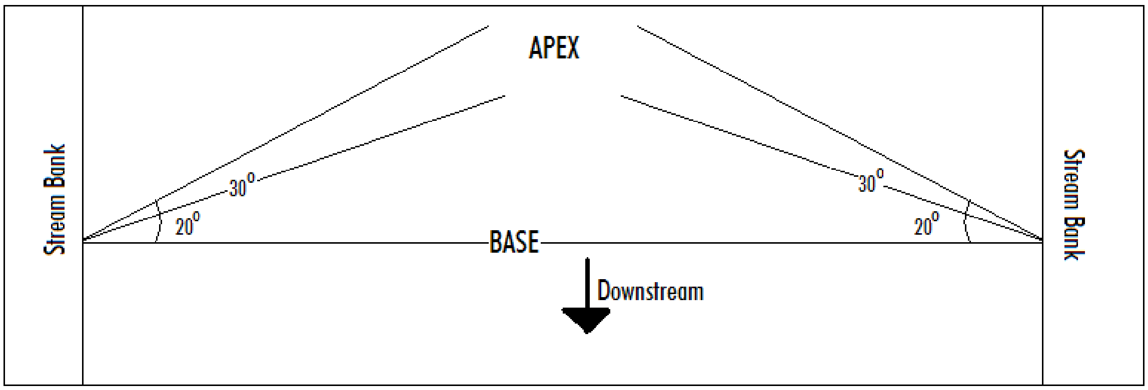

Figure 41. Vortex rock weir design (Taylor, 2010).

To determine the shape and materials needed for the construction of the weir, several formulae were used:

$$\text{Volume (V)} = \text{Length (l)} \times \text{Width (w)} \times \text{Height (h)}$$

Where the length (l) refers to the desired length of the rock weir to be constructed, the width (w) refers to the calculated width of the weir (using a height to base ratio of 1:3), and the height (h) refers to the desired height of the construction. The intent of the rock weir construction is to raise the level of water in the outflow pool, which is controlled by the weir's low flow notch (an area at the apex of the weir through which water can flow through during low flow conditions, serving as the weir's lowest point of elevation). The elevation of the low flow notch should ideally be 0.2D higher than the base of the culvert outflow (where D refers to the culvert's diameter) (DFO, 2015). The ends of the constructed weirs were tied into the banks about 15 cm beyond the full bankfull width of the streams.

Large, flat, footer stones make up the first layer of the rock weir. Weir stones, which are generally thicker than footer stones, are used to build the remainder of the weir. Smaller riprap is used as filler as well as bank stabilizer. Due to the prevalence of tailwater blow-outs since the 2016 restoration season, larger rocks are used whenever possible to reinforce the structure. Weirs are sealed with sediment from the stream bed, if available, to assist with blocking flow through the weir. Over time, the spaces in the weir will fill with various debris and leaf litter flowing through the stream.

The amount of water flow a weir can experience is affected by the size of the upstream catchment area, the channel slope, upstream land use, and rainfall. These factors must be taken into consideration when designing a rock weir structure that can withstand the elements. In order to determine the minimum rock diameter required to withstand high flow velocity conditions, it is necessary to calculate the incipient rock diameter as well as the amount of force the water would exert on the streambed as it flowed over it, known as the tractive force (Cummings *et al.*, 2004):

$$\tau \text{ (kg/m}^2) = \text{Incipient Diameter (cm)}$$

Where τ represents tractive force, which is a measure of the amount of force that water will exert on a streambed as it flows over it. The equation used to calculate the tractive force is:

$$\tau = 1000 \times d \times s$$

Where d represents the depth of flow (in metres) and s represents the slope of the water surface. Measurements retrieved from the culvert assessments are used to determine the depth of flow (based on cross-sectional measurements) and downstream slope. However, during extreme dry conditions, measurements taken at the time of assessment may not be representative of usual conditions. To avoid issues with under-sizing, bankfull height measurements can be used in place of depth of flow where extremely low water levels were observed to have occurred.

7.5 Site Specific Rock Weir Calculations

7.5.1 JOU001 — Joudrey Brook

Remediation:
One rock weir to raise tailwater pool level.

Rock Volume:
Rocks located at the crossing site were used to construct the weir.

Rock Size:
Based on the measurements recorded during the full culvert assessment survey, the downstream slope at JOU001 is -0.1418; the average water depth in the downstream is 0.105 m. Based on these measurements, the tractive force can be calculated:

T = 1000 x d x s
T = 1000 X 0.105 m X 0.1418
T = 14.89 cm
An incipient diameter of 14.89 cm was calculated, using a safety factor of 2, gives a minimum rock size (diameter) of 29.78 cm.

7.5.2 EAL001 — East Allen Lake Tributary

Remediation:
One rock weir to raise tailwater pool level.

Rock Volume:
Rocks located at the crossing site were used to construct the weir.

Rock Size:
Based on the measurements recorded during the full culvert assessment survey, the downstream slope at EAL001 is 0.0059; the average water depth in the downstream is 0.082 m. Based on these measurements, the tractive force can be calculated:

T = 1000 x d x s
T = 1000 X 0.082 m X 0.0059
T = 0.48 cm
An incipient diameter of 0.48 cm was calculated, using a safety factor of 2, gives a minimum rock size (diameter) of 0.96 cm.

7.5.3 RFB001 — Rochford Brook

Remediation:
One rock weir to raise tailwater pool level.

Rock Volume:
Volume (v) = Length (l) x Width (w) x Height (h)
V =3.5m x 0.33m x 0.11m = 0.12m^3
A volume of 1.5m^3 was ordered.

Rock Size:
Based on the measurements recorded during the full culvert assessment survey, the downstream slope at RFB001 is 0.019; the average water depth in the downstream is 0.23 m. Based on these measurements, the tractive force can be calculated:

T = 1000 x d x s
T = 1000 X 0.23 m X 0.019
T = 4.37 cm
An incipient diameter of 4.37 cm was calculated, using a safety factor of 2, gives a minimum rock size (diameter) of 8.74 cm.

7.5.4 EAS009 — East Moose River

Remediation:
Maintenance to rock weir initially installed in 2015.

Rock Volume:
Rocks located at the crossing site were used for weir maintenance.

Rock Size:
Based on the measurements recorded during the full culvert assessment survey, the downstream slope at EAS009 is 0.0707; the average water depth in the downstream is 0.11 m. Based on these measurements, the tractive force can be calculated:

T = 1000 x d x s
T = 1000 X 0.11 m X 0.0707
T = 7.77 cm
An incipient diameter of 7.77 cm was calculated, using a safety factor of 2, gives a minimum rock size (diameter) of 15.55 cm.

7.6 Electrofishing Data Sheet

Electrofishing Field Sheet #:

Crew:

Site Information				
Site Name		Date (dd/mm/yyyy)		
Stream Name		Time		
Wetted Width (m)		UTM Easting (m)		
Reach Length (m)		UTM Nothing (m)		
Depth (m)	*D1 :*	*D2 :*	*D3 :*	*Average :*

Water Quality							
pH		DO (mg/L)		Conductivity (µS/cm)		Salinity (g/L)	
Water Temp (°C)		DO (% SAT)		Turbidity (NTU)		TDS (mg/L)	

Pass Information

Pass Number	Time Start	Time End	Total Time	Pulse Width (ms)	Pulse Frequency (Hz)	Duty Cycle (%)	Volts

Species Information

Pass Number	Species	Fork Length (cm)	Pass Number	Species	Fork Length (cm)

7.7 Electrofishing Survey Parameters

Table 5. Variables collected during electrofishing surveys.

Variable	Units	Description
Air Temperature	Celcius	The temperature of the air on the day of the assessment
Turbidity	NTU	Transparency of the water due to the presence of suspended particles
Salinity	g/L	The amount of dissolved salts in the water
Pass Number		Sample number
Time Start		Time recorded from the Electrofishing unit before the start of a pass
Time End		Time recorded from the Electrofishing unit at the end/completion of a pass
Total Time		Time End – Time Start using the numbers recorded from the Electrofishing unit (See 'Time Start' and 'Time End')
Pulse Width	ms	Duration of each individual pulse of electricity
Pulse Frequency	Hz	Number of pulses per second
Conductivity	μS/cm	The ability of a solution (water) to carry an electrical current
Duty Cycle	%	Frequency or pulse rate is
Date		The date on which the assessment was completed
Depth	cm	Depth measured at 3 locations that is representative of the survey site. Taken within the reach length.
Volts	V	Electrical pressure
DO	% SAT	The amount of oxygen dissolved in the water
DO	mg/L	The amount of oxygen dissolved in the water
Species		Identity of fish captured.
Fork Length	cm	Length of fish measured from the tip of the snout to the end of the middle caudal fin rays.
Field Crew		The assessors collecting the data
pH		The acidity of the water in the watercourse
Reach Length	m	Linear distance of area being surveyed
Site Name		The name of the site where the survey is taking place. Usually 'Test' or 'Control'
Stream Name		The name of the watercourse where the survey is taking place
TDS	mg/l	Total dissolved solids, the measurement of the combined content of all inorganic and organic substances in its suspended form
Time		The time that the assessment began
UTM Coordinates		GPS position of the HSI assessment location, described with Northings and Eastings, using a NAD83 projection
Water Temperature	Celcius	Downstream water temperature
Wetted Width	m	Width of the river that contains water at the time of the measurement

7.8 Electrofishing Survey Results

Table 6. Electrofishing results for the Fales River Sub-watershed.

Site	Date	Reach Length (m)	Pass	Total Time of Pass / Deployment	Pulse Frequency (Hz)	Volts (V)	Species Count Information: Atlantic Salmon	Brook Trout	Creek Chub	3-Spined Stickleback	White Sucker	American Eel	Brook Lamprey	Brown Trout	Total
44.9231, -64.9017	July 11, 2022	154.00	1	1486 seconds	60	150	0	2	0	0	0	4	0	0	6
	Sept 7, 2022	85.00	1	1397 seconds	80	250	0	1	0	1	2	2	0	0	6
44.9503, -64.8915	July 11, 2022	118.00	1	1385 seconds	60	150	0	0	0	0	0	1	0	0	1
44.9590, -64.9123	July 11, 2022	70.00	1	1069 seconds	80	350	5	0	7	1	1	19	2	0	35
	July 26, 2023	75.00	1	830.9 seconds	80	250	0	0	6	1	1	3	0	0	11
44.9587, -64.9145	July 26, 2023	65.00	1	460 seconds	80	250	0	0	2	0	0	4	0	0	6

Table 7. Electrofishing results for the Black River Sub-watershed.

							Species Count Information								
Site	Date	Reach Length (m)	Pass	Total Time of Pass / Deployment	Pulse Frequency (Hz)	Volts (V)	Atlantic Salmon	Brook Trout	Creek Chub	3-Spined Stickleback	White Sucker	American Eel	Brook Lamprey	Brown Trout	Total
44.9153, -64.9776	July 12, 2022	75.00	1	752 seconds	60	150	0	0	4	0	1	5	0	0	10
44.9489, -64.9495	July 12, 2022	115.00	1	480 seconds	80	250	0	5	14	0	24	3	0	0	46
44.9239, -64.9487	July 12, 2022	81.00	1	708 seconds	80	250	0	17	0	0	0	0	0	0	17

Table 8. Electrofishing results for the Roxbury Brook Sub-watershed.

							Species Count Information								
Site	Date	Reach Length (m)	Pass	Total Time of Pass / Deployment	Pulse Frequency (Hz)	Volts (V)	Atlantic Salmon	Brook Trout	Creek Chub	3-Spined Stickleback	White Sucker	American Eel	Brook Lamprey	Brown Trout	Total
44.8568, -65.1992	July 14, 2022	110.00	1	990 seconds	80	250	1	1	12	0	0	6	0	0	20
	Sept 6, 2022	110.00	1	1056 seconds	80	250	0	0	11	2	0	9	1	0	23
	October 17, 2023 (Fyke Net)	N/a	N/a	19.5 hours	N/a	N/a	0	0	0	0	0	0	0	0	0
44.8597, -65.2018	July 14, 2022	135.00	1	1041 seconds	80	250	0	1	19	2	3	9	0	0	34
	Sept 6, 2022	90.00	1	1196 seconds	80	250	0	1	13	3	2	11	6	0	36
	October 17, 2023 (Fyke Net)	N/a	N/a	19.5 hours	N/a	N/a	0	0	0	0	0	0	0	0	0
44.8616, -65.2031	July 14, 2022	125.00	1	1022 seconds	80	250	1	1	5	4	3	18	5	0	37
	Sept 6, 2022	115.00	1	1340 seconds	80	250	0	3	5	6	2	18	0	0	34

Table 9. Electrofishing results for the Round Hill River Sub-watershed.

Site	Date	Reach Length (m)	Pass	Total Time of Pass / Deployment	Pulse Frequency (Hz)	Volts (V)	Species Count Information								
							Atlantic Salmon	Brook Trout	Creek Chub	3-Spined Stickleback	White Sucker	American Eel	Brook Lamprey	Brown Trout	Total
44.7722, -65.4042	July 13, 2022	75.00	1	568.5 seconds	80	250	0	1	8	0	0	6	0	0	15
	October 17, 2023 (Fyke Net)	N/a	N/a	19.5 hours	N/a	N/a	0	0	0	0	0	0	0	0	0
44.7661, -65.3991	July 13, 2022	137.00	1	970 seconds	80	250	0	2	10	0	0	4	0	0	16
	September 15, 2023	50.00	1	2027.2 seconds	80	250	0	0	1	0	0	4	0	0	5
	October 17, 2023 (Fyke Net)	N/a	N/a	19.5 hours	N/a	N/a	0	0	0	0	0	0	0	0	0
44.7592, -65.4010	July 13, 2022	100.00	1	1181 seconds	80	250	0	1	2	0	4	3	0	0	10
	Sept 6, 2022	85.00	1	804 seconds	80	250	0	0	6	0	2	7	0	0	15

Table 10. Electrofishing results for the Sharpe Brook Sub-watershed.

Site	Date	Reach Length (m)	Pass	Total Time of Pass / Deployment	Pulse Frequency (Hz)	Volts (V)	Species Count Information								
							Atlantic Salmon	Brook Trout	Creek Chub	3-Spined Stickleback	White Sucker	American Eel	Brook Lamprey	Brown Trout	Total
45.05528, -64.6345	August 22, 2022	75.00	1	604 seconds	80	250	0	8	5	0	1	3	0	12	29
45.0414, -64.6461	August 22, 2022	70.00	1	1691 seconds	80	250	0	38	9	0	10	0	0	0	57
45.0374, -64.6420	September 13, 2023	75.00	1	1248 seconds	80	250	0	14	0	3	0	0	0	3	20

Table 11. Pre- and post-remediation electrofishing results for EAS009.

Site	Date	Reach Length (m)	Pass	Total Time of Pass / Deployment	Pulse Frequency (Hz)	Volts (V)	Species Count Information								
							Atlantic Salmon	Brook Trout	Creek Chub	3-Spined Stickleback	White Sucker	American Eel	Brook Lamprey	Brown Trout	Total
44.6392, -65.5326	August 10, 2023 PRE-Remediation	30.00	1	660.4 seconds	80	250	0	0	0	0	1	5	0	0	6
	September 29, 2023 POST-Remediation	30.00	1	963.5 seconds	80	250	0	0	0	0	1	0	0	0	1

Table 12. Pre- and post-remediation electrofishing results for PET002.

Site	Date	Reach Length (m)	Pass	Total Time of Pass / Deployment	Pulse Frequency (Hz)	Volts (V)	Species Count Information: Atlantic Salmon	Brook Trout	Creek Chub	3-Spined Stickleback	White Sucker	American Eel	Brook Lamprey	Brown Trout	Total
44.8740, -65.1307	August 10, 2023 PRE-Remediation	100.00	1	938.6 seconds	80	250	0	10	9	0	0	4	0	0	23
	September 29, 2023 POST-Remediation	100.00	1	1013.9 seconds	80	250	0	3	7	0	0	6	0	0	16

Table 13. Electrofishing results for TRO010.

Site	Date	Reach Length (m)	Pass	Total Time of Pass / Deployment	Pulse Frequency (Hz)	Volts (V)	Species Count Information: Atlantic Salmon	Brook Trout	Creek Chub	3-Spined Stickleback	White Sucker	American Eel	Brook Lamprey	Brown Trout	Total
44.7636, -65.5015	August 10, 2023 PRE-Remediation	50.00	1	305.7 seconds	80	250	0	10	0	0	0	11	0	0	21

Table 14. Electrofishing results for RFB001.

Site	Date	Reach Length (m)	Pass	Total Time of Pass / Deployment	Pulse Frequency (Hz)	Volts (V)	Species Count Information								
							Atlantic Salmon	Brook Trout	Creek Chub	3-Spined Stickleback	White Sucker	American Eel	Brook Lamprey	Brown Trout	Total
45.0568, -64.6741	September 13, 2023 Upstream of Culvert	60.00	1	365.1 seconds	80	250	0	0	7	0	0	0	0	3	10
	September 13, 2023 Downstream of Culvert	60.00	1	174.2 seconds	80	250	0	0	1	2	0	0	0	5	8

7.9 eDNA Sampling Results

Table 15. eDNA sampling results for the Sharpe Brook Sub-watershed.

Site Name	Location	Sample ID	Collection Date & Time	Filter Date	Filter Start & End Times	Results		
						Atlantic Salmon	Chain Pickerel	Smallmouth Bass
Sharpe Brook Rail Trail	45.0630, -64.6324	SHB001	Nov 6, 2022 12:16 pm	Nov 7, 2022	12:31 – 12:41 pm	Negative	Negative	Negative
Sharpe Brook Rail Trail		SHB002	Nov 6, 2022 12:19 pm	Nov 7, 2022	12:31 – 12:39 pm	Negative	Negative	Negative
Sharpe Brook Rail Trail		SHB003	Nov 6, 2022 12:21 pm	Nov 7, 2022	12:47 – 1:00 pm	Negative	Negative	Negative
Downstream Box Culvert	45.0415, -64.6460	SHB004	Nov 6, 2022 12:49 pm	Nov 7, 2022	12:47 – 12:50 pm	Negative	Negative	Negative
Downstream Box Culvert		SHB005	Nov 6, 2022 12:50 pm	Nov 7, 2022	12:58 – 1:07 pm	Negative	Negative	Negative
Downstream Box Culvert		SHB006	Nov 6, 2022 12:57 pm	Nov 7, 2022	1:11 – 1:28 pm	Negative	Negative	Negative
Upstream Box Culvert	45.0408, -64.6469	SHB007	Nov 6, 2022 1:02 pm	Nov 7, 2022	1:11 – 1:16 pm	Positive	Negative	Negative
Upstream Box Culvert		SHB008	Nov 6, 2022 1:03 pm	Nov 7, 2022	1:18 – 1:23 pm	Negative	Negative	Negative
Upstream Box Culvert		SHB009	Nov 6, 2022 1:04 pm	Nov 7, 2022	1:26 – 1:31 pm	Negative	Negative	Negative