Fish Passage Restoration and Habitat Enhancement

Addressing habitat fragmentation and productivity in the Annapolis River watershed

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December 2015

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NSLC Adopt-A Stream, Fisheries and Oceans Canada, Sage Environmental Program

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List of Acronyms

BC	British Columbia
CARP	Clean Annapolis River Project
cm	Centimeter
DFO	Department of Fisheries and Oceans
DNR	Department of Natural Resources
Km	Kilometer
mm	Millimeter
NSE	Nova Scotia Environment
NSLC	Nova Scotia Liquor Commission
SUV	Sport utility vehicle
TIR	Transportation Infrastructure Renewal

Acknowledgements

Clean Annapolis River Project (CARP) would like to thank the following for their support in the completion of the 2015 Fish Passage and Habitant Enhancement Project.

- Nova Scotia Salmon Association's NSLC Adopt A Stream program.
- Fisheries and Oceans Canada's Recreational Fisheries Conservation Partnership Program for their financial support
- Clean Foundation's Nova Scotia Youth Conservation Corps program .
- The Sage Environmental Program for their financial support.
- Amy Weston (Project Manager) and Bob Rutherford (Committee Chair) of NSLC Adopt A Stream for their continued project support, guidance and expertise.
- Will Daniels (Field Technician) of NSLC Adopt A Stream for his in-field project support and guidance.
- CARP management staff (Lindsey Freeman, Susan Lane and Levi Cliche) for their in-office support and guidance, as well as CARP field staff (Jeff Medicraft Jon Gray, and Shawna Hannam), summer staff (Randy Fredericks and Emma Dondale), and volunteers (Chris Spencer, Devon Medicraft, Jaya Fahey, Seth Omer, Craig Fancy, and Nick Durling) for their in-field support.
- Staff of East Coast Aquatics (Mike Parker and Andy Sharpe) for their guidance and in-field support

Executive Summary

When fish migration is restricted in a stream, it can have a negative impact on fish populations. With this in mind CARP initiated the Broken Brooks project in the Annapolis River Watershed in 2007 to address habitat fragmentation caused by barrier culverts that can impede the upstream and downstream movements of fish. Insufficient water depths, incorrect sizing, steep slopes and large outflow drops are just a few of several problems that can characterize a culvert as a barrier. Culverts were categorized as being fully passable, partial, or full barriers based on the criteria for a target species adapted from Nova Scotia Environment (NSE), Department of Fisheries and Oceans (DFO) and Terra Nova National Park protocols. The target species used by CARP was a brook trout, which is a native fish found in freshwater streams and lakes throughout Nova Scotia. A target brook trout size of 5 cm was used for assessments. Culverts identified through this categorization process as being barriers were subsequently prioritized for remediation, and potential restoration options were identified.

The Broken Brooks program was initiated by CARP in 2007, and was continued in the 2010 to 2014 field seasons, with the purpose of assessing and restoring aquatic connectivity within the Annapolis River watershed. Road-watercourse crossings along the main stem of the Annapolis River were the focus for the project in its early days. In 2012, the focus shifted to assessing aquatic connectivity within identified sub-watersheds, to allow for the characterization of an entire sub-system.

The 2013 and 2014 field seasons continued with assessments and restorations focused mainly in the Moose and South Annapolis River systems. Since Broken Brooks was first started, total of 1,486 sites have been visited, and 403 detailed watercourse crossing assessments have been completed within the greater watershed.

The Nictaux River sub-watershed was the subject for a restoration management plan completed by CARP in 2013. Some excavator work including the reconstruction and bolstering of degraded rock weir structures, was initiated on the Nictaux River in 2014 to improve habitat complexity and productivity for salmonids. This work was continued in the 2015 field season with the completion of adjustment work on three of the rock structures where reconstruction work began in 2014, and with the reconstruction and bolstering of three additional new weirs in 2015.

In 2015, the Fish Passage Restoration and Habitat Enhancement project focused on implementing restoration actions on culverts assessed and prioritized in previous years through the Broken Brooks program. Forty-five culverts were shortlisted for potential restoration based on their outflow drop, slope and upstream habitat gain. These selected culverts were re-visited to determine feasibility of remediation activities. Fifteen sites received restoration work, which resulted in the completion of 6 debris removals and 10 tailwater control restorations, restored access to 33 km of upstream habitat, and improved access to an additional 13.7 km.

Fish chutes (chutes) and baffles were introduced into CARP's restoration arsenal this year. Seven custom-made galvanized steel chutes were installed in conjunction with rock weirs to address outflow drops up to and greater than 40cm. Eastern cedar posts (sized 3x3's and 5x5's) were installed as baffles or low flow barriers in six culverts as part of restoration activities.

Four deflector weirs and a double digger log were installed using hand tools by CARP staff and volunteers downstream of the rock weirs. These two actions, part of the Nictaux sub-watershed restoration plan resulted in improving habitat enhancement and fish passage to more than 1 km of the Nictaux River.

1.0 Introduction

The construction of watercourse-crossing structures such as culverts has the potential to significantly affect the ecological integrity of aquatic ecosystems and impede the movement of fish species such as brook trout and Atlantic salmon. In past studies of stream crossings, culverts have been found to create more barriers and have resulted in more habitat loss from fragmentation than any other crossing types (Gibson et al., 2005; Harper and Quigley, 2000; Warren and Pardew; 1998). Watercourse crossings that are poorly designed, installed incorrectly, or that do not receive regular maintenance can become barriers to fish passage. Barrier crossings can result in habitat fragmentation which can destroy existing habitat, restrict fish access to upstream habitats, isolate fish populations, and increase fish vulnerability to predation and disturbance (Gibson et al., 2005).

In 2007, CARP's Broken Brooks program was conceptualized and initialized to address the issue of fragmented fish passage within the Annapolis River watershed. Since 2010, field work has occurred with the focus of assessing the barrier status of watercourse crossings. This work was started using a culvert protocol adapted from a variety of sources throughout Canada and the United States. In the beginning, road watercourse crossings located along the main stem of the Annapolis River were the main project focus. In 2012, the culvert assessment protocol was further refined, and the target species size was reduced to a brook trout of 5 cm or larger. CARP also adopted a sub-watershed assessment approach to culvert assessments in 2012 to allow for improved sub-watershed scale management and planning. Since 2010, over 400 sites in the Annapolis River watershed have received detailed assessments, and many of those assessed were determined to be barriers to fish passage. Data collected from these assessments have been used to prioritize culverts for remediation and guide restoration efforts.

In 2015, CARP launched its Fish Passage Restoration and Habitat Enhancement project, to address fish passage issues identified through the Broken Brooks program. The focus of the 2015 season was on restoring barrier culverts identified within previously identified priority sub-watersheds (see Wagner, 2013). Additionally, restoration work begun in 2014 as part of CARP's sub-watershed planning process was continued on the Nictaux River in the 2015 field season.

2.0 Methodology

The fish habitat restoration and enhancement work carried out by CARP in 2015 was focused in two main areas: restoring fish passage, and improving in-stream habitat in the Nictaux River. The 2015 work built upon efforts begun in previous years to address both identified fish passage issues and habitat concerns within priority sub-watersheds.

2.1 Fish Passage Restoration

The focus of the 2015 field season was on fish habitat restoration efforts, more specifically remediation of culverts identified as barriers to fish passage through previous culvert assessment work. No new assessments were completed, however previously assessed culverts were reviewed and prioritized for restoration. The process leading to the completion of the culvert restorations consisted of the following two steps;

1. Prioritizing barriers for remediation
2. Remediation planning and preparation

2.1.1 Prioritization of Barriers for Remediation

In the 2015 season culverts selected for remediation were chosen from a list of culverts in the Annapolis River Watershed that had been previously identified, fully assessed and prioritized from 2010 to 2014. 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 (Coté, 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 suit the needs and meet the capabilities of Clean Annapolis River Project (Taylor, K., 2011). The criteria used to determine recommended remediation options were adapted from guidelines that were created by the British Columbia Ministry of Environment (BC Ministry of Environment, 2008). Recommended remediation options and their associated criteria are listed below in Table 1. After the remediation option for each barrier culvert was established, the culverts were then prioritized for remediation. Two key variables considered during the prioritization process were the number of downstream barriers and the upstream habitat gain. Culverts were assigned a score based upon how well they met each of the various prioritization criteria, and then either classified as high, medium, or low priority (for more detailed information, refer to Appendix 6.1).

Table 1. Remediation options for culverts that do not meet provincial guidelines

Barrier Type	Remediation Option	Criteria
Partial Barrier	Debris removal	No outflow drop Slope $< 0.5\%$ Debris obstructing inflow or outflow
	Channel roughening	No outflow drop Slope $< 1.0\%$
	Tailwater control	Outflow drop < 30 cm Slope $< 2.0\%$
	Baffle installation	Outflow drop $<$ 1 body length of target species Slope $\geq 2.5\%$
Full Barrier	Baffle installation and tailwater control	Outflow drop < 30 cm Slope $\geq 2.5\%$
	Removal of structure/ fish ladder	Outflow drop > 30 cm Slope $\geq 7.0\%$

The list of prioritized barrier culverts that had received detailed assessments was reviewed in 2015, and from these 45 culverts (Table 2) were identified as possibilities for remedial actions (see Figure 1). Criteria used to shortlist barrier culverts for remediation were:

- Whether they were located in a stream identified as fish habitat
- Their priority ranking was either medium to high priority
- The type of restoration actions needed (i.e. tailwater control restoration or debris removal)
- Their proximity to or location within a priority sub-watershed

Shortlisted culverts were revisited to determine the feasibility of restoration. If a culvert had a rusted or rotted out bottom, caved in sides or was beyond CARP's ability to remediate it was removed from the shortlist and re-classified as requiring major structural work and/or removal. If the culvert was in good condition and seemed feasible to remediate, appropriate restoration action(s) were selected based on the remediation tools CARP had at their disposal. From the 45 culvert sites that were revisited, 15 were selected for remediation. Five were chosen for debris removals and ten were chosen for installation of tailwater control structures. Some of the sites where tailwater control structures were installed also required the installation of baffles. CARP also installed fish chutes at the outflows of several culverts to compliment tailwater control remediation activities in 2015, with the help and guidance of Adopt A Stream staff.

Table 2. List of Prioritized Barriers for Restoration

Culvert ID	Stream Name	UTM Easting	UTM Northing	Fish Habitat	Barrier Type	Priority	Recommended Action
ALL017	Grand Lake Flow	300384	4951577	Yes	Full	Medium	Tailwater control
BAL001	Balcom Brook	299033	4955387	Yes	Full	Medium	Removal of structure/Fish ladder
BUT006	Button Brook	320283	4966500	Yes	Full	High	Tailwater control
EAS006	East Moose River	299119	4946751	Yes	Full	Medium	Baffle installation and tailwater control
EAS009	East Moose River	299139	4945996	Yes	Full	Medium	Removal of structure/fish ladder
EAT002	East Troop Brook	308447	4963730	Yes	Full	Medium	Tailwater control
EBR011	East Branch Roundhill River	316246	4954999	Yes	Full	Medium	Tailwater control
EVA001	Evans Brook	339435	4979960	Yes	Full	Medium	Tailwater control
GRF006	Unknown	298456	4957338	Yes	Full	Medium	Removal of structure/fish ladder
HLD002	Holdsworth Brook	279464	4946132	Yes	Partial	Medium	Tailwater control; Debris Removal
KEM002	Kempt Brook	337170	4975730	Yes	Full	Medium	Tailwater control
LEO002	Leonard Brook	327434	4972164	Yes	Full	Medium	Tailwater control
MEA001b	Unknown	349041	4979896	Yes	Full	Medium	Tailwater control
MOR006	Morton Brook	337152	4982217	Yes	Full	Medium	Tailwater control; Debris Removal
MOR007	Morton Brook	337328	4982540	Yes	Full	Medium	Removal of structure/fish ladder
MOR008	Morton Brook	336906	4983558	Yes	Full	Medium	Baffle installation and tailwater control
MRV005	Moose River	293538	4950104	Yes	Full	Medium	Removal of structure/fish ladder
MRV006	Moose River	293166	4949572	Yes	Full	Medium	Tailwater control
MRV011	Moose River	294600	4947849	Yes	Full	Medium	Tailwater control

Culvert ID	Stream Name	UTM Easting	UTM Northing	Fish Habitat	Barrier Type	Priority	Recommended Action
NEB004	Neilys Brook	345710	4986463	Yes	Full	Medium	Removal of structure/fish ladder
NIC002	Nictaux River	339406	4977435	Yes	Full	Medium	Baffle installation and tailwater control
NIC003	Nictaux River	339426	4977464	Yes	Full	Medium	Debris removal and tailwater control
NIC004	Nictaux River	339634	497741	Yes	Full	Medium	Baffle installation and tailwater control
NIC024	Unknown	339416	4945770	Yes	Full	Medium	Removal of structure/fish ladder
NIC049A	Kelly Brook	338377	4955470	Yes	Full	Medium	Debris Removal; tailwater control
PET004	Petes Brook	331698	4971162	Yes	Full	Medium	Baffle installation and tailwater control
RHR013A	Roundhill River	308358	4956243	Yes	Full	High	Baffle installation and tailwater control
RHR022B	Roundhill River	311015	4953236	Yes	Partial	Medium	Tailwater control
RHR023A	Roundhill River	311241	4953297	Yes	Partial	High	Debris Removal; Tailwater control
RHR023B	Roundhill River	311241	4953297	Yes	Full	High	Debris Removal; Tailwater control
RHR024A	Roundhill River	309172	4952467	Yes	Full	Medium	Removal of structure/fish ladder
ROC004b	Rockland Brook	360765	4985776	Yes	Full	High	Tailwater control
SAD003	Saunder's Brook	300321	4948556	Yes	Full	Medium	Tailwater control
SAW003a	Saudners West	320894	4968685	Yes	Full	Medium	Tailwater control
SAW003b	Saudners West	320894	4968685	Yes	Full	Medium	Tailwater control
SHE004	Shearer Brook	323275	4968680	Yes	Full	Medium	Baffle installation and tailwater control
SOL012	Solomon Chute Brook	318750	4967957	Yes	Full	Medium	Removal of structure/fish ladder
SPU003	Spurr Stream	312679	4958391	Yes	Full	Medium	Tailwater control
SPU004	Spurr Stream	312829	4957998	Yes	Full	High	Tailwater control
TRO010a	Troop Brook	302036	4959737	Yes	Full	High	Tailwater control
TRO010b	Troop Brook	301173	4959078	Yes	Full	Medium	Tailwater control
TRO011	Troop Brook	303124	4959748	Yes	Full	Medium	Tailwater control
TRO012	Troop Brook	302791	4959811	Yes	Full	Medium	Baffle installation and tailwater control
MR020A	Moose River	297907	4947326	Yes	Full	Medium	Tailwater Control; Debris removal
MR020B	Moose River	297907	4947326	Yes	Full	Medium	Tailwater Control; Debris removal
MR021A	Moose River	298743	4946821	Yes	Full	Medium	Tailwater Control
MR021B	Moose River	298743	4946821	Yes	Full	Medium	Tailwater Control

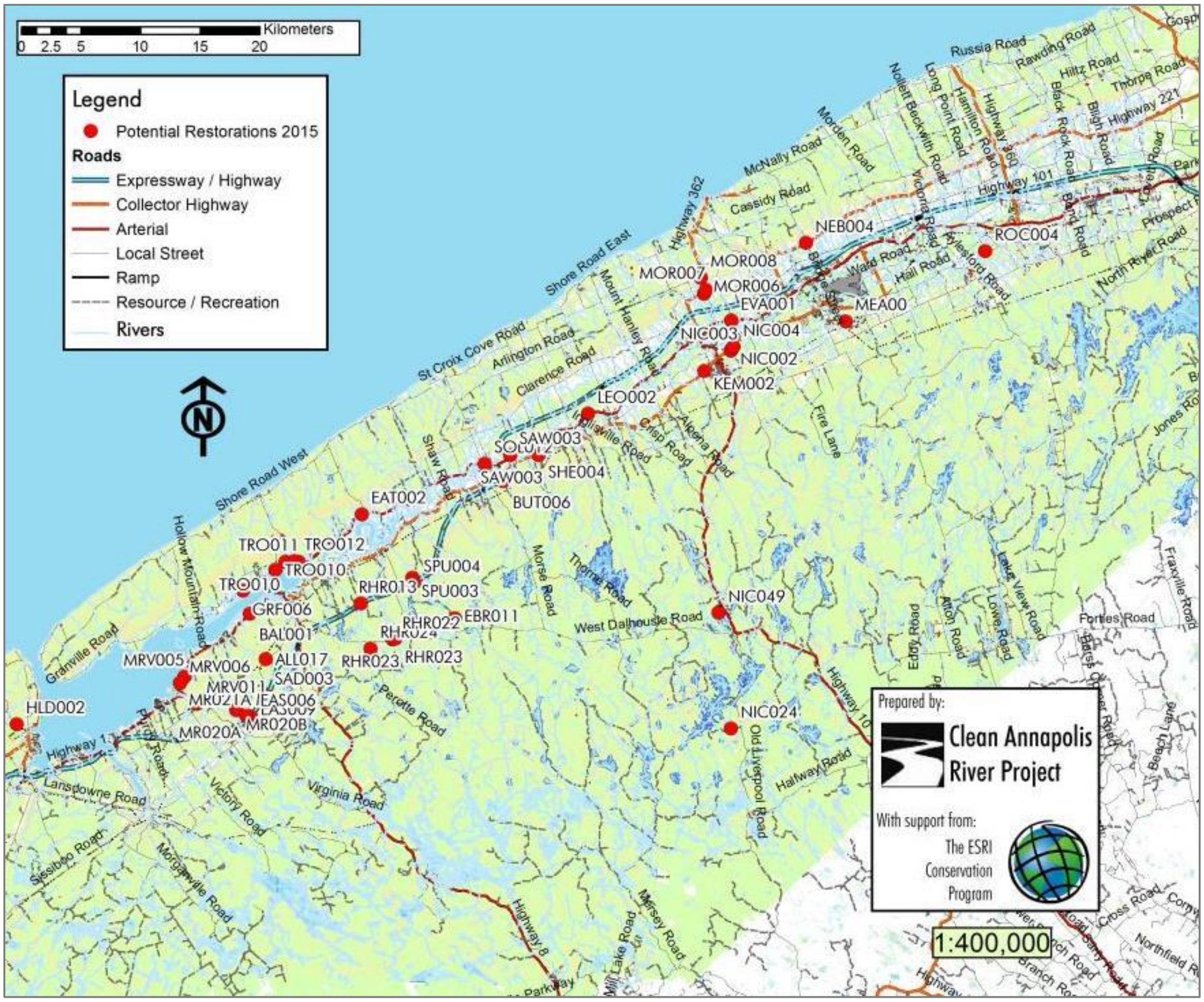

Figure 1. Shortlisted sites for 2015 potential restorations.

2.1.2 Remediation Planning and Preparation

Once the prioritization process and selection of watercourse crossings for restoration actions was completed, preparatory work ensued to source the materials and necessary permits to complete the work. Sections 2.1.2.1 through 2.1.2.4 describe what sort of calculations and considerations were needed for each type of restoration action undertaken in 2015.

2.1.2.1 Debris Removals

Leaf litter, fallen branches, rocks and garbage are deposited into streams either directly from the stream banks or erosion, or indirectly during high flow events. This debris can be carried downstream through the watercourse and it has the potential to accumulate at the inflow or outflow of a culvert. Once a debris build up begins, more debris will continue to build up around it, and eventually it will create a barrier to fish attempting to pass through the culvert. Debris removals are therefore an important part of restoration work that is needed to maintain fish passage and adequate water flow through watercourse crossings.

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Debris removals in 2015 were completed when culverts were revisited to determine restoration feasibility. Shovels, pry bars, a pick-axe, buck-saw, brush clippers and gloves were used by CARP staff to remove accumulated debris creating fish passage barriers. More information about debris removals that were completed can be found in sections 3.1.1 to 3.1.5.

Sites selected for debris removals were: RHR022, PET004, SHE004, ANN004, BAL001 and MRV006. RHR022 was located on the Roundhill River, and all others were located on smaller tributaries that flow directly into the Annapolis River.

2.1.2.2 Tailwater Controls

Culverts can often have problems that cannot be remediated by removal of debris alone. Some of the most common issues that need to be tackled when it comes to barrier watercourse crossings are problems such as outflow drops that result in perched culverts which fish cannot swim through or excessive velocities in culverts caused by culvert slopes that are too steep. One of the options that can be used to address these problems is the construction of a tailwater control structure, which is a structure that essentially controls the height of the outflow pool on the downstream side of a culvert. Structures such as rock weirs can be used as tailwater controls to reduce the velocity of water flowing through a culvert, or to elevate the water levels in outflow pools.

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 the existing tail water control or establishing a new one, the depth of an outflow pool can be increased, reducing or eliminating any outflow drop. The construction of tailwater controls alone as a remediation for outflow drops is not recommended for outflow drops that exceed 30cm, as they become less effective, and are more likely to pose another barrier to fish passage.

Ten culverts were selected for tailwater control actions in 2015, many of which were located within priority sub-watersheds of the Annapolis River, such as the Moose, Nictaux, Black and Roundhill River sub-watersheds. EAS009 and ALL017, which are tributaries of the Moose River, were also selected because they were sites of new culverts installations which resulted in significant outflow drops. Other priority sub-watershed restoration sites that were selected were: NIC002, on a tributary of the Nictaux River, BLK006 on a tributary of the Black River, and RHR013, located on the Roundhill River.

Additional culverts that received tailwater control structures were not located in priority sub-watersheds, but were selected due to the large upstream habitat gains that they could provide: BUT005, BAL001, ROC004, MOR008, and NEB004. For more information about individual site activities, please refer to sections 3.2.1 through 3.2.10.

2.1.2.3 Rock Weirs

Rock weirs were used in 2015 as tailwater control structures to elevate outflow pool depths. In seven cases they were also used in conjunction with a fish chute to manage excessive outflow drops. Research completed by CARP in past years has led to the use of a vortex rock weir design for tailwater controls which utilizes a 20° or 30° U-shaped design along the bankfull width. In 2015 restorations, CARP used a 30° angle design (Figure 2).

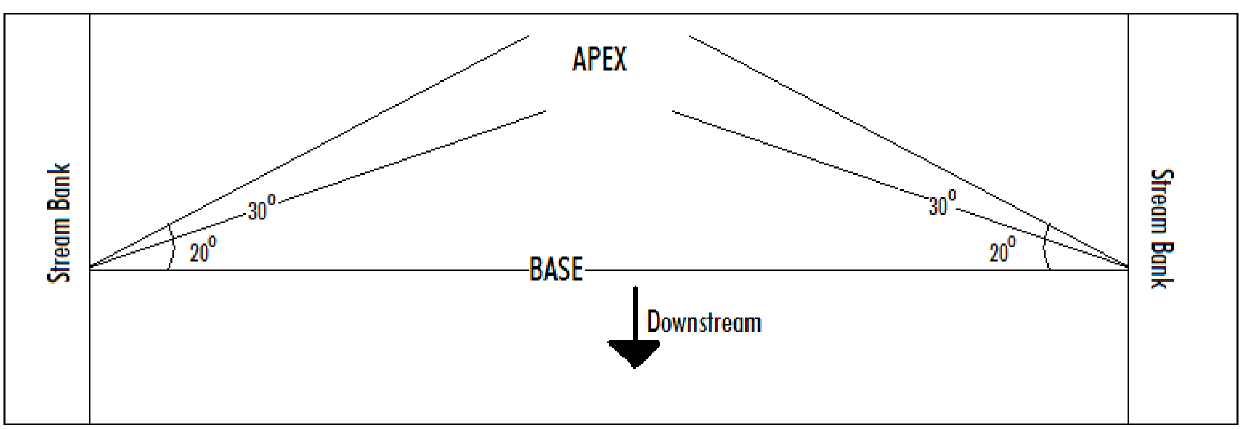

Figure 2. Rock Weir Design (Taylor 2010).

There are several calculations required for the planning of rock weirs. Downstream channel measurements were taken at the first riffle when the culverts were re-visited and construction of a rock weir was necessary. These measurements were used to calculate the amount of rocks required to build the weir. To determine the amount of rock that would be required to build the rock weir, the following formula was used (Taylor, 2010):

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

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 width ratio of 1:3), and the height (h) refers to the desired height of 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 and which is also 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 15cm beyond the full bankfull width of the streams.

Large, flat footer stones were used to construct the base of rock weir structures. Weir stones, which are generally smaller than footer stones, were used to build the remainder of the weir. Pebbles and cobbles were used as fill to seal the gaps between the larger weir stones.

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 was 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).

$$\tau \text{ (kg/m2)} = \text{Incipient Diameter (cm)}$$

Where, τ represents tractive force. The equation for tractive force is:

$$\tau = 1000 \text{ X } d \text{ X } s$$

Where, d is depth of flow in metres and s is the slope of water surface

Individual rock calculations for all constructed weirs can be found in Appendix 6.8. Weirs were constructed to DFO speculations at sites where no fish chutes were installed at the outflows. For more detailed instructions on the construction of a rock weir, please refer to Appendix 6.4.

2.1.2.4 Fish Chutes

Seven culverts were chosen as sites where fish chutes could be incorporated into the restoration activities: EAS009, ALL017, BAL001, RHR013, BLK006, ROC004, and NEB004. Two culverts, BAL001 and ROC004 were selected for remediation work despite their large outflow drops in excess of 60 cm, to test whether the combination of a fish chute and tailwater control would be sufficient to overcome such a barrier. These sites were selected because of the significant upstream habitat gain that could be obtained from restoration.

Fish chutes are a newer solution for outflow drops and CARP had not used them before. Will Daniels, a field technician from Adopt-A-Stream with experience in fish chute design and installation, provided technical support and guidance for this aspect of the restoration work. Of the seven sites visited, culvert measurements were used to calculate required chute dimensions, using formulae for determining baffle notch sizes (Appendix 6.7). The fish chutes were based on two designs (shown in Figures 3 and 4) and were ordered from Dura-Tech and Marine Industries in Dartmouth N.S. Fish chutes were custom designed for all of the culverts remediated, and were made of 5mm (3/16") galvanized steel plate. They were designed to have a slope of approximately 3.5% and to remediate an outflow drop of 20cm (8"). The chutes were designed to either be attached directly to a steel culvert or to a wooden weir affixed to a wooden or concrete culvert.

In the case of a concrete culvert with a weir and a low flow notch already in place the chute was made to fit in the existing notch (RHR013). The chutes were attached to the culverts with stainless steel bolts and nuts in the case of steel culverts, galvanized lag bolts for wooden culverts, and galvanized and/or stainless expansion bolts for concrete culverts.

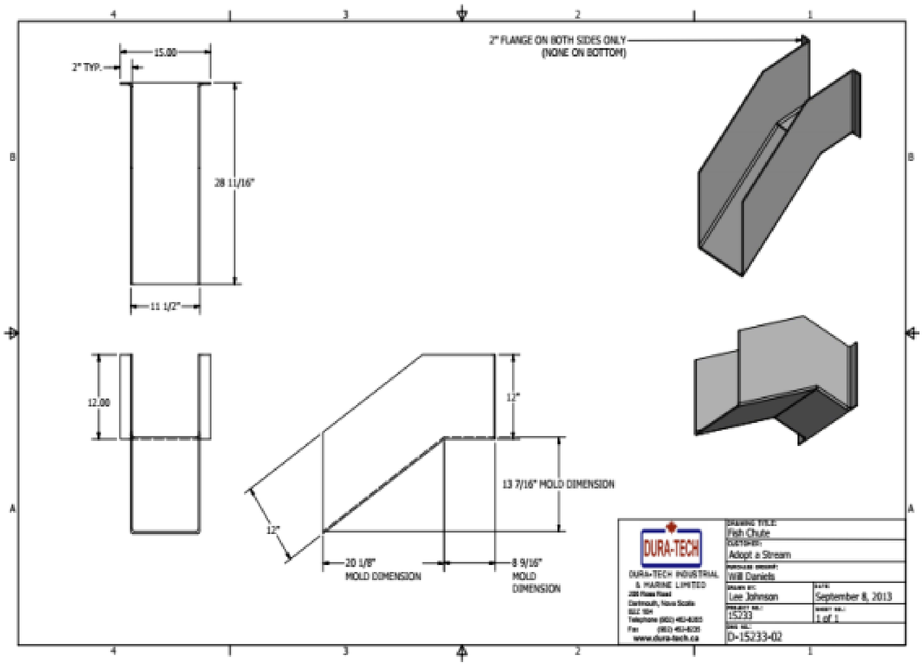

Figure 3. Design for Flat Bottom Culverts.

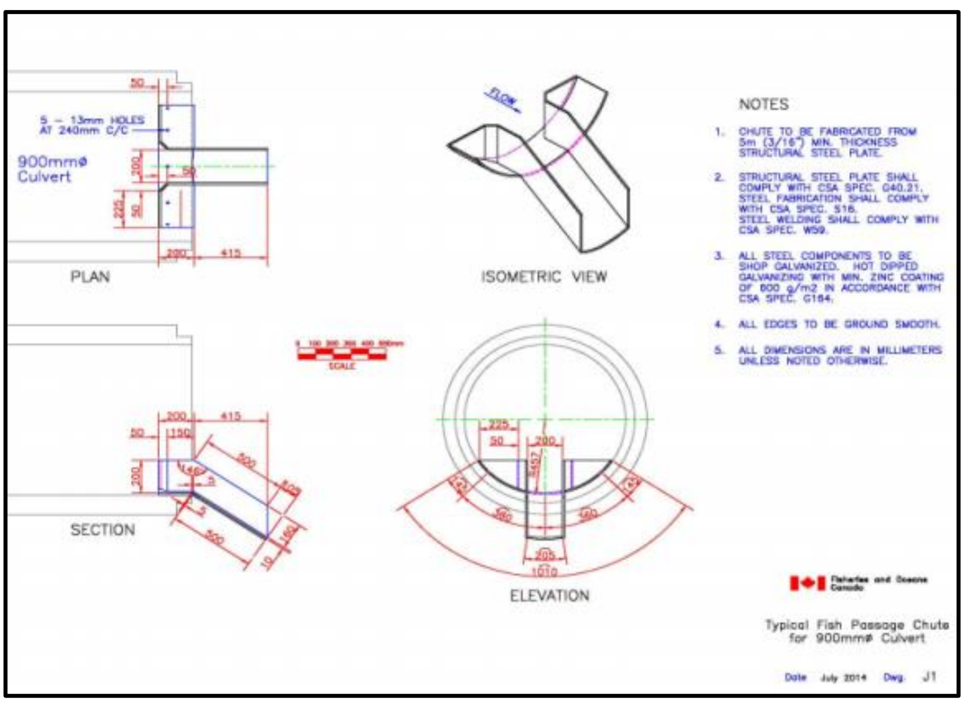

Figure 4. Design for Round Culverts.

Culverts with flat bottoms and similar flow requirements (BAL001, BLK006, and NEB004) used chutes of the same size. RHR013 was a large double cement culvert with a pre-existing low flow notch that required a chute made to fit into the existing notch. ROC004 required a double wide chute due to the site's historical flow data. EAS009 and AL017 were both round culverts and required similar designs but different sized chutes. Figures 3 and 4 show the general shapes of chutes that were installed in box culverts and cylindrical culverts. Detailed information about each individual culvert design can be found in Appendix 6.5, Fish Chute Designs.

2.1.2.5 Baffles

Structures such as baffles can help to reduce water velocities through a culvert and be used to raise the water level in a culvert as well. Baffles direct water flowing through a culvert to notches sized for low flow conditions. The redirection of flow between baffles creates artificial pools and eddies and helps slow water velocities.

Baffles were used in 2015 to alleviate low water levels flowing through culverts. Culverts with excessive slopes and high water velocities were only selected for remediation if they already had baffles installed. Design criteria for baffles were calculated using DFO baffle spacing and baffle notch sizing formulae (refer to Appendices 6.6 and 6.7 for more information)

Baffles installed in 2015 by CARP were made from cedar posts, (8ft 3x3's and 6ft 5x5's) which were installed using galvanized lag bolts or galvanized and/or stainless steel expansion bolts, depending on the culvert. Lag bolts were used in wooden culverts and expansion bolts were used in concrete culverts. Stainless steel nuts and bolts were needed to attach a 3x3 post to a steel culvert.

The cedar posts were also used to install low flow barriers in all of the double culverts where fish chutes were installed, and were placed at the inflow of one of two culverts. This allowed the redirection of water to the culvert with no barrier during low flow conditions, to improve water levels for fish passage. Cedar posts were installed at the outflow as well to help increase the water level in the culvert, direct the water to fish chutes, and provide an anchor for chutes.

The baffles were pre-cut to size at CARP's office from measurements and calculations completed from in-field measurements. Any final adjustments that were needed were made on site during the installation process. Further information can be found in the results sections 3.2.3 to 3.2.10.

2.2 In-stream Habitat Restoration and Enhancement

Additional work that was completed in 2015 included in-stream habitat restoration and enhancement efforts on the Nictaux River, which was identified as a restoration priority in the sub-watershed restoration plan created for the Nictaux River in 2013 (Freeman, 2014b). This work was a continuation of restoration efforts begun in 2014, to improve spawning habitats for salmonids and other species. Excavator work was continued in 2015, to restore existing degraded rock weirs, and was carried out by East Coast Aquatics. Three wing deflectors and two digger logs were also installed on the Nictaux River using hand tools to contribute to habitat enhancement as well. Figure 5 shows the locations where instream restoration and enhancement efforts were focused in the 2015 field season, and is discussed in more detail in Sections 2.2.1 and 2.2.2.

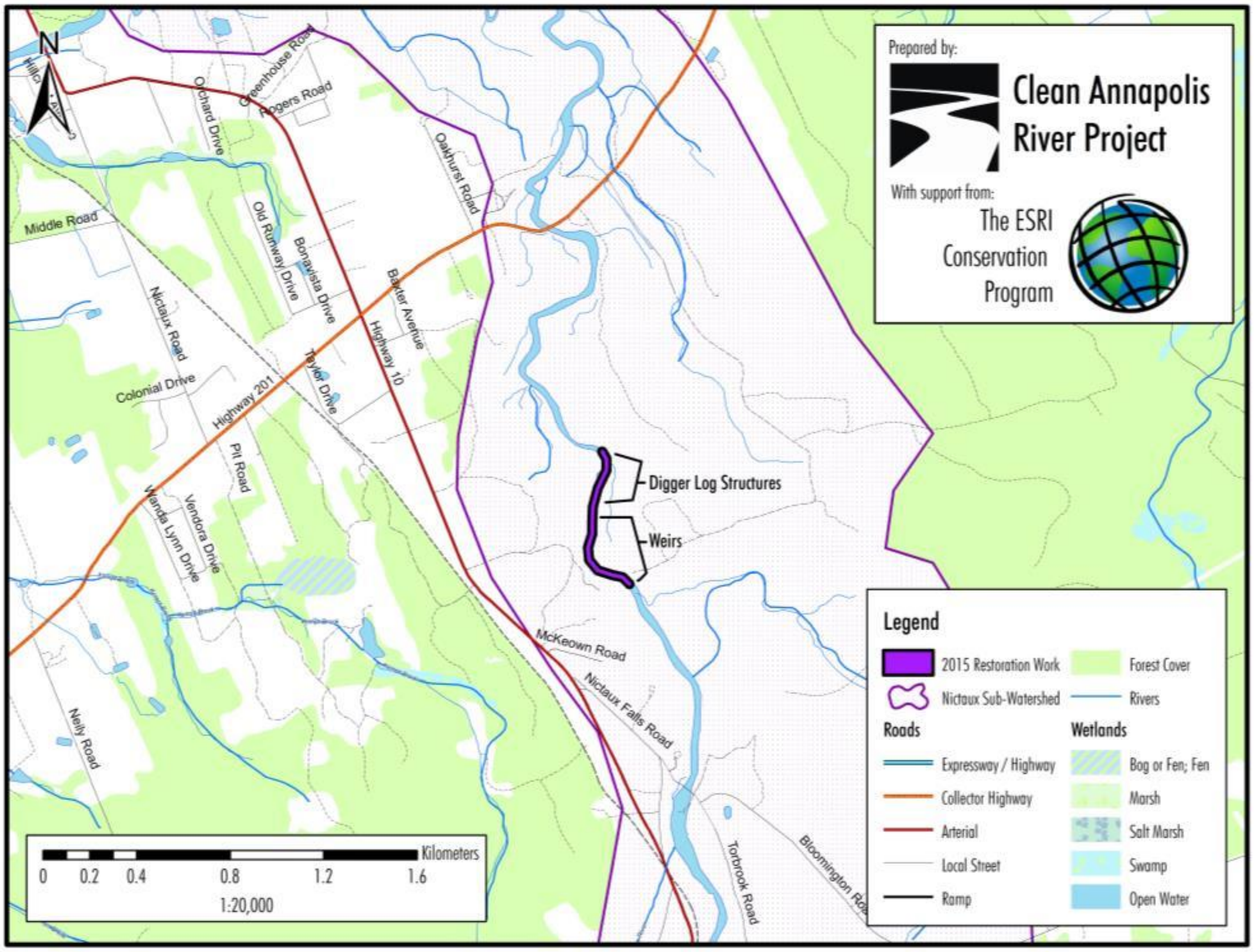

Figure 5. Location of instream habitat enhancement and restoration work on the Nictaux River 2015.

2.2.1 *Excavator Work on the Nictaux River*

Excavation work was initiated on the Nictaux River with the intent of improving salmonid habitat in 2014, and continued into the 2015 field season. Plans for work on the Nictaux River in 2015 included the continued bolstering of wing deflectors on three of the derelict rock weirs that had received reconstruction work in 2014. Additionally, three additional derelict weirs received reconstruction work in 2015, resulting in a total of 7 of 13 weirs that have received work to date (See Figure 6).

In 2014, the furthest downstream weirs were where restoration activities began. Weirs A and B were redesigned and reconstructed to more effectively carve out pools and build gravel bars to add cover and improve spawning habitats. Work was initiated on Weirs C and D in 2014, but more rock was required to complete additional work. Lastly, a boulder cluster was also placed upstream of Weir H in 2014 (Freeman, 2014a).

Information on the original design and dimensions of the existing weirs was unavailable, and therefore measurements were taken to determine structure characteristics in 2014. Consultation with partners and experts occurred to determine the appropriate actions required to remediate the existing weirs to improve salmonid habitat. This proved to be a challenge, due to the altered flows and morphology of the river due to upstream hydroelectric activities. As a result of the varied nature of weir separation distances, a design width of 17m was agreed upon after further examination of the site, and consultation with partners.

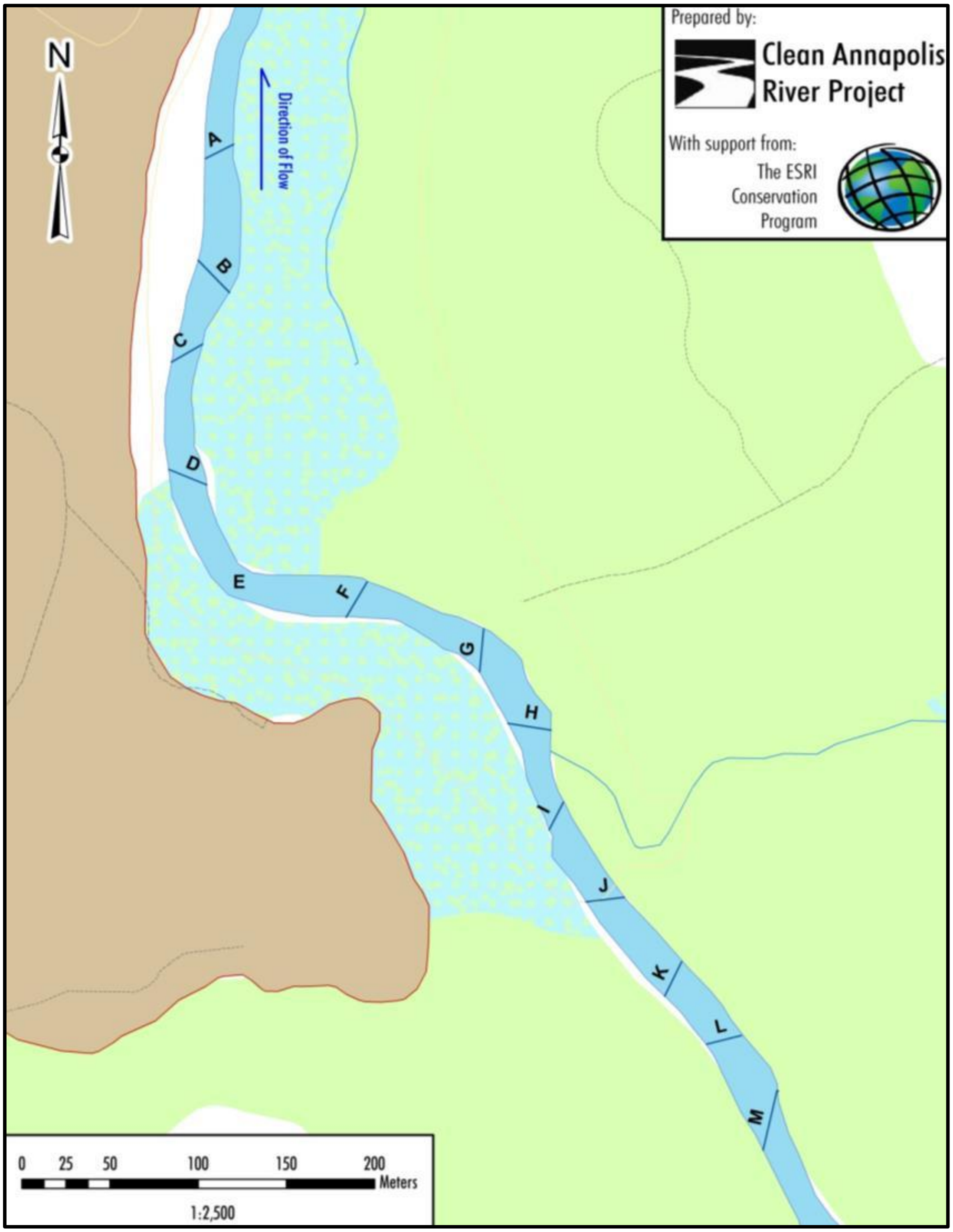

Figure 6. Map showing thirteen derelict rock structures along the Nictaux River (Freeman, 2014a).

Additional boulders were transported to sites for re-construction activities in 2015. Weirs "A" and "B", which received work in 2014, needed some modifications, and their wing deflectors were bolstered with additional rock. Additional bolstering of the right bank and left wing deflector also occurred at Weir "C". A small trench was also dug by the excavator in front of the left bank deflector to allow CARP staff to install a log deflector by hand to reinforce the bank. No additional work was completed at Weir “D”. Weirs “E”, “F”, and “G” had their restoration work completed as planned from discussions with experts, and recommendations in the *Broken Brooks 2014: Improving In-Stream Fish Habitats through Restoration* report (Freeman, 2014a). These weirs received re-construction efforts in 2015, primarily focused on creating improved wing deflector structures.

Further information about the excavator work completed in the 2015 field season is described in Section 3.3.

2.2.2 Digger Logs and Wing Deflectors

Fish like trout and salmon need narrow, deep streams to ensure passage at times of low flow. Rock or wood wing deflectors help to improve passage in wide, shallow streams by narrowing and deepening a channel by consolidating flow, flushing sediments from the main channel, and depositing them along riverbanks. Similarly, digger logs help to improve habitat quality for fish by imitating naturally fallen trees which enhance cover and habitat diversity in a stream. Digger logs help to carve out pools and riffles in featureless channels as water moves over the rocks and logs placed in the streams. This in turn provides many habitat benefits such as cool refuges, productive feeding areas, and spawning areas. Digger logs also help to consolidate flow to restore a deeper channel path (thalweg) and re-establish a natural meandering pattern (Clean Foundation, 2015).

Digger logs and wing deflectors were installed using hand tools in the Nictaux River system in the 2015 field season, and their locations were determined after consultation with partners and experts. Wing deflectors and digger logs were constructed according to Adopt-A-Stream design protocols, which were adapted from the DFO publication titled ‘*Ecological Restoration of Degraded Aquatic Habitat: A Watershed Approach’* (DFO, 2006). Materials used to create the deflector weirs and digger logs were taken from the site, where possible. Additional materials such as rocks were trucked in as needed.

The process of constructing the digger log and deflector weir structures consisted of measuring installation sites to determine their bankfull widths and the number of structures needed. Digger logs were installed on a 30° angle between streambanks, and deflector weirs installed using a right angle triangular shape, where the upstream tip of the weir measured a 30° angle from the bank, the downstream a 60°, and the tip in the stream a 90° angle (see Figures 7 and 8).

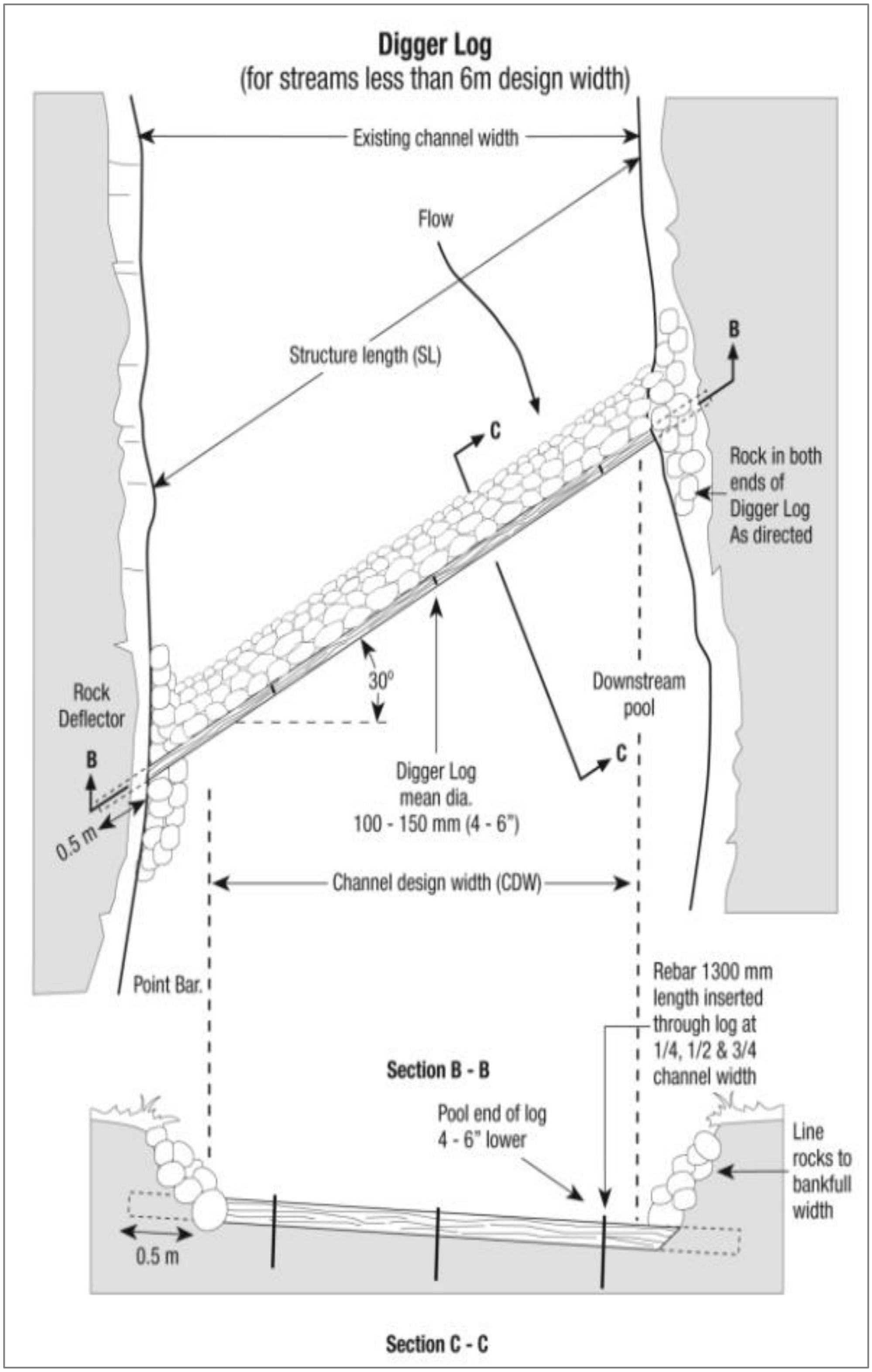

Figure 7. Digger log installation guidelines (DFO, 2006).

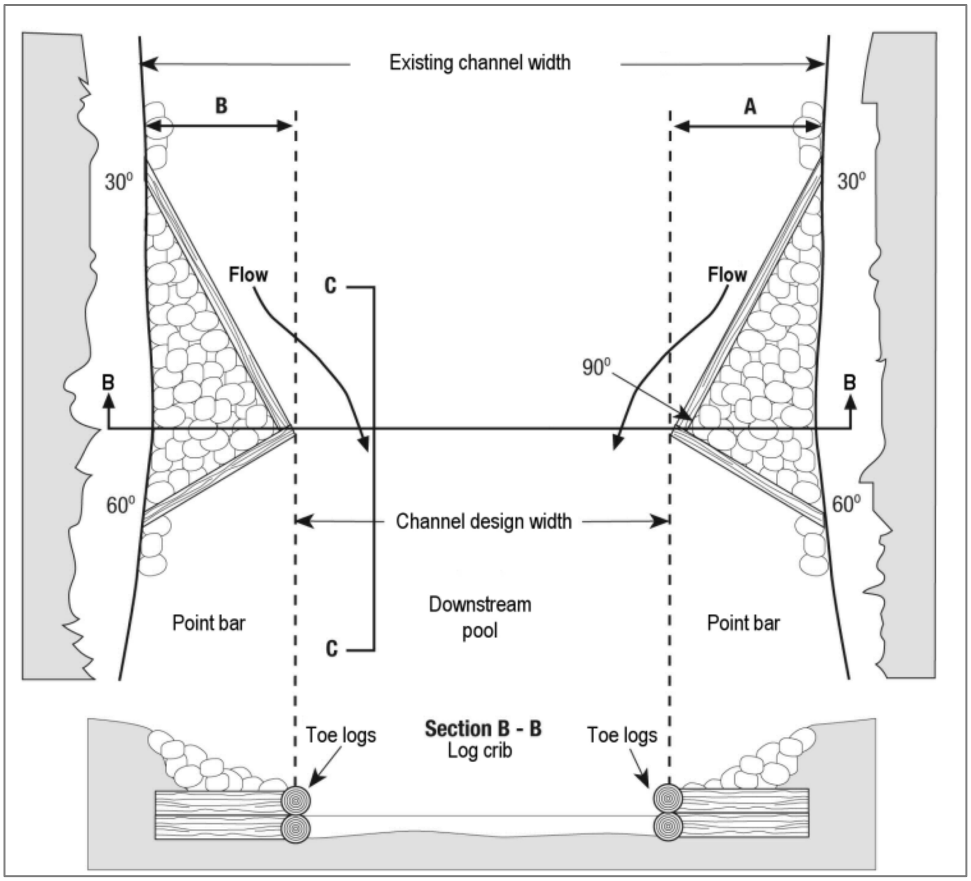

Figure 8. Deflector weir installation guidelines (DFO, 2006).

Trees with straight trunks were selected and cut on site for construction of the digger logs and deflector weirs. Logs were then floated downstream to restoration sites. The large end of each harvested log was fitted tight to the bank, and lined up with the opposite bank; a trench was then dug along the full length of the log, to firmly entrench the log in the river bottom. Once in place in the trench, holes were drilled into installed logs using a gas powered drill. Re-bar was then used to secure logs to the streambed.

After the log was secured, rocks were packed in around the log to help hold it in place and prevent water cutting in underneath the log. The upstream side of the digger logs were sloped to allow the water to flow smoothly over the log and dig a pool on the downstream side.

Wing deflectors were constructed in two ways: a pyramidal log structure, or a single log backfilled with rocks. With the pyramidal structure, two logs were secured to the streambed side by side to create a deflector base, and a third log was rolled on top, positioned in the hollow formed where the two bottom logs met and pinned through the bottom logs. This pyramidal shaped structure was needed to overcome the depth of the water next to the bank. Alternatively, in areas where water depth was shallower, a single log structure was used to create the wing deflector, and secured to the streambed using the same method as for the digger logs.

Back filling of the wing deflectors was done with either leftover lengths of the trees cut for the weirs and the digger logs and other debris from fallen trees nearby or with rocks from the streambed. Branches saved from cut trees cut were attached with spikes to the deflector logs and to stakes pounded into the river bank in an overlapping end over end fashion to create a mat that would contain rocks and encourage deposition during high flow events.

Site-specific wing deflector and digger log installation is discussed further in the Results, Section 3.4.

3.0 Results

The 2015 season was very successful, with 15 sites selected for restoration actions: 6 debris removals, 10 tailwater restorations, 7 fish chutes, 3 low flow barrier installations, and 2 baffle installations (see Table 3). A total of 33 km of upstream habitat was made available, and an additional 13.7 km of upstream habitat passage was improved. Three wing deflectors and two digger logs were installed by hand in the Nictaux River, and existing large rock weirs were remediated, improving habitat productivity in a 1 km stretch of the Nictaux River.

Table 3. Summary of 2015 Restorations.

Restoration Site	Watercourse Name	Easting	Northing	Upstream Habitat Gain (km)	Restoration Work Completed
ALL017	Grand Lake Flowage	300384	4951577	1.5	Vortex rock weir, fish chute
ANN04	Annapolis River tributary	336449	4976964	1.75	Debris Removal
BAL001	Balcom Brook	299033	4955387	2	2 Vortex rock weirs, fish chute, baffles, debris removal
BLK006	Black River	344041	4978760	1.5	Vortex rock weir, fish chute
BUT006	Button Brook	320899	4966806	5	Vortex rock weir
EAS009	East-Moose River	299139	4945996	1.62	Vortex rock weir, fish chute
MOR008	Morton Brook	336906	4983558	1.6	Vortex rock weir
MRV006	Moose River	293166	4949572	0.75	Debris Removal
NEB004	Neilys Brook	345710	4986463	1.5	Vortex rock weir, fish chute
NIC002	Nictaux River	339406	4977435	1.5	Vortex rock weir, bank stabilization
Nictaux River	Nictaux River ; from- To-	339483 339408	4975739 4976157	1	Excavator work, digger logs, deflector weirs
PET004	Pete's Brook	331698	4971162	2.25	Debris Removal
RHR013	Roundhill River	308358	4956243	13.7	Vortex rock weir, fish chute
RHR022	West Roundhill River	311015	4953236	3	Debris Removal
ROC004	Rockland Brook	360765	4985776	7	Vortex rock weir, fish chute, baffles
SHE004	Shearer Brook	323275	4968680	1.5	Debris Removal

3.1 Debris Removals

Debris removals were done by CARP staff with help from Bear River First Nations summer staff. Organic debris such as sticks, leaves, and rocks were left near sites but out of the floodplain to prevent future blockages. Non-organic debris such as household garbage, metal, tires, and electronic appliances was separated and disposed of properly. A lot of debris was cleaned up at tailwater restoration sites as well. The six removals completed are outlined in Table 4 and shown in Figure 9.

Table 4. Debris removals completed in 2015.

Culvert ID	Watercourse Name	Nearest Community	UTM Easting	UTM Northing	Barrier Type	Outflow Drop (cm)	Slope (%)	Upstream Habitat Gain (km)
ANN04	Annapolis River tributary	Lawrencetown	336449	4976964	Full Barrier	0	0.6	1.75
PET004	Pete's Brook	South Williamston	331698	4971162	Full Barrier	0	3.56	2.25
BAL001	Balcom Brook	Allains Creek	299033	4955387	Full Barrier	62	0.57	2
RHR022	West Roundhill River	Perotte	311015	4953236	Partial Barrier	0	0	3
SHE004	Shearer Brook	West Paradise	323275	4968680	Full Barrier	0	3.52	1.5
MRV006	Moose River	Clementsport	293166	4949572	Full Barrier	0	1.47	0.75

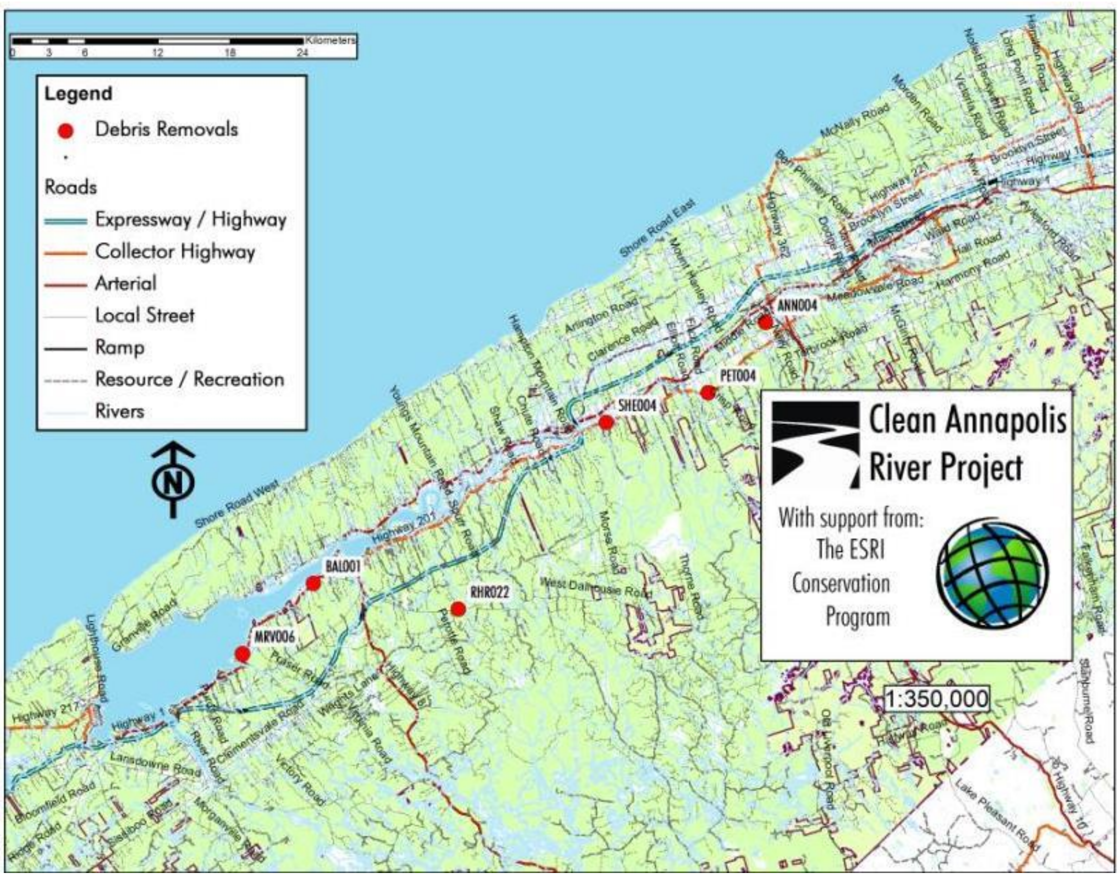

Figure 9. Map showing locations of 2015 debris removals.

3.1.1 ANN004 Annapolis Tributary (No Name)

Location: Middle Road, Lawrencetown, Annapolis County
Remediation: Debris Removal
Outflow Drop: 0 cm
Slope: 0.6 %
Upstream Habitat Gain: 1.75 km
Comments: A culvert on a tributary of the Annapolis River near Lawrencetown had debris built up at the inflow that completely restricted fish passage. All that was needed were some gloves and a coordinated effort to restore fish passage to 1.75 km of upstream habitat. Figures 10 through 12 show photos of the debris removal.

Figure 10. ANN004 Before debris removal.

Figure 11. ANN004 After debris removal.

Figure 12. ANN004 Crews removing culvert debris.

3.1.2 PET004 Pete's Brook

Location: Highway 201, South Williamston, Annapolis County
Remediation: Debris removal.
Outflow Drop: *0 cm*
Slope: 0.35 %
Upstream Habitat Gain: 2.25 km
Comments: Located on a tributary of the Annapolis River called Pete's Brook, PET004 was a square box wooden culvert falling apart at the inflow. Debris was removed to restore fish passage however major structural work or replacement is still required to address impending culvert failure. Figures 13 through 15 show the inflow prior to and after debris removal.

Figure 13. PET004 Before debris removal.

Figure 14. PET004 After debris removal.

Figure 15. PET004 looking upstream through culvert after debris removal.

3.1.3 RHR022 Tributary of Round Hill River (No name)

Location: West Dalhousie Road, Perotte, Annapolis County
Remediation: Debris removal.
Outflow Drop: 0 cm
Slope: 0 %
Upstream Habitat Gain: 3 km
Comments: One of two culverts at RHR022, located on a tributary of the Round Hill River, a sub-watershed of the Annapolis River, was found to be plugged solid with rocks and debris. Shovels, a few pairs of hands, and some team work made this a working culvert conducive for fish passage. Figures 16 and 17 show before and after photos of the site.

Figure 16. RHR022 Before debris removal.

Figure 17. RHR022 After debris removal.

3.1.4 SHE004 Shearer Brook

Location: Balcom Road, West Paradise, Annapolis County
Remediation: Debris removal.
Outflow Drop: 0 cm
Slope: 3.52 %
Upstream Habitat Gain: 1.5 km
Comments: This culvert, on a tributary of the Annapolis River, required more of a channel clean up than a debris removal. Rocks were blocking access to the culvert at the outflow and were restricting passage in the stream. Pry bars, and shovels were used to create better in-stream passage, making 1.5 km of upstream habitat available. Figures 18 through 20 show before and after photos of the site.

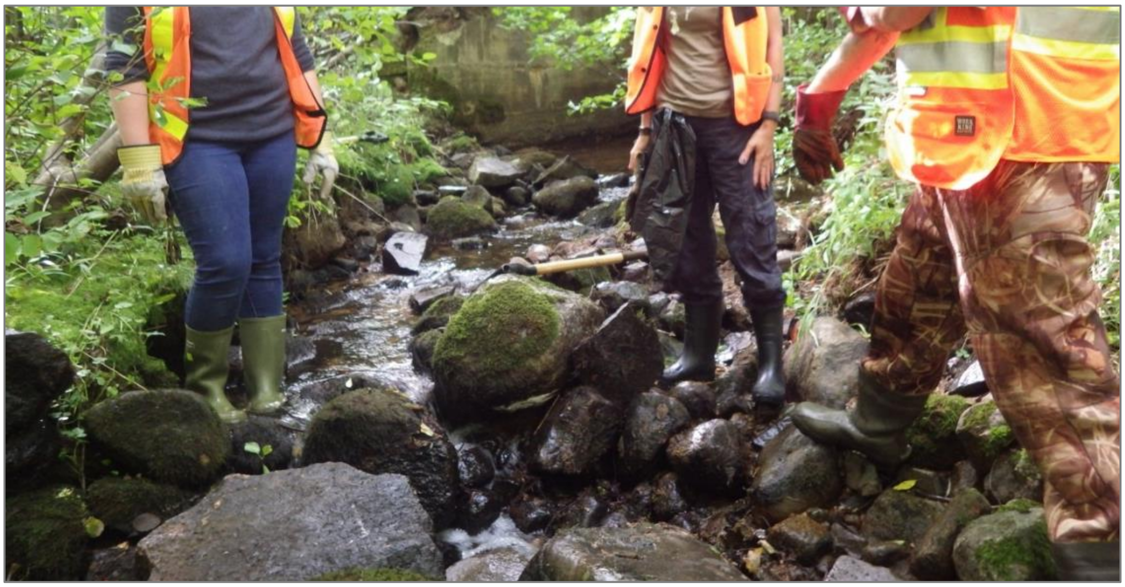

Figure 18. SHE004 Before debris removal, looking upstream.

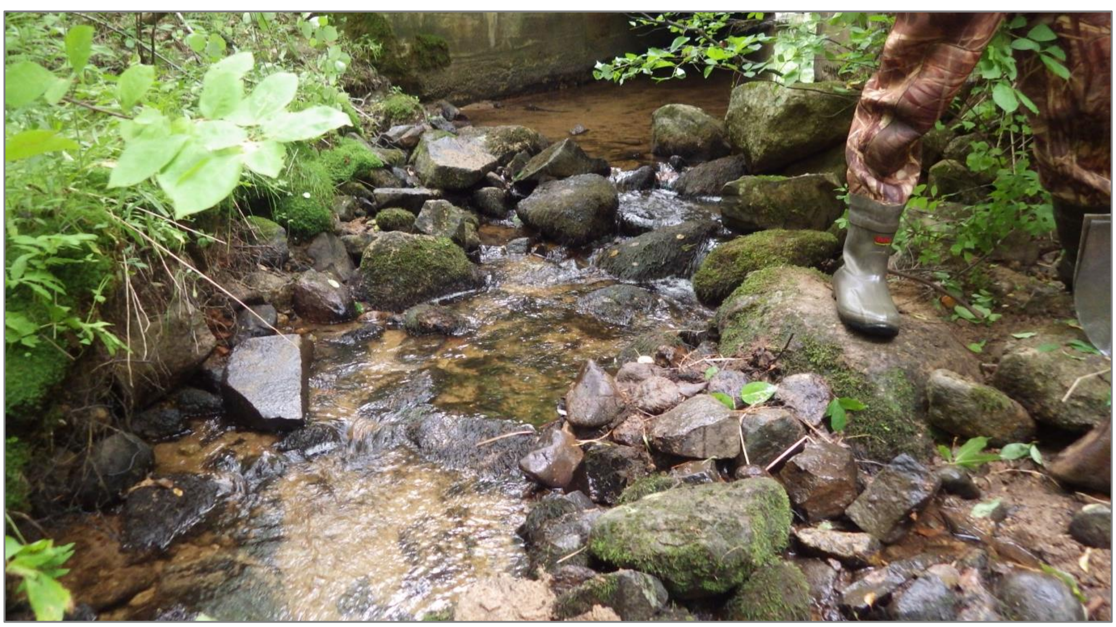

Figure 19. SHE004 After debris removal, looking upstream.

Figure 20. Removal of in-stream debris at SHE004.

3.1.5 BAL001 Balcom Brook

Location: Highway 1, Allains Creek, Annapolis County
Remediation: In-stream debris removal, not a beaver dam.
Outflow Drop: 62 cm
Slope: 0.57 %
Upstream Habitat Gain: 2 km
Comments: BAL001 was the location of multiple restorations including an in-stream debris clean-up (For a description of other restoration activities, please see Section 3.2.3). At the site, there was a huge pile of accumulated sticks, branches, leaves, and small trees present which were altering the stream's direction. The jam was cleared using hand tools such as saws, brush cutters and shovels to restore the stream. Additional remediation activities at the site included the installation of two rock weirs, a fish chute, baffles and a low flow barrier, to improve fish passage through the culvert. Figures 21 through 23 show images of the debris removal activities at BAL001.

Figure 21. BAL001 Before debris removal, showing debris blockage in the stream.

Figure 22. BAL001 stream after debris removal.

Figure 23. BAL001 during debris removal activities.

3.2 Tailwater Restorations

Tailwater restorations in 2015 consisted of the installation of rock weirs, fish chutes, and baffles. Table 5 and Figure 24 give a summary of the tailwater restoration activities that occurred in 2015, and show their locations.

- Two culverts, BUT006, MOR008 and NIC002 were remediated using rock weirs to raise their tailwater pools
- BAL001 required the installation of two rock weirs to raise its tailwater pool to a level that allowed fish to access a fish chute that was installed at the culvert outflow. Baffles were also installed in BAL001 to increase the level of water in the culvert during low flow conditions.
- RHR013 and EAS009 both required the installation of a rock weir and fish chute combination to alleviate their outflow drops.

The remaining four culverts, BLK006, ROC004, NEB004, and ALL017 had baffles installed in addition to rock weirs and fish chutes. The baffles aimed to increase the level of water in the culverts during low flows. At sites where double culverts were present, low flow barriers were installed in the inflow of one of the two culverts.

Table 5. Summary of Tailwater Restorations

Culvert ID	Watercourse Name	Nearest Community	UTM Easting	UTM Northing	Barrier Type	Outflow Drop	Slope (%)	Upstream Habitat Gain (km)
EAS009	East Moose River	Princedale	299139	4945996	Full	41.5	0.34	1.62km
NIC002	Nictaux River	Nictaux	339406	4977435	Full	31.5	2.86	1.5km
RHR013	Roundhill River	Round Hill	308358	4956243	Full	40	3.5	13.7km
ALL017	Grand Lake Flowage	Princedale	300384	4951577	Full	29.8	0.68	1.5km
BAL001	Balcom Brook	Allains Creek	299033	4955387	Full	62	0.57	2km
BLK006	Black River	East Tremont	344041	4978760	Full	39.8	0.08	1.5km
MOR008	Morton Brook	Lily Lake	336906	4983558	Full	24.4	1.21	1.6km
NEB004	Neilys Brook	North Kingston	345710	4986463	Full	43.2	0.3	1.5km
ROC004	Rockland Brook	Windemere	360765	4985776	Full	66.5	3	7km
BUT006	Button Brook	Bridgetown	320899	4966806	Full	11	1.9	5km

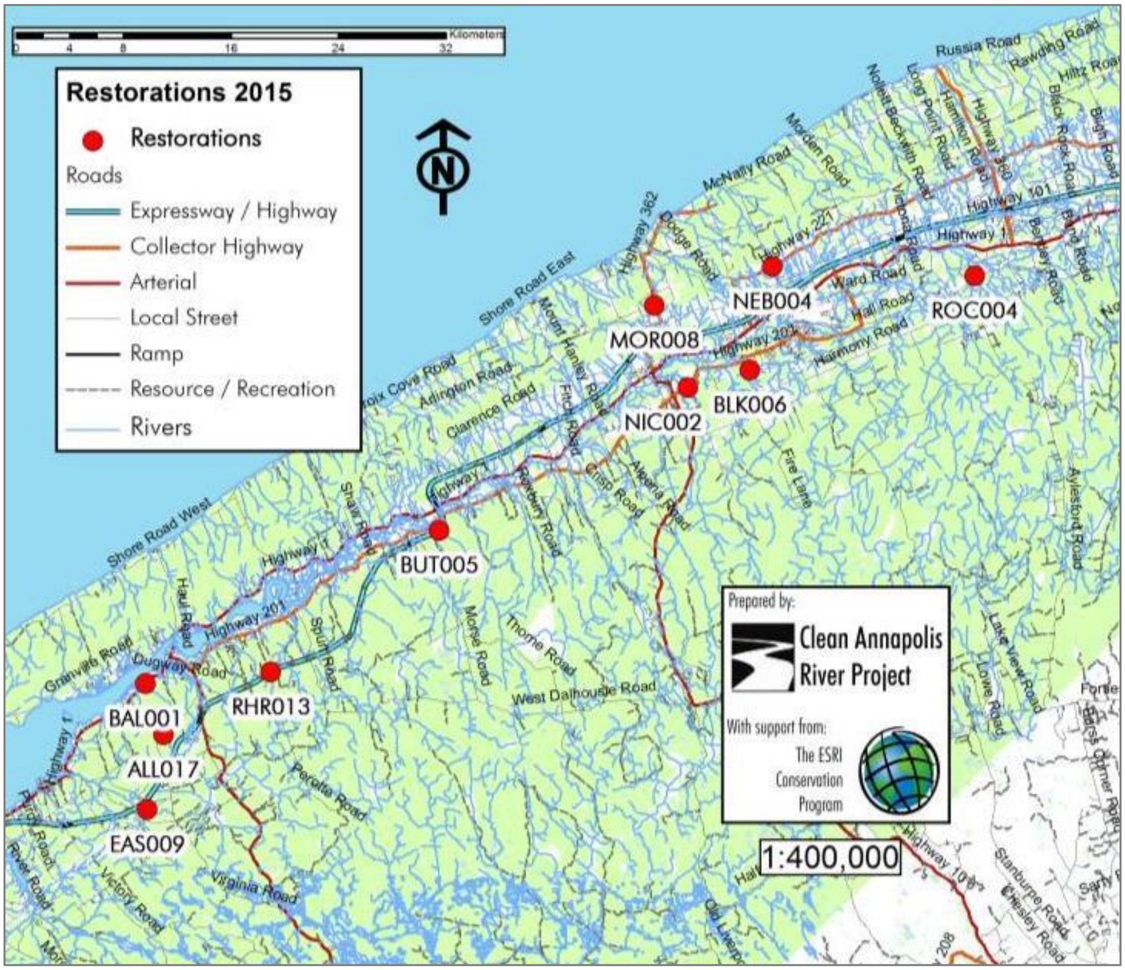

Figure 24. Map showing 2015 culverts where tailwater restorations occurred.

3.2.1 BUT006 Button Brook

Location: Highway 101 between Annapolis Royal and Bridgetown
Remediation: Tailwater control using a vortex rock weir.
Outflow Drop; 11 cm
Slope: 1.9 %
Upstream Habitat Gain: 5 km
Weir Rocks Required: *All rocks available on site. No calculations required to order rocks.*
Rock Size An incipient diameter of 11.21cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of 22.42 cm.
Fish Chute: No fish chute was required
Baffles Required: No baffles were required
Comments: Button Brook is a stream that flows directly into the Annapolis River. BUT006 is a large round steel culvert with concrete baffles. An outflow drop of 11cm was easily remedied with a tailwater control in the form of a rock weir that was built using materials found on the site. Available rocks were fashioned into a rock weir and used some mud, grass and moss to seal the structure. A few broken baffles in the culvert require further repair work. Figures 25 to 28 show images of the restoration activities for this site.

Figure 25. BUT006 Before remediation.

Figure 26. BUT006 After remediation.

Figure 27. BUT006 Finished weir.

Figure 28. BUT006 Closer finished view showing derelict baffles.

3.2.2 NIC002 Tributary of the Nictaux River

Location: Hwy 201, Nictaux, Annapolis County
Remediation: 1 Vortex rock weir tailwater control structure installed, and 1 fish chute still required.
Outflow Drop: 31.5 cm
Slope: 2.86 *%*
Upstream Habitat Gain: 1.5km
Weir Rocks Required: *4 m^3*
Rock Size: An incipient diameter of 10.49 cm was calculated; using a safety factor of 2, a minimum rock size (diameter) of 20.98 cm was calculated.
Fish Chute: No
Baffles Required: culvert size too small to install baffles
Comments: This round steel culvert on an unnamed tributary of the Nictaux River was in need of a rock weir and a fish chute to alleviate a 34 cm outflow drop. This was a fast flowing stream due to a steep channel slope so rip rap was used to reinforce the weir and the banks around it. The chute measured for NIC002 was missed when the chutes were ordered so no chute was available at the time of installation. Originally two weirs were planned for remediation but due to the channel slope only one weir was required at the time of construction. A large flat stone was used in place of the fish chute to create a slide to the outflow pool. Figures 29 to 33 show remediation work at site NIC002.

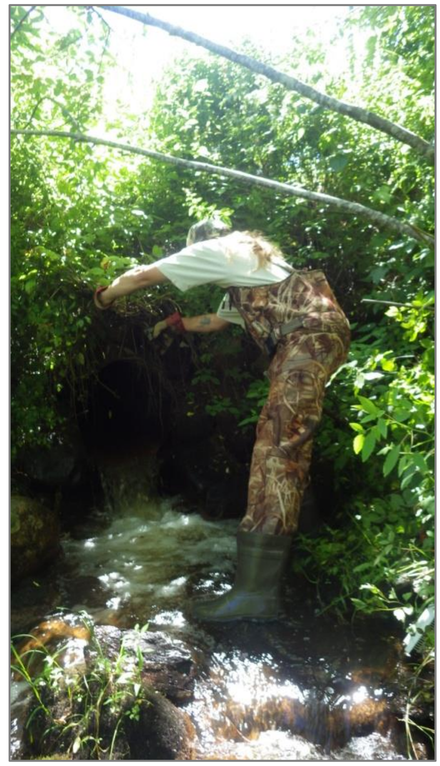

Figure 29. NIC002 Before remediation.

Figure 30. NIC002 After remediation, showing tailwater control structure and bank reinforcement.

Figure 31. Mapping out the tailwater control weir prior to construction.

Figure 32. Reinforcing the banks at site NIC002.

Figure 33. Completed tailwater control and bank reinforcement.

3.2.3 BAL001 Balcom Brook

Location: Hwy 1, Allains Creek, Annapolis County
Remediation: 2 Vortex rock weirs for tailwater control, 1 low flow baffle barrier, and 1 fish chute installation.
Outflow Drop: 62 cm
Slope: 0.56 %
Upstream Habitat Gain: 2 km
Weir Rocks Required: 7 m^3
Rock Size: An incipient diameter of 4.565 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of 9.13 cm.
Fish Chute: A manufactured fish chute was installed as part of restoration activities. See appendices Section 6.5 for more detailed fish chute design information.
Baffles Required: Twenty-four cedar posts were used to divide the culvert, create 6 pairs of baffles, and make a low flow barrier.
Comments: This culvert, on a tributary of the Annapolis River west of the causeway in Annapolis Royal, required a number of restoration activities. The site was located on Balcom Brook, and flowed directly into the Annapolis Basin. There was broken concrete divider in this culvert which was not addressed through remediation activities, and will required removal. Electric tools and a generator were required to complete the restoration work at this culvert, to install a culvert divider, baffles and low flow barrier. Stainless steel expansion bolts and galvanized steel lag bolts were needed to attach cedar posts to the cement culvert. Battery operated drills with extra batteries, hammers, wrenches, socket sets, and a chain saw were also used in installation activities. Due to the size of the outflow drop (over 60cm) and the downstream slope at this site, it was necessary to construct two tailwater control structures and also install a fish chute in order to restore fish passage through the culverts. On site materials were used where possible to aid in the construction of both rock weirs that were installed downstream of the culvert outflow. Figures 34 through 43 show the remediation activities that occurred on site.

Figure 34. BAL001 Broken concrete divider that requires removal.

Figure 35. BAL001 Before remediation activities.

Figure 36. BAL001 After remediation activities.

Figure 37. BAL001 First weir installed downstream of the culvert outflow.

Figure 38. BAL001 Second weir, downstream of culvert outflow and first weir, after completion.

Figure 39. BAL001 View upstream towards culvert from completed weirs.

Figure 40. BAL001 Newly created divider, ready for baffles and fish chute installation.

Figure 41. Baffles after installation at BAL001.

Figure 42. BAL001 Downstream view of baffles, divider, and low flow barrier.

Figure 43. Fish chute after installation.

3.2.4 MOR008 Morton Brook

Location: Highway 362, Lily Lake, Annapolis
Remediation: 1 Vortex rock weir for tailwater control
Outflow Drop: 24.4 cm
Slope: 1.21 %
Upstream Habitat Gain: 1.6 km
Weir Rocks Required: Rocks available on-site, no calculations required
Rock Size: 21.18 cm
An incipient diameter of 10.59 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of 21.18 cm.
Fish Chute: No fish chute was required.
Baffles Required: No baffles were required.
Comments: Most of the materials used to construct the rock weir were found on site, except for the larger footer stones. Clay, grass and fine gravel from on-site were used to seal the upstream side of the weir. Installation of a tailwater control structure restored fish passage through the culvert, opening up access to 1.6 km of upstream habitat (See Figures 44 through 48).

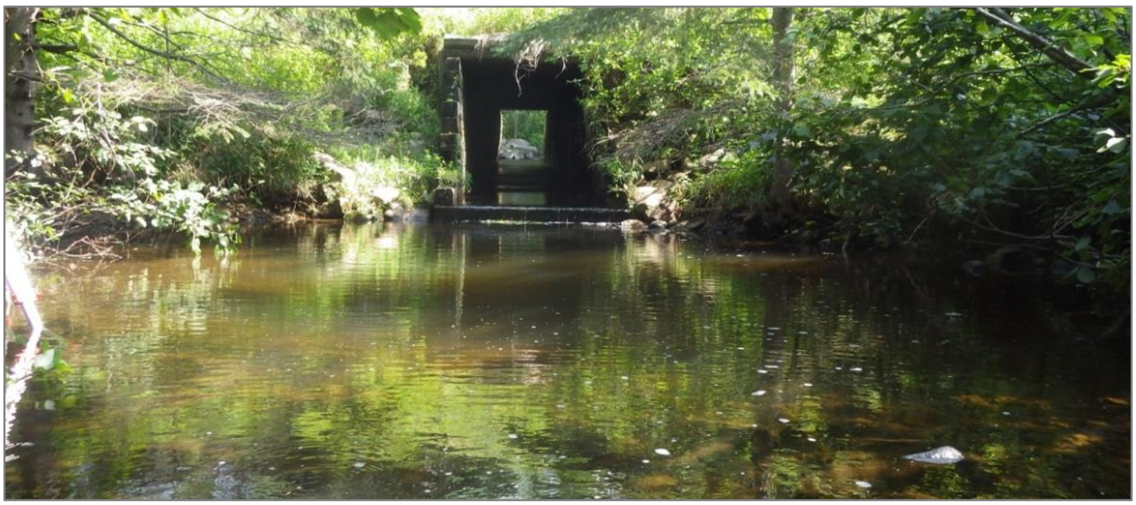

Figure 44. MOR008 Before tailwater control installation.

Figure 45. MOR008 After tailwater control installation.

Figure 46. Measuring out the placement of the downstream rock weir.

Figure 47. Construction of the tailwater control structure at MOR008.

Figure 48. Completed tailwater control structure.

3.2.5 RHR013 Round Hill River

Location: Highway 101 between Annapolis Royal and Bridgetown
Remediation: 1 Vortex rock weir for tailwater control and 1 fish chute installed. A low flow barrier still needed at the culvert inflow and more large rocks need to be removed from the inflow, outflow and baffles in the culvert.
Outflow Drop: 40 cm
Slope: 3.5 %
Upstream Habitat Gain: 13.7 km
Weir Rocks Required: Rocks were available on site so no calculations were required.
Rock Size: An incipient diameter of 21.75 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of 43.5 cm.
Fish Chute: A manufactured fish chute was installed as planned as part of remediation activities. See Section 6.5 in the Appendices for more information.
Baffles Required: A low flow barrier still needs to be installed at the inflow of one of the culverts.
Comments: This culvert is located on a flashy system, subject to very high, rapid flows, and very low flows. A rock weir was constructed on site in 2013 (Figure 49) as a tailwater control structure and was partially removed by a high flow event. This year a fish chute was installed along with a shorter weir to allow fish access to the culvert and more than 13 km of upstream habitat. Instead of the standard 30 degree angle for the wings of the weir a roman arch style or a half a circle weir was built to improve redirection of pressure from high flow events. A fish chute was installed at the culvert outflow notch using electrical tools and a generator. The baffle installation planned for the inflow of one of the culverts was not completed due to high water flows when the fish chute was installed and the removal of the large rocks was not completed due to time constraints when manpower was available. The site will need to be revisited in future to complete these actions. Figures 49 through 55 show some of the restoration activities that took place in 2015.

Figure 49. Remnants of weir built in 2013.

Figure 50. RHR013 Before weir reconstruction.

Figure 51. After weir reconstruction.

Figure 52. RHR013 Volunteers helping to construct a rock weir.

Figure 53. Completed weir structure at RHR013.

Figure 54. Preparing to install the fish chute.

Figure 55. RHR013 after tailwater control and fish chute installation were complete.

3.2.6 EAS009 East Moose River

Location: Fraser Rd., Princedale, Annapolis County
Remediation: 1 Vortex rock weir for tailwater control, and 1 fish chute
Outflow Drop: 41.5 cm
Slope: 0.34 %
Upstream Habitat Gain: 1.62 km
Weir Rocks Required: 2 m^3
Rock Size: An incipient diameter of 5.24 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of 10.48 cm.
Fish Chute: A manufactured fish chute was installed as part of the restoration plan. See Section 6.5 of the appendices for more information.
Baffles Required: No baffles were required.
Comments: On a tributary of the Moose River, this culvert was just replaced last year and was re-installed with the same outflow drop as the old culvert. Quarry rocks were used alongside rocks onsite for the weir construction. The weir was sealed with clay, grass and sticks found onsite, and the outflow pool was lined with the clay to improve weir function. Even with the observed low flows in-stream at the time of construction, fish such as brook trout, suckers, and American eel were present on site. Figures 56 to 62 show some of the remediation activities that took place at the site.

Figure 56. EAS009 Before remediation activities.

Figure 57. EAS009 After weir construction, prior to fish chute installation.

Figure 58. EAS009 After construction of tailwater control and fish chute installation.

Figure 59. Checking height of culvert to set notch stone.

Figure 60. Construction of the tailwater control weir at EAS009.

Figure 61. View of functioning fish chute after installation at EAS009.

Figure 62. A small pool was created below the weir at EAS009 to improve fish access.

3.2.7 BLK006 Unnamed Tributary of Black River

Location: Meadowvale Road, East Tremont, Kings County.
Remediation: 1 Vortex rock weir for tailwater control, and 1 fish chute
Outflow Drop: 39.8 cm
Slope: 0.08 %
Upstream Habitat Gain: 1.5 km
Weir Rocks Required: 6m^3
Rock Size: An incipient diameter of 5.04 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of 10.08 cm.
Fish Chute: A manufactured fish chute was installed as part of remediation activities. See appendices, Section 6.5 for more information.
Baffles Required: A weir to hold the fish chute was made from cedar posts and attached to the wooden culvert with galvanized lag bolts.
Comments: A broken wooden beam needed to be removed from the culvert outflow to allow for proper positioning of the fish chute. Due to the high sediment content in this stream, straw bales were used to alleviate the transport of sediment downstream during rock weir construction (see Figure 65). There were two beavers present during weir construction that were building a dam at the culvert inflow. A local landowner said the beavers were a regular nuisance and had permission from DNR to remove the dam whenever required. Once weir construction was complete CARP removed the dam. Figures 63 through 71 show the restoration activities that took place at BLK006.

Figure 63. BLK006 Before remediation activities. Note the large outflow drop and fallen timber.

Figure 64. BLK006 After tailwater control weir construction.

Figure 65. BLK006 Sediment trapping downstream of outflow.

Figure 66. Beaver at the inflow and outflow of BLK006.

Figure 67. BLK006 Volunteer and staff building the tailwater control weir.

Figure 68. The completed tailwater control weir at BLK006.

Figure 69. Beaver dam at inflow of BLK006.

Figure 70. Installing the fish chute at BLK006 with help from Adopt-A-stream staff.

Figure 71. Fish chute at BLK006 after installation.

3.2.8 ROC004 Rockland Brook

Location: Hall Road, Windemere, Kings County
Remediation: 1 Vortex rock weir for tailwater control and 1 fish chute were installed.
Outflow Drop: 66.5 cm
Slope: 3 %
Upstream Habitat Gain: 7 km
Weir Rocks Required: 7 m^3
Rock Size: An incipient diameter of 12.4 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of 24.8 cm.
Fish Chute: A manufactured fish chute was installed as part of remediation activities. See Section 6.5 in the appendices for more information.
Baffles Required: Six cedar posts (sized 3″x3″x8′) and one additional cedar post (sized 5″x5″x6′) were used to install the fish chute, 2 sets of baffles and a low flow barrier in one side of this double box wooden culvert. Attachment to the culvert was made with galvanized lag bolts.
Comments: Baffles installed with the low flow barrier will alleviate low water levels during low flow periods and will give fish a resting spot during higher flows. A local landowner who supervised the installation reported that he observed the weir during a severe rain event and the weir was directing high flows towards the middle of the stream and away from the eroding right stream bank, just as planned when the weir was installed. Rocks that were not needed for weir construction were used to reinforce the right bank above and below the weir, and a section of streambank near the culvert that was eroding as well. Figures 72 to 79 show remediation activities that occurred on-site.

Figure 72. ROC004 Before remediation.

Figure 73. ROC004 After tailwater control weir construction.

Figure 74. ROC004 Completed tailwater control weir.

Figure 75. ROC004 Looking upstream through the weir notch towards the culvert outflow.

Figure 76. ROC004 Culvert after weir construction, before chute installation.

Figure 77. ROC004B After fish chute installation.

Figure 78. ROC004 Fish chute, baffles in right side, and low flow barrier at left inflow.

Figure 79. View of ROC004 after all remediation activities were completed.

3.2.9 NEB004 Neilly Brook

Location: Highway 221, North Kingston, Kings County
Remediation: 1 Vortex rock weir for tailwater control, 1 fish chute, and 1 low flow barrier were installed.
Outflow Drop: 45.2 cm
Slope: 0.30 %
Upstream Habitat Gain: 1.5 km
Weir Rocks Required: 6 m^3
Rock Size: An incipient diameter of 7.9 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of 15.8 cm.
Fish Chute: A manufactured fish chute was installed as part of remediation activities. For more information, see Section 6.5 in the appendices.
Baffles Required: No baffles were required but 4 cedar posts were needed for installation of the fish chute and the low flow barrier. Galvanized lag bolts were used for attachment.
Comments: This restoration was completed with the help of volunteers from two different high school classes. Some channel clearing and streambank reinforcement was completed during the tailwater control weir construction to reduce erosion on the left bank downstream of the weir. A small quantity of moss mixed with mud from onsite were used to help seal the weir, but more matter will need to accumulate and plug the holes in the weir to improve its function during low flow conditions. A fish chute was installed at the outflow to help overcome the 45 cm drop, and a low flow barrier was installed in one of the culverts to improve water passage through the culvert during low flow conditions. Figures 80 to 86 show restoration activities that took place at NEB004.

Figure 80. NEB004 Before restoration work.

Figure 81. NEB004 After tailwater control weir installation.

Figure 82. NEB004 Downstream after bank reinforcement.

Figure 83. Volunteers hard at work constructing a rock weir at NEB004.

Figure 84. Finished tailwater control weir at NEB004.

Figure 85. NEB004 after fish chute installation.

Figure 86. NEB004 after installation of a low flow barrier at the inflow.

3.2.10 ALL017 Grand Lake Flowage Streamlet

Location: Princedale, Annapolis County
Remediation: 1 Vortex rock weir for tailwater control and 1 fish chute were installed.
Outflow Drop: 29.8 cm
Slope: 0.68 %
Upstream Habitat Gain: 1.5 km
Weir Rocks Required: 5 m^3
Rock Size: An incipient diameter of 3.06 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of 6.12 cm.
Fish Chute: A manufactured fish chute was installed as planned. See appendix section 6.5 for more detail.
Baffles Required: No baffles were required. A short piece of cedar was used as a low flow barrier in one of two culverts to increase the flow in the adjacent culvert during low flow conditions.
Comments: One of the two steel culverts at ALL017 had a low flow barrier installed, the other a manufactured fish chute. Fine gravel and some clay found onsite were used to plug holes in the weir. Constructed during a low flow period, this weir will need several high flow events to bring debris to seal the weir to improve its function during low flow conditions. Figures 87 through 91 show some before and after photos of culvert remediation work that took place.

Figure 87. ALL017 Before construction of tailwater control weir.

Figure 88. ALL017 After tailwater control weir construction.

Figure 89. ALL017 Finished tailwater control weir.

Figure 90. ALL017 after fish chute installation.

Figure 91. ALL017 Installation of low flow barrier at culvert inflow (culvert without the fish chute).

3.3 Excavator Work on the Nictaux River

Excavation work occurred in the summer of 2015 to continue the implementation of restoration actions started in 2014 to remediate derelict rock weirs in the Nictaux River. Three weir adjustments were made to bolster wing deflectors on weirs where reconstruction activities took place in 2014, and three new weirs also received remediation work in 2015. Rocks were required to be brought into sites for additional restoration activities in 2015, and were transported to downstream weir sites with a tractor and trailer (See Figure 92). Excavation work began at the furthest weirs downstream (i.e. Weir A) and progressed upstream of Weir G (See Figure 93). Rock was trucked into site to complete additional work on Weirs A, B and C in 2015 to bolster and adjust their wing deflectors. Upon inspection, it was determined that Weir D did not require any additional work this season. Weirs E, F, and G were redesigned and reconstructed in 2015 to more effectively carve out pools and build gravel bars to improve spawning habitats. These weirs primarily received work to their wing deflectors, and few adjustments were needed to the in-stream weir rocks.

Figure 92. Excavator and tractor used to move weir rocks to weir sites.

Re-visitation of the site in the spring will be important to observe how the weirs settled after being subjected to higher fall and winter flows. Future actions should also be identified for the weirs upstream of Weir G to improve habitat quality within the reaches between Weirs G and L. Figures 94 through 105 show some before and after photos of some of the instream work that was completed in 2015.

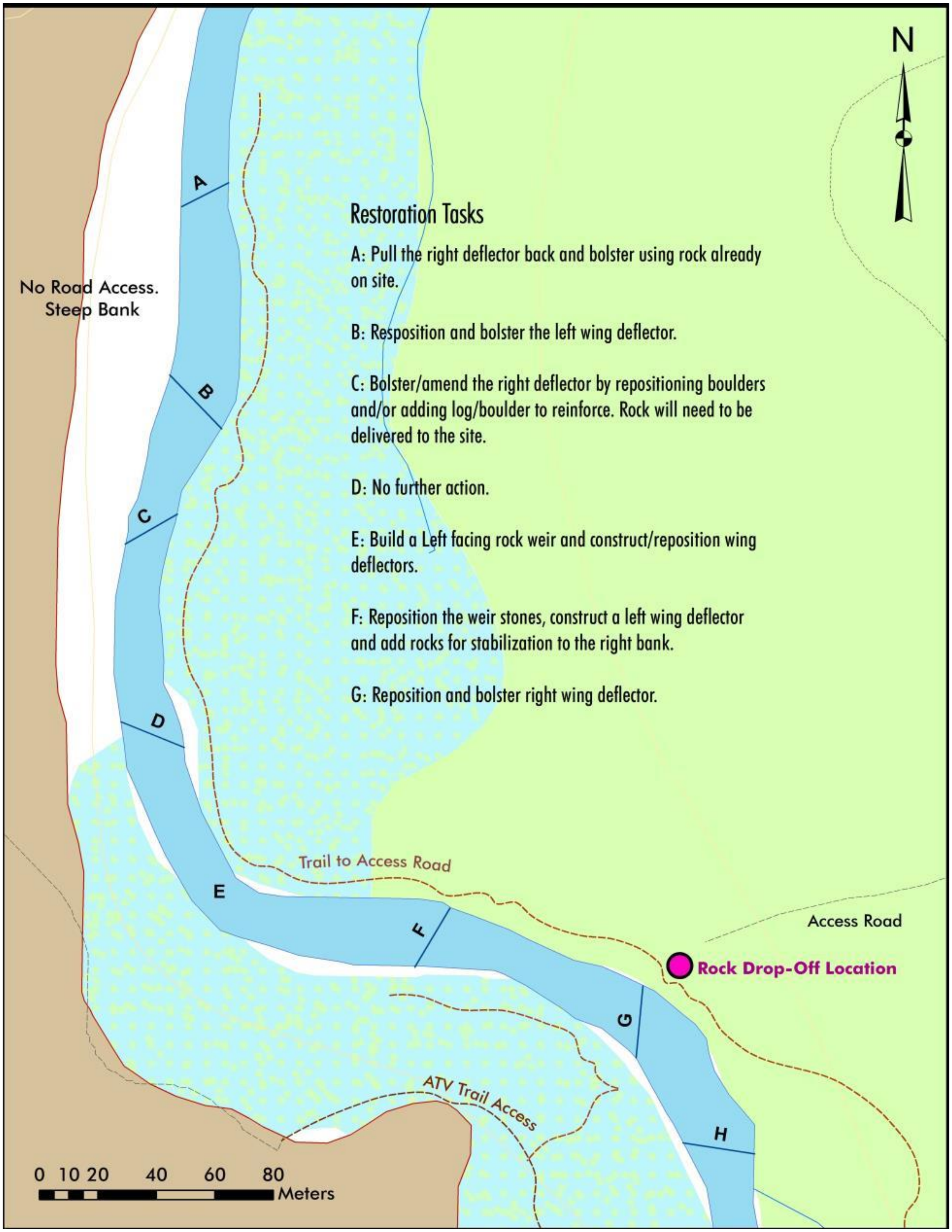

Figure 93. Site map of Nictaux in-stream restoration work and list of 2015 restoration activities.

Figure 94. Weir "A" before adjustments to right wing deflector.

Figure 95. Weir "A" after all adjustments were completed.

Figures 94 and 95 show Weir A before and after adjustments were completed. The right wing deflector was bolstered and slightly re-shaped using both large and small rocks. Additionally, one or two of the weir rocks had been displaced by high flows, and were repositioned and reinforced with additional rock.

Figure 96. Weir "B" Before additional bolstering activities.

Figure 97. Weir "B" After adjustments were completed.

Figures 96 and 97 show restoration activities that occurred at Weir B in 2015. The majority of adjustments were made to the left wing deflector with the addition of some bigger rocks downstream and smaller stones were used for backfill. The right wing deflector had a couple of new large rocks added and was bolstered with smaller stones.

Figure 98. Weir "C" Before wing deflector adjustments.

Figure 99. Weir "C" After completion of restoration activities.

Weir “C” (see Figures 98 and 99) required some rearrangement of weir rocks to reinforce and direct the flow away from the left bank. A wing deflector was also created to achieve this effect, and a trench was dug to accommodate the placement of the log used to construct the deflector (See Figure 109). Re-shaping and addition of more material to the right wing deflector was also completed. The log deflector was installed and backfilled by hand by CARP staff after the weir excavation work was completed.

Figure 100. Weir "E" Before restoration activities.

Figure 101. Weir "E" after re-construction of wing deflectors.

Weir “E” required re-construction work in 2015 (see Figures 100 and 101). After consultation with experts, it was decided that the in-stream weir rocks were well placed, but that the structure required two deflector weirs: a left wing deflector to direct flows away from the bank downstream, and a right wing deflector. Large rocks were added on-site to create the deflectors, which were backfilled as well.

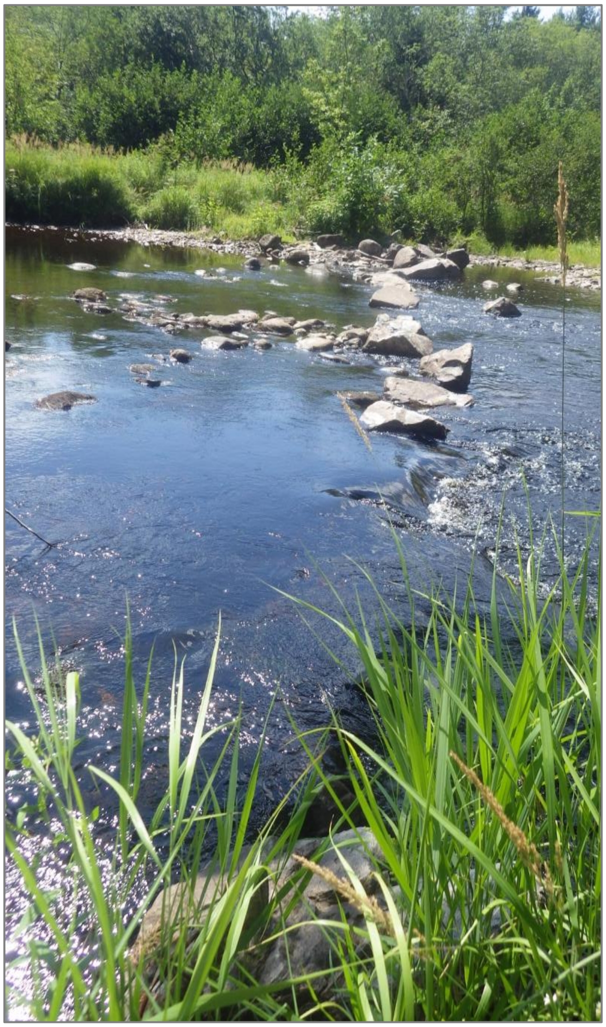

Figure 102. Weir "F" before instream restoration work.

Figure 103. Weir "F" after instream restoration work.

Weir “F” required reshaping of the left bank wing deflector, which was repositioned, and large rocks were added to it. Rocks were added to the right bank to improve its stability and minimize bank erosion. The main part of the weir was also adjusted and reset. Figures 102 and 103 show the before and after photos of the restoration activities that occurred at Weir F.

Figure 104. Weir "G" before remediation activities.

Figure 105. Weir "G" after the addition of the right wing deflector.

Weir G did not require a lot of re-construction work. Some large rocks were used to reshape and rebuild the right wing deflector, and were backfilled with rubble. A deflector was not required on the opposite bank, and the in-stream portion of the weir required little remediation. Figures 104 and 105 show the work before and after completion.

3.4 Digger Logs and Wing Deflectors

Three wing deflectors and a double length digger log were installed on the Nictaux River in 2015. One deflector was installed on the left bank of Weir "C" to redirect the flow of the river away from an eroding bank.

A double digger log structure was also installed approximately 400 meters downstream of Weir A at a shallow part of the river that did not support fish passage at low flow conditions and where the right bank was eroding during high flows. The structure required the installation of two digger logs to span the entire width of the river, and left and right wing deflectors were also installed on the right bank to curb bank erosion.

After the double digger log structure was installed it was decided that a wing deflector was needed on the left bank as well due to a sand bank vulnerable to erosion where that end of the weir joined the bank.

3.4.1 Deflector weir on weir "C"

Figures 106 and 107 show before and after photos of the left bank of Weir C, prior to and after the installation of the left wing deflector. Figures 108 through 110 show some of the installation process that took place to secure the deflector and backfill it with rocks. This was a single log structure backfilled with rocks. A suitable tree found just upstream of the weir was cut down, trimmed, and cut to length for the deflector weir. The unused end of the tree was floated downstream and used in the digger log structure wing deflectors.

Figure 106. Before remediation activities.

Figure 107. After log deflector installation.

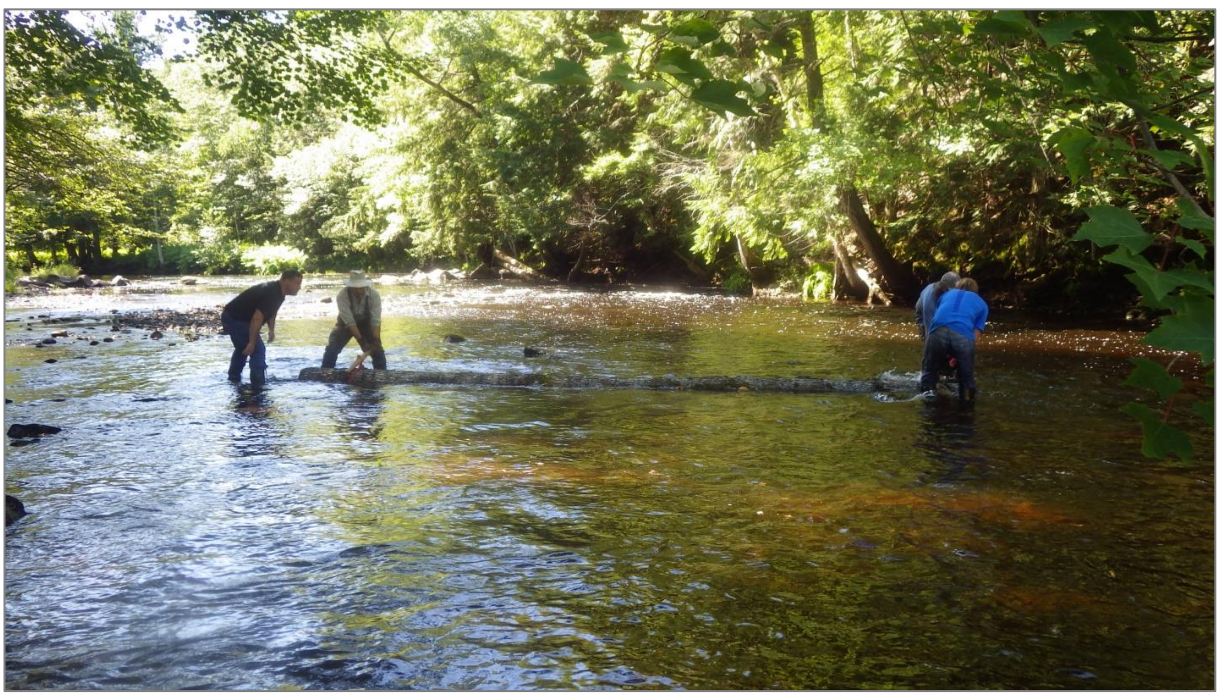

Figure 108. Log carried/floated/dragged to weir.

Figure 109. Crew members securing a log to the streambed as part of the installation of a wing deflector at Weir C.

Figure 110. Finished wing deflector.

3.4.2 Double Digger Log Installation

Two ten meter oak logs, cut from nearby trees, were placed end to end to create a digger log structure (Figure 111). The narrower ends were faced away from the banks to aid in directing the flow of the river towards the center of the river. Prior to installation, the location where the logs were installed was a wide stretch of very shallow water whose thalweg was closest to the right bank, resulting in serious river bank erosion. The shallow water was also restricting fish passage during low flows. Figure 113 shows how the installed digger log has directed the flow towards the middle of the river, taking pressure off the right bank. The erosion on the right bank can be seen in this picture as well.

Rocks from the streambed were packed in around the digger logs to start creating a downstream pool. Three deflector weirs were added to this structure to aid in directing flow to the middle and to help prevent erosion of the riverbanks. Figures 112 to 117 show some of the work that was completed in the installation of the double digger log structure.

Figure 111. Straight trees were used to create the digger logs. Conifers are the most ideal.

Figure 112. Before, showing tree cut (one of three needed), ready for trimming.

Figure 113. After, digger logs in place.

Figure 114. Fitting the log tight to the bank.

Figure 115. Logs were secured to the streambed using re-bar.

Figure 116. Placing rocks on the upstream side of the digger log.

Figure 117. Finished double digger log structure, prior to installation of wing deflectors.

3.4.3 Digger Log Wing Deflectors

Left and right wing deflectors were installed along with the double digger logs. A full wing deflector was installed on the right bank (both upstream and downstream), while the left wing deflector had a structure installed on only the upstream side of the digger log. The one on the left bank, made with a pyramidal arrangement of three logs (two on bottom one on top), was backfilled with rocks found nearby on the river bottom. The right deflector upstream of the digger log was also pyramidal, backfilled with medium and large woody debris cut up from nearby dead trees and left over wood from the trees cut for the weirs and digger logs. The downstream deflector weir was made from one large log and backfilled with woody debris as well. Both the upstream and downstream parts of the right deflector had large branches from cut trees attached to them and which were staked into the riverbank to allow them to better absorb the energy from high flow events. Figures 118 to 125 show the digger log wing deflector installations.

Figure 118. Before digger log and wing deflector installation, upstream view.

Figure 119. After digger log and wing deflector installation, downstream view.

Figure 120. Upstream triple log portion of the left wing deflector during the installation process.

Figure 121. Reinforcing wing deflectors with trees and branches tied into the banks with stakes.

Figure 122. Completed right bank deflector.

Figure 123. Left bank before installation of wing deflector.

Figure 124. Securing the left bank pyramidal log structure in place.

Figure 125. Left bank deflector finished.

4.0 Recommendations

Recommendations are based on this year's field season experience as well as previous work through the Broken Brooks program. Recommendations for the 2015 field season are listed under the three main types of restoration activities that occurred.

4.1 Culvert Restorations

1) Fish chutes proved to be a viable restoration tool for culvert restoration activities to address culverts with larger outflow drops, and should continue to be included in CARP's future tailwater control restoration activities.
2) A designed structure should be created to simulate the low flow notches that are constructed as part of tailwater control weir structures. Something similar to a fish chute could be developed for use as part of the rock weir designs, and improve weir efficiency, as well as ease of installation.
3) Sites where restoration activities have taken place should be revisited regularly, and maintenance of constructed rock weirs should be included in future restoration planning.

4.2 Digger Logs and Deflector Weirs

1) To improve the ease and efficiency of digger log installation, the use of a generator and a heavy duty hammer drill should be considered for driving re-bar into the streambed to secure the logs.
2) The digger log structure installed in the Nictaux River should be revisited and assessed for functionality, durability and any maintenance requirements next field season
    a. The right wing deflector should be revisited to verify whether the new method utilized to stabilize the bank and backfill the deflector will be feasible for continued use.
    b. The structure should be inspected to ensure it is redirecting flows as intended.

4.3 Excavator Work on the Nictaux River

1) Restoration work on the Nictaux River will need to be continued in the future to:
    a. Revisit structures that received remediation work in 2016 to ensure their functionality
    b. Identify and implement future actions for weirs upstream of Weir G
    c. Improve habitat quality downstream of Weir A through possible construction of further instream structures and/or other activities such as sandwanding.

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6.0 Appendices

6.1 Prioritization Process for Culverts

Taken from Freeman (2014a):

High priority culverts are those that gain the greatest benefit from remediation. There are two key variables considered during the prioritization process:

1. Number of downstream barriers – Barriers downstream can reduce a fish's chance of migrating between the main channel and the watercourse.

2. Upstream habitat gain – If the barrier at a road-watercourse crossing were to be restored, this is the estimated quantity of upstream habitat that would be made accessible.

The two variables were subdivided into categories, each with a corresponding score (Table 4). The culvert with the highest cumulative score was deemed to be the highest priority culvert. The prioritization in 2013 and 2014 varied from those completed in past years, as two variables were used rather than three. The "adjacency to main channel" category was removed, as it was closely related to the "number of downstream barriers" category and was resulting in ranking culverts twice for the same characteristic (the number of barriers between the main channel and the culvert being assessed).

Table 6. Road-watercourse crossing prioritization index.

Variable	Criterion	Score
Number of downstream barriers	0 barriers	10
	1 barrier	5
	>2 barriers	0
Upstream habitat gain	>4.5 km	20
	4 – 4.5 km	18
	3.5 – 4 km	15
	3 – 3.5 km	14
	2.5 – 3 km	12
	2 – 2.5 km	10
	1.5 – 2 km	8
	1 – 1.5 km	6
	0.5 – 1 km	4
	<0.5 km	2

After receiving a prioritization score, culverts were then classified into one of three categories: high, medium or low priority, based upon their scores (Table 5). Previously, culverts were prioritized solely based upon the amount of upstream habitat (in km) gained through restoration. This however, did not account for the presence of downstream barriers. A comprehensive list of all culverts that have received detailed assessments by CARP was compiled in 2014, but barrier culverts need to be re-prioritized for remediation activities.

Table 7. Prioritization categories for culverts based on prioritization scores.

Priority Category	Prioritization Score Range
High	24 to 30
Medium	9 to 23
Low	2 to 8

6.2 NSE Notification Form

Nova Scotia Environment *Notification for Designated Activities* *watercourse alterations*

NOVA SCOTIA
Environment

NOTIFICATION FORM

OFFICE USE ONLY		*Application #*
Date Rec'd (yyyy/mm/dd)	*Ext. Ref. #*	*NSE File #*

The notification form must be received by Nova Scotia Environment at least 5 days before work commences. Work may only start after you (the notifier) have received a notification receipt from Nova Scotia Environment.

If you provide your email address and your notification is complete, Nova Scotia Environment will aim to send you the notification receipt by email within 5 days. If there is no email provided, Nova Scotia Environment will aim to put the notification receipt in the mail within 5 days.

PLEASE PRINT OR TYPE. Complete sections 1, 3, 4, applicable parts of 5, and 6 or the notification will not be accepted. Please keep a copy of your notification form. Incomplete forms will not be returned to the notifier.

Type of notification:	New ☐	Renewed ☐	Amended ☐	If this is a renewed or amended notification, provide previous notification #

SECTION 1 - NOTIFIER

Notifier: Are you the owner of the property where the activity will take place ; the person with primary responsibility for the designated activity, such as a certified watercourse alteration sizer or installer ; an agent for owner or the person with primary responsibility .

Company/Organization/Municipality					
Business Number (BN) *if applicable*					
Mr. ☐ Ms. ☐ Mrs. ☐ Other:			Professional Designation		
First Name		Middle Initial	Family Name		
Phone	Home ( )	Business ( )	Ext.	Other ( )	Ext.
Fax ( )		E-mail			
Civic/Street Address					
Mailing Address (if different than Civic)					
County			City/Town		
Province		Postal Code		Country	

SECTION 2 - NOTIFICATION CONTACT (Optional)

Company/Organization/Municipality					
Business Number (BN) *if applicable*					
Mr. ☐ Ms. ☐ Mrs. ☐ Other:			Professional Designation		
First Name		Middle Initial	Family Name		
Phone	Home ( )	Business ( )	Ext.	Other ( )	Ext.
Fax ( )		E-mail			
Civic/Street Address					
Mailing Address (if different than Civic)					
County			City/Town		
Province		Postal Code		Country	

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6.3 TIR Work Within Highways Right-of-Way Permit

NOVA SCOTIA
Transportation and Infrastructure Renewal

Work Within Highway Right-of-Way Permit

Who needs this permit? If you are planning any activity / work on the roadway or within the highway right-of-way, including installing a driveway or erecting a structure within 100 metres of any highway, a permit is required prior to starting the work. Please read the **"Information for Work Within Highway Right-of-Way Permit"** brochure (brochure) before completing this application.

For Staff Use Only

Permit Approved ____ (Check here)
Permit Denied ____ (Check here)
Permit #: ____________
Deposit Receipt #: ____________
Deposit Amount: ____________
Permit Valid until: ____________

1 Applicant Information (please print)

Name: ______________________________

Mailing address: ______________________________

______________________________ Postal code: ____________

Daytime phone number: ____________ Email address (if applicable): ____________

2 What type of work will you be doing by the roadside? (check all that apply)

☐ Access to a public highway/roadway for the purpose of: ☐ Sewer ☐ Water ☐ Cable ☐ Driveway ☐ Other ________

☐ Work will disturb existing road surface. If so, what type? ☐ Asphalt ☐ Concrete ☐ Gravel ☐ Other ________

☐ Building a structure within 60 metres of the limit of a controlled access highway

☐ Building a structure within 100 metres of centerline of a public highway/roadway

3 Check type of structure or access you require. If not applicable, go to number 4

☐ Residential ☐ Agricultural ☐ Commercial ☐ Industrial ☐ Recreational ☐ Institutional ☐ Other ________

4 Give enough information so our staff can find your property (complete as much as possible)

Name of subdivision: ____________ Name of lot owner: ____________

Civic or lot number: ____________ Property ID #: (if known) ____________

Name of community: ____________ in ____________ County

Name of highway/roadway: ____________ on the ☐ North ☐ South ☐ East ☐ West side of highway

Approximately ________ (Distance) km's ________ (NSWE) of ____________ (Bridge or any defined point on Highway)

GPS Coordinates: (if known) ____________ N ____________ E

Distance of nearest part of structure to centerline of highway is ________ metres

Number of lots to be serviced by this access is ________

Distance from centerline of highway to sewer, well, spring, etc. is ________ metres

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6.4 Rock Weir Design and Construction

6.4.1 Rock Weir Design

Taken from Taylor, 2010

The tailwater control is located downstream of the outflow pool. It is the highest elevation point leading into the natural downstream channel. The objective is to increase the height of the existing tailwater control or establish a new one. Increasing the height will thus increase the depth of the outflow pool reducing or eliminating the outflow drop. After extensive literature review, it was decided that a vortex rock weir design would be used as means of a tailwater control. This is a U-shaped design, where the apex points upstream. The weir is designed to be either on a 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 126).

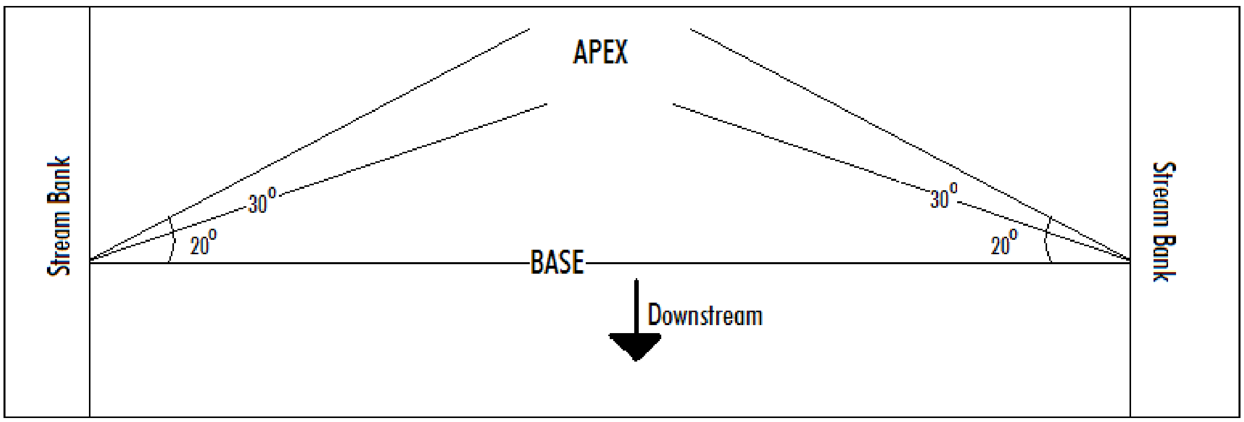

Figure 126. Vortex rock weir design.

Footer stones, which are large, flat 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. Pebbles and cobbles are used as fill throughout the construction. For example: for every centimeter high the weir is built, the width of each side of the base is one and a half times that (1.5 cm). Therefore the width of the whole weir is 3 times the height. The apex of the structure is the lowest point of elevation, referred to as the low flow notch (an area along the weir where water can flow through during low flow conditions). The elevation of the low flow notch should be at or slightly higher than the elevation of the inflow end of the culvert if possible. The ends of the weir should be at or above bankfull height.

The recommended size of the outflow pool is a width twice the culvert's diameter, and for a double culvert, twice the combined diameter. The recommended length is three times the culvert's diameter, and for a double culvert, three times the combined diameter. The recommended depth of an outflow pool is 1.0 metre.

6.4.2 Rock Weir Construction

Construction of a weir consists of the following steps:

1) Determine the location of the weir relative to the culvert

According to recommended guidelines, the outflow pool downstream of a culvert should have a length that is three times the culvert's diameter and twice its width (DFO, 2015). Culvert diameter is therefore measured and used to estimate the distance required for the placement of the downstream tailwater control. A survey stake is used to mark where the apex of the weir should be placed.

2) Demarcate the shape of the weir

Strings are next tied to the stake marking the weir apex, and used to measure out a 30° angle from the bankfull edges to the center stake. Strings are tied high enough on the stakes to be used as a guide to follow without interfering with weir construction.

3) Measure the required elevation for the low flow notch.

The elevation of the low flow notch, should ideally be 0.2D (where D is the culvert diameter) higher than the culvert outflow elevation. This will allow the water from the outflow pool to back into the culvert, and raise the water level through the culvert. A survey level and rod should be used to ensure that the low flow notch is placed at the correct height. This will be the lowest point of the weir.

4) Construct the weir

Once the weir shape and height have been measured out, the next step is to then begin the weir's construction. Larger footer stones are used to construct the base of the weir, and are entrenched 1/3 of their height in the streambed to anchor the weir in place (DFO, 2015). The base is installed using the strings as a guide, fitting rocks as tight together as possible. Once the base and low flow notch are in place, the strings are removed and the weir body of the weir is built. Large stones, although smaller than the footer stones, are used to construct the body of the weir. Stones are placed at a 1:3 ratio (where the base of the weir is 3x its height), and are sloped upwards towards the banks. The edges of the weirs are built up over the banks to prevent water eroding around the edges. Any spaces in the weirs are then plugged to increase the impermeability of the weir, using materials available on site such as mud, grass and moss. Some of the weirs will require some time and a few high flow events before they will hold enough water to work properly in low flow periods. This allows small debris in the high flows to become deposited in the weir cracks and holes, creating a less permeable structure.

5) Bolster banks/ outflow pool

When the weir construction is complete, any leftover rock can be used to re-inforce eroding stream banks or bolster the edges of the pools.

6) Re-inspect weirs

It is a good idea to re-visit weirs regularly to ensure that they are functioning as designed, and to perform maintenance as may be required.

6.5 Fish Chutes Designed for 2015

6.5.1 Design for BAL001, BLK006, and NEB004

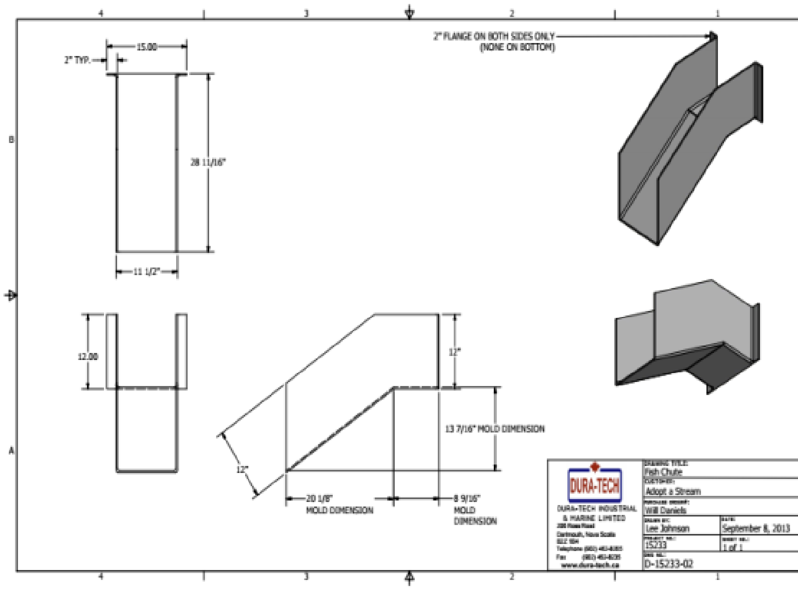

Figure 127. Fish chute designs for BAL001, BLK006, and NEB004.

Fish chutes were built according to the previous drawing with the exception of the following modifications: Notch depths (i.e. from top of baffle to floor of culvert) were 200mm/8" (not 12"). Notch widths were 300mm/12" (not 11 1/2").

6.5.2 Design for ROC004

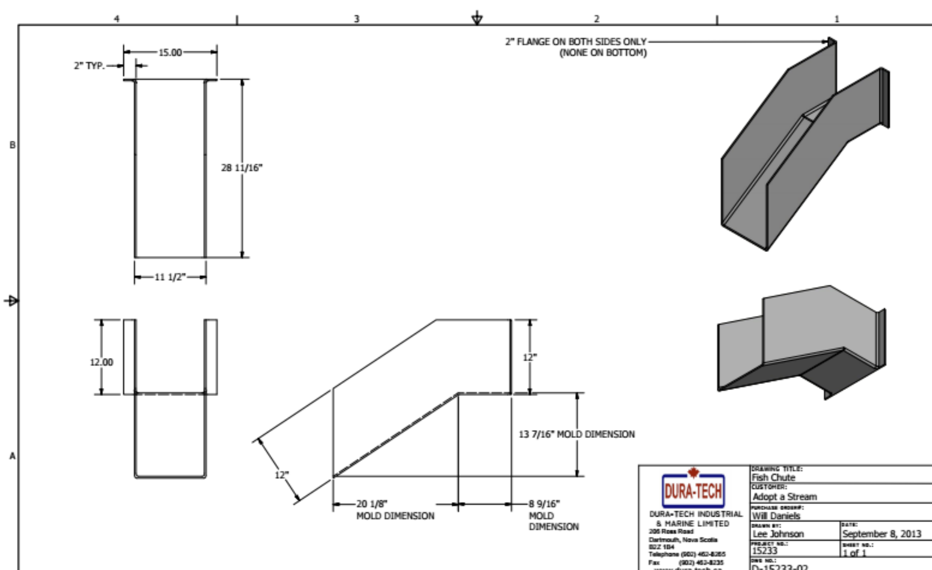

Figure 128. Fish chute design for ROC004.

The fish chute was built according to the drawing in Figure 131, except for the following modifications: Notch depth (i.e. from top of baffle to floor of culvert) was 250mm/10" (not 12") Notch width was 600mm/24" (not 11 1/2").

6.5.3 Design for RHR013

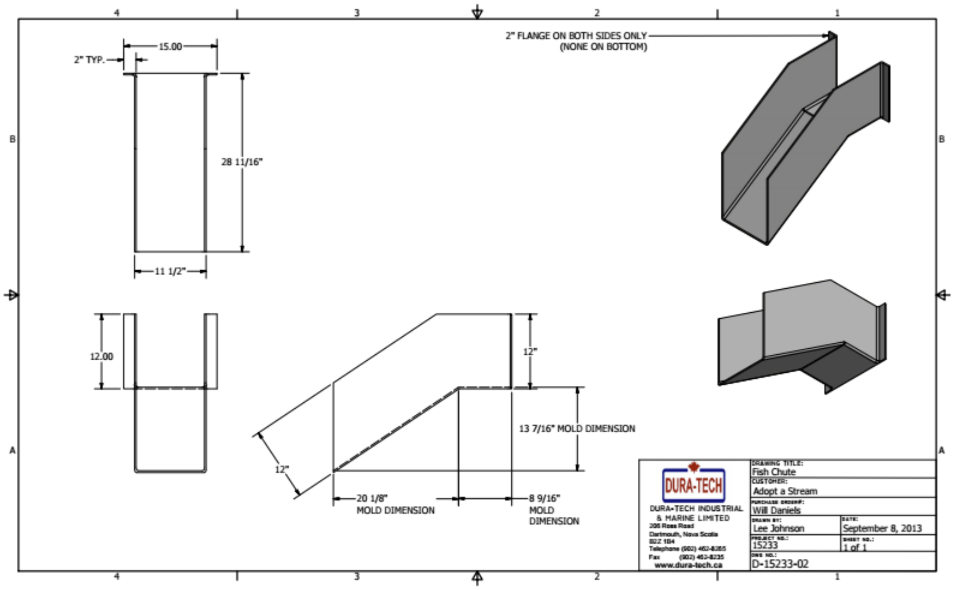

Figure 129. Fish chute design for RHR013.

The fish chute was built according to Figure 132 except for the following modifications; Notch depth (ie. from top of baffle to floor of culvert) was 290mm (not 12"). Notch width was 300mm/12" (not 11 1/2"). The notch floor extended 300mm/12" (not 8 9/16"). Flanges were 10cm wide.

6.5.4 Design for ALL017

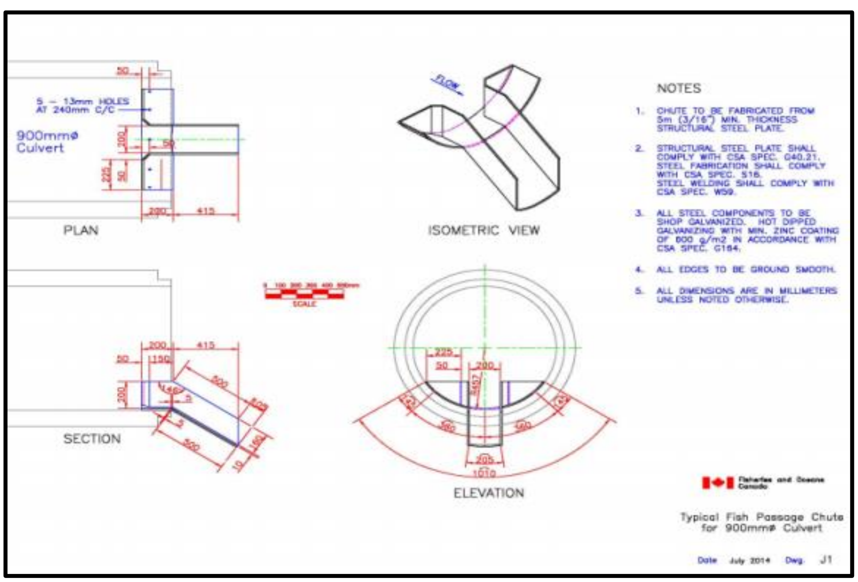

Figure 130. Fish chute design for ALL017.

The fish chute was built according to the previous drawing except for the following modifications. Notch depth (i.e. from top of baffle to floor of culvert) was 150mm (not 200mm), and the diameter of the culvert where the chute was installed was 600mm (not 900).

6.5.5 Design for EAS009

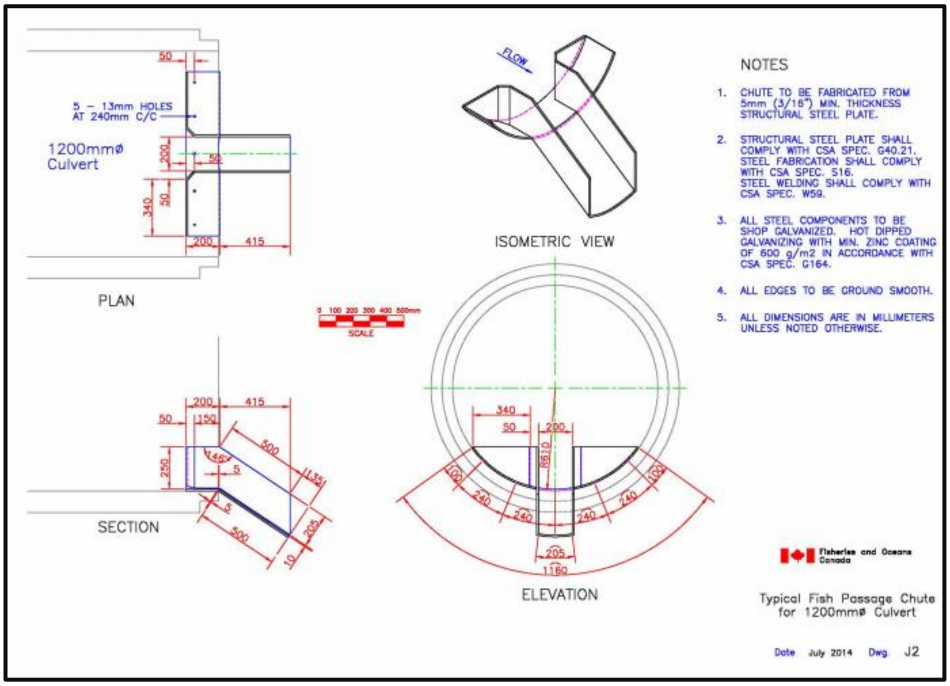

Figure 131. Fish chute design for EAS009.

The fish chute was built according to the previous drawing except for the following modifications: Notch depth (ie. from top of baffle to floor of culvert) was 150mm (not 200mm). The diameter of the culvert where the chute was installed was 1000mm (not 1200mm)

6.6 Baffle Notch spacing

From (DFO, 2015)

Baffle spacing is influenced by notch depth, depth of water, culvert fabrication methods, fish species behavior and fish swimming abilities. These factors have been taken into consideration in these *Guidelines* by setting standards for baffle height, baffle drops, spacing minimums and maximums and by setting standard notch sizes.

The minimum distance between baffles should be 1.63 m in order to dissipate enough flow energy between baffles. The maximum spacing of baffles depends on the prescribed drops between water surfaces in pools and the established culvert slope.

Formula to calculate maximum baffle spacing

$l = \Delta h$ / culvert slope
Where,
l is the maximum spacing between baffles.
Note: If the culvert is prefabricated, choose the spacing that will fit best with the manufacturer's specification. That will still be less than **l**. **l** will also determine the location of the most upstream baffle. You have reached the last baffle when the distance between a baffle and the upstream end of the culvert is less than **l**.
Δ h is the maximum drop between baffles (0.20 metres (m) or 0.15 m when passage for smelt is needed).
culvert slope (%) is the gradient of the culvert.

6.7 Baffle Notch Sizing

From DFO, 2015.

Determining baffle notch sizes

In order to ensure that there is enough water volume between the baffles for fish to rest in, the baffle height must be 500mm. Baffle width is based on structural integrity and is a manufacturing determination. The notch is normally located in the middle of the baffle. However, it can also alternate from one side to the other. The notch size (width and depth) is designed to have enough water for fish passage in the notch during periods of lower flows (June Q60) in the watercourse. There may be times during the year that there is not enough water going over the notch to allow passage of fish. In general, this is a temporary concern usually alleviated by the next rainfall. The notch depth is a minimum of 50 mm greater than the drop between baffles, ensuring that the notch will generally be submerged during periods of fish migration The notch of the baffle should be sloped 1:2 in a downstream direction The edges of the baffle should be rounded by 1/3 of the baffle width at the upstream side of the baffle. These small details in notch design make the surfaces more gradual and help fish pass through the notch more easily.

Table 8 below shows proper notch sizes based on the minimum amount of flow required to fill the notch. If the watercourse does not have the minimum flow required for a certain size notch, then the design must follow the next lowest minimum flow. This decreases the notch size ensuring a full notch at the June Q60. For example if the June Q60 flow is calculated to be 0.052 m^3/s the design must default to the next minimum flow of 0.045 m^3/s to ensure the notch is full.

Table 8. Baffle notch sizes.

Minimum flow to fill notch area (June Q_{60})	Notch width (z)	Notch depth (x)	Baffle height (b)	Max. drop between baffles (△h)
0.023 m^3/s	150mm	200mm	500mm	150mm
0.030 m^3/s	200mm	200mm	500mm	150mm
0.045 m^3/s	300mm	200mm	500mm	150mm
0.064 m^3/s	300mm	250mm	500mm	200mm*
0.085 m^3/s	400mm	250mm	500mm	200mm*
0.107 m^3/s	500mm	250mm	500mm	200mm*
0.128 m^3/s	600mm	250mm	500mm	200mm*

The June Q60 flow can be calculated by using a prorated calculation method wherein the hydrometric data from Environment Canada is used and prorated to the watercourse crossing site using standard runoff coefficients. Below are calculations used for determining baffle notch sizes for the fish chutes and baffles installed in the 2015 field season.

June Q60 Design Flow for Culvert Sites located in Nova Scotia Primary Watersheds:
DA Meteghan/Salmon Rivers
DB Sissiboo/Bear Rivers
DC Annapolis River
DD Cornwallis/Gaspereau Rivers
DE St. Croix River
DF Kennetcook River
DG Shubenacadie/Stewiacke Rivers

1) Determine the Mean Annual Runoff value for the culvert site:
(Locate value from the Mean Annual Runoff Map)
Site Mean Annual Runoff (MAR) = mm
2) Determine the watershed Drainage Area value for the culvert site:
Site Drainage Area (DA) = km^2
3) Prorate the required Culvert Site Design Flows from the Benchmark Values:
JUNE Q60 = june q60 x MAR/mar x DA/da = m^3/s
Note: Benchmark Values were averaged from Gauging Stations: 01DD004
01DD005

Benchmark Values: mean annual runoff (mar) = 725 mm drainage area (da) = 12.3 km^2
Results for Annapolis River **june q60 = 0.145 m^3/s**

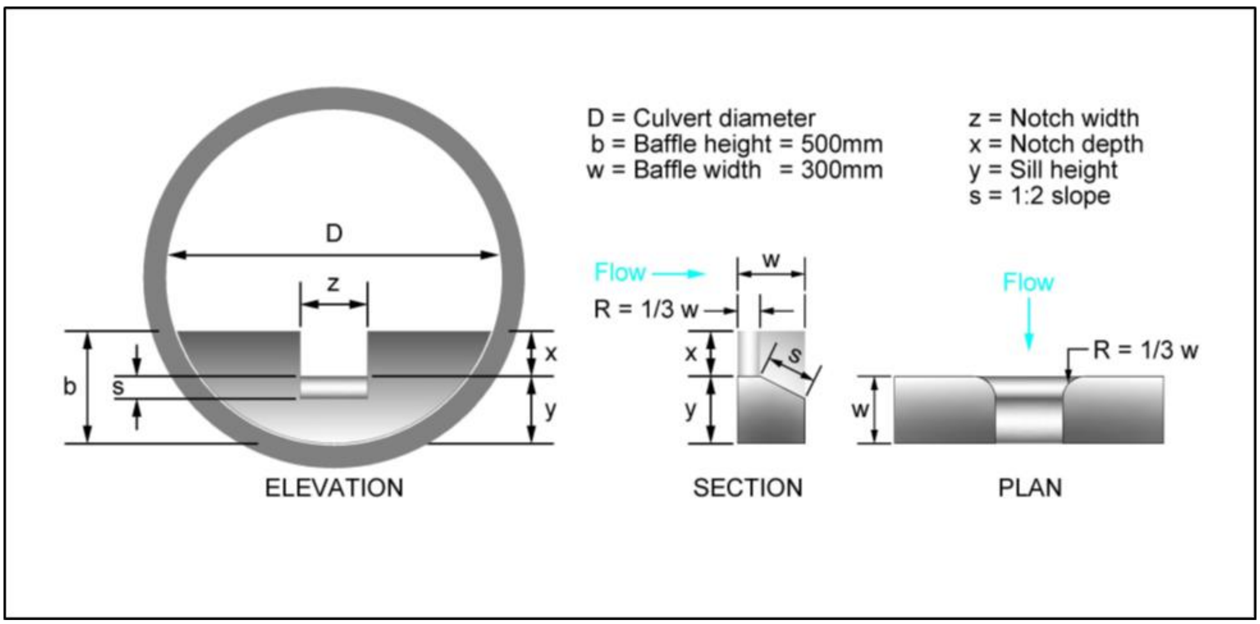

Figure 132. Baffle notch sizing for concrete culvert baffle (cross-sectional area).

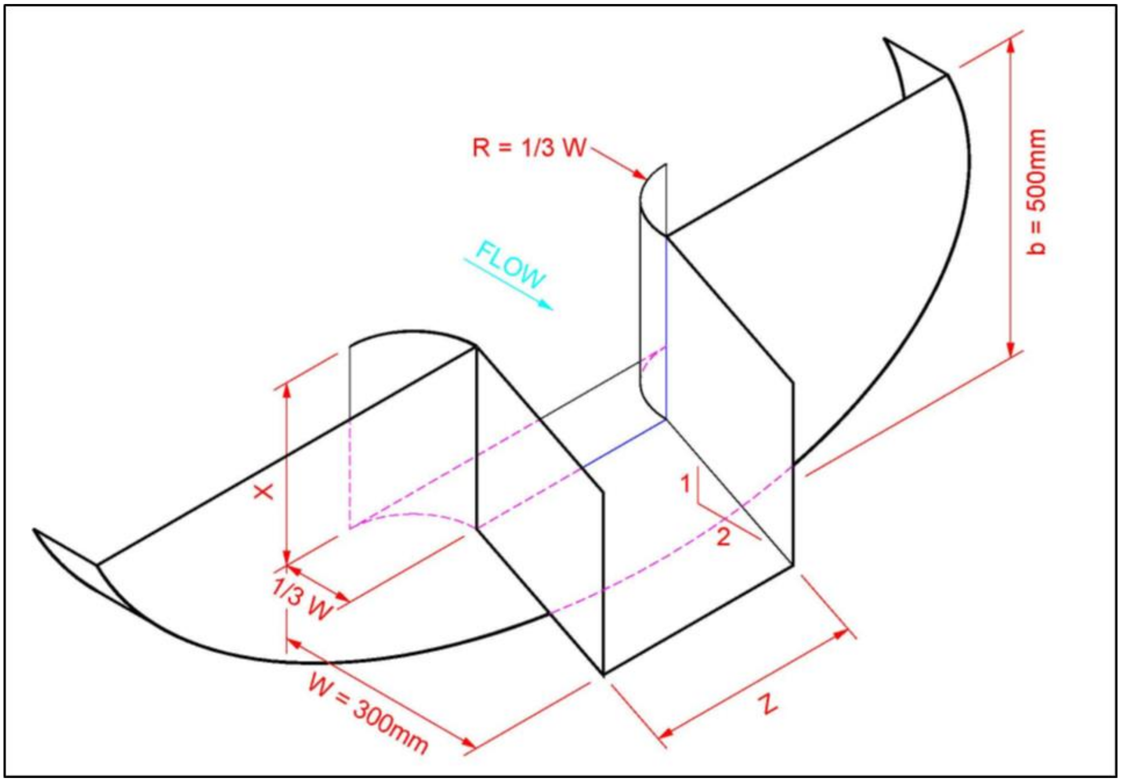

Figure 133. Baffle sizing for metal culvert baffle.

When Rainbow smelts are present the Δh is 150 mm
Notch sizes derived using the Larinier (2003) formula.

Q = 0.4 z √2g h1.5 (1 – (h - Δh/h)1.5)0.385
where
Q = full notch flow
z = notch width
h = notch height
Δh = elevation difference between baffles
g = gravitational acceleration

6.8 Rock Weir Calculations

To determine the amount of rock that would be required to build rock weirs, the following formulae were used (Taylor, 2010):

Volume (V) = Length (l) x Width (w) x Height (h)

To determine the minimum size of rock that would be required to construct a rock weir able to withstand the velocity of the water the incipient diameter of bed material was calculated (Cummings et al., 2004).

T (kg/m2) = Incipient Diameter (cm)
Where, *T* represents tractive force. The equation for tractive force is:

T = 1000 X d X s
Where, d is depth of flow in metres and s is the slope of water surface

6.8.1 BAL001 Balcom Brook

Location:

20 T 0299033 4955387

Remediation:

2 rock weirs to raise tail water pool level, a low flow baffle in one side of double box culvert to increase flow to other side, and a manufactured chute to allow fish access to the culvert.

Weir rock volume:

Volume (V) = Length (l) x Width (w) x Height (h)
2 weirs; 4m x 1.35m x .45m = 2.43m^3 x 2 = **4.86 m^3** **ordered: 7m^3**

Rock size:
T = 1000 X d X s
Where, d is depth of flow in metres and s is the slope of water surface
Based on the measurements recorded during the full culvert assessment survey, the downstream slope at BAL001is 0.0571; the average water depth in the downstream is 0.08 m. Based on these measurements, the tractive force was calculated:
T = 1000 X 0.08 m X 0.0571
T = 4.568 cm

An incipient diameter of 4.568 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of **9.13cm.**

6.8.2 EAS009 East Moose River

Location: Fraser Rd., Princedale

20 T 0299139 4945996

Remediation:

Construct a rock weir to raise tail water pool level, and install a manufactured slide to allow fish access to the culvert.

Weir rock volume :

Volume (V) = Length (l) x Width (w) x Height (h)

4m x .90m x .30m = **1.1m^3** **ordered: 2m^3**

Rock size:

T = 1000 X d X s

Where, d is depth of flow in metres and s is the slope of water surface

Based on the measurements recorded during the full culvert assessment survey, the downstream slope at EAS009 is 0.034; the average water depth in the downstream is 0.154m. Based on these measurements, the tractive force was calculated

T = 1000 x d x s

T = 1000 x 0.154 x 0.034

T = 5.24 cm

An incipient diameter of 5.24 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of **10.48cm.**

6.8.3 ALL017 Grand Lake Flowage Streamlet

Location: Clementsvale Rd, Princedale

20 T 0300384 4951577

Remediation:

Construct a rock weir to raise tailwater pool level, and install a manufactured chute to allow fish access to the culvert.

Weir Rock Volume:

Volume (V) = Length (l) x Width (w) x Height (h)

V = 5m x 1.35 m x .45m = **3.04 m^3** **Ordered – 5m^3**

Rock Size:

T = 1000 X d X s

Where, d is depth of flow in metres and s is the slope of water surface

Based on the measurements recorded during the full culvert assessment survey, the downstream slope at ALL017 is 0.0.068; the average water depth in the downstream is 0.154m. Based on these measurements, the tractive force was calculated

T = 1000 X d X s

T = 1000 x 0.45 x 0.068

T = 3.06 cm

An incipient diameter of 3.06 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of **6.12 cm.**

6.8.4 NIC002 Nictaux River Tributary

Location: Hwy.201, Nictaux

20 T 0339405 4977436

Remediation:

2 rock weirs to raise tailwater pool level, and a manufactured slide to allow fish access to the culvert.

Weir rock volume:

Volume (V)= Length (l) x Width (w) x Height (h)

2 weirs: V = 3.5 x .90m x .30 x 2 = **2.05m^3** **Ordered – 4m^3**

Rock Size:

T = 1000 X d X s

Where, d is depth of flow in metres and s is the slope of water surface

Based on the measurements recorded during the full culvert assessment survey, the downstream slope at NIC002 is 0.131; the average water depth in the downstream is 0.08m. Based on these measurements, the tractive force was calculated

T = 1000 X d X s

T = 1000 x 0.0.08 x 0.131

T = 30.42 cm

An incipient diameter of 10.48 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of **20.98 cm.**

6.8.5 BLK006 Black River

Location: Meadowvale Rd., East Tremont

20 T 0342449 4979106

Remediation:

Construct a rock weir to raise tailwater pool level, and install a manufactured chute to allow fish access to the culvert. At least one 6x6's needs to be removed to allow for proper positioning of slide.

Weir rock volume:

Volume (V)= Length (l) x Width (w) x Height (h)

V = 5 x 1.80 x .60 = **5.4 m^3** **Ordered – 6m^3**

Rock Size:

T = 1000 X d X s

Where, d is depth of flow in metres and s is the slope of water surface

Based on the measurements recorded during the full culvert assessment survey, the downstream slope at BLK006 is 0.072; the average water depth in the downstream is 0.07m. Based on these measurements, the tractive force was calculated

T = 1000 X d X s

T = 1000 x 0.07 x 0.072

T = 5.04 cm

An incipient diameter of 5.04 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of **10.08 cm.**

6.8.6 ROC004 Rockland Brook

Location: Hall Rd. Windemere

20 T 0360765 4985776

Remediation:

Construct a rock weir to raise tailwater pool level, and install a manufactured chute to allow fish access to the culvert.

Weir rock volume:

Volume (V)= Length (l) x 1/2Width (w) x Height (h)

V = 5.5 x 1.80/2 x .60 = **5.94 m^3** **Ordered - 7m^3**

Rock Size:

T = 1000 X d X s

Where, d is depth of flow in metres and s is the slope of water surface

Based on the measurements recorded during the full culvert assessment survey, the downstream slope at ROC004 is 0.102; the average water depth in the downstream is 0.12m. Based on these measurements, the tractive force was calculated

T = 1000 X d X s

T = 1000 x 0.12 x 0.102

T = 12.24 cm

An incipient diameter of 12.24 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of **24.48 cm.**

6.8.7 RHR013 Round Hill River

Location: Hwy 101, Near Tupperville

20 T 0308358 4956243

Remediation:

Construct rock weir to raise tailwater pool level and install manufactured chute to allow fish access to culvert. A low flow barrier (6x6) needed to be installed at inflow and some large rocks needed to be removed from culvert and culvert inflow.

Weir rock volume:

Lots of usable rocks were on site, no calculations required to order rocks.

Rock Size:

T = 1000 X d X s

Where, d is depth of flow in metres and s is the slope of water surface

Based on the measurements recorded during the full culvert assessment survey, the downstream slope at RHR013 is 0.289; the average water depth in the downstream is 0.075m. Based on these measurements, the tractive force was calculated

T = 1000 X d X s

T = 1000 x 0.075 x 0.289

T = 21.675cm

An incipient diameter of 21.675 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of **43.35 cm.**

6.8.8 Morton Brook MOR008

Location: Hwy 362, Lily Lake

20T 0336906 4983558

Remediation:
Construct rock weir to raise tail water pool level. Take along larger bed stones for weir base and use on site rocks for construction.

Weir rock volume:
Lots of usable rocks are on site, no calculations required to order rocks. Some larger flat bed-stones needed for the base were hand-picked by CARP staff at Parker Mtn. Quarry and brought to the weir site the day of the weir construction.

Rock Size:
T = 1000 X d X s
Where, d is depth of flow in metres and s is the slope of water surface
Based on the measurements recorded during the full culvert assessment survey, the downstream slope at MOR008 is 0.0121; the average water depth in the downstream is 0.0875m. Based on these measurements, the tractive force was calculated
T = 1000 X d X s
T = 1000 x 0.0875 x 1.21
T = 10.59
An incipient diameter of 10.59 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) **of 21.18cm.**

6.8.9 NEB004 Neilly Brook

Location: Hwy 221, North Kingston

20T 0345710 4986463

Remediation:
Construct rock weir to raise tailwater pool level and install manufactured schute to allow fish access to culvert. A low flow barrier (4 x 4) needs to be installed in one side of double box culvert to increase flow to other side.
Weir rock volume:
Volume (V)= Length (l) x Width (w) x Height (h)Weir rock volume: V = 5 x 1.80 x .60 = **5.4m^3** **Ordered – 6m^3**
Rock Size:

T = 1000 X d X s
Where, d is depth of flow in metres and s is the slope of water surface
Based on the measurements recorded during the full culvert assessment survey, the downstream slope at NEB004 is .079; the average water depth in the downstream is 0.010m. Based on these measurements, the tractive force was calculated

T = 1000 X d X s
T = 1000 x 0.10 x 0.079
T = 7.9
An incipient diameter of 7.9 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of **15.8 cm.**

6.8.10 BUT 006 Button Brook

Location: Hwy 101, near Bridgetown

20T 320283 4966500

Remediation:
Construct rock weir to raise tailwater pool level.
Weir rock volume:
Lots of usable rocks are on site, no calculations required to order rocks.
Rock Size:
T = 1000 X d X s
Where, d is depth of flow in metres and s is the slope of water surface
Based on the measurements recorded during the full culvert assessment survey, the downstream slope at BUT006 is 0.19; the average water depth in the downstream is 0.0875m. Based on these measurements, the tractive force was calculated.

T = 1000 X d X s
T = 1000 x 0.059 x .019
T = 11.21

An incipient diameter of 11.21 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of **22.42cm.**