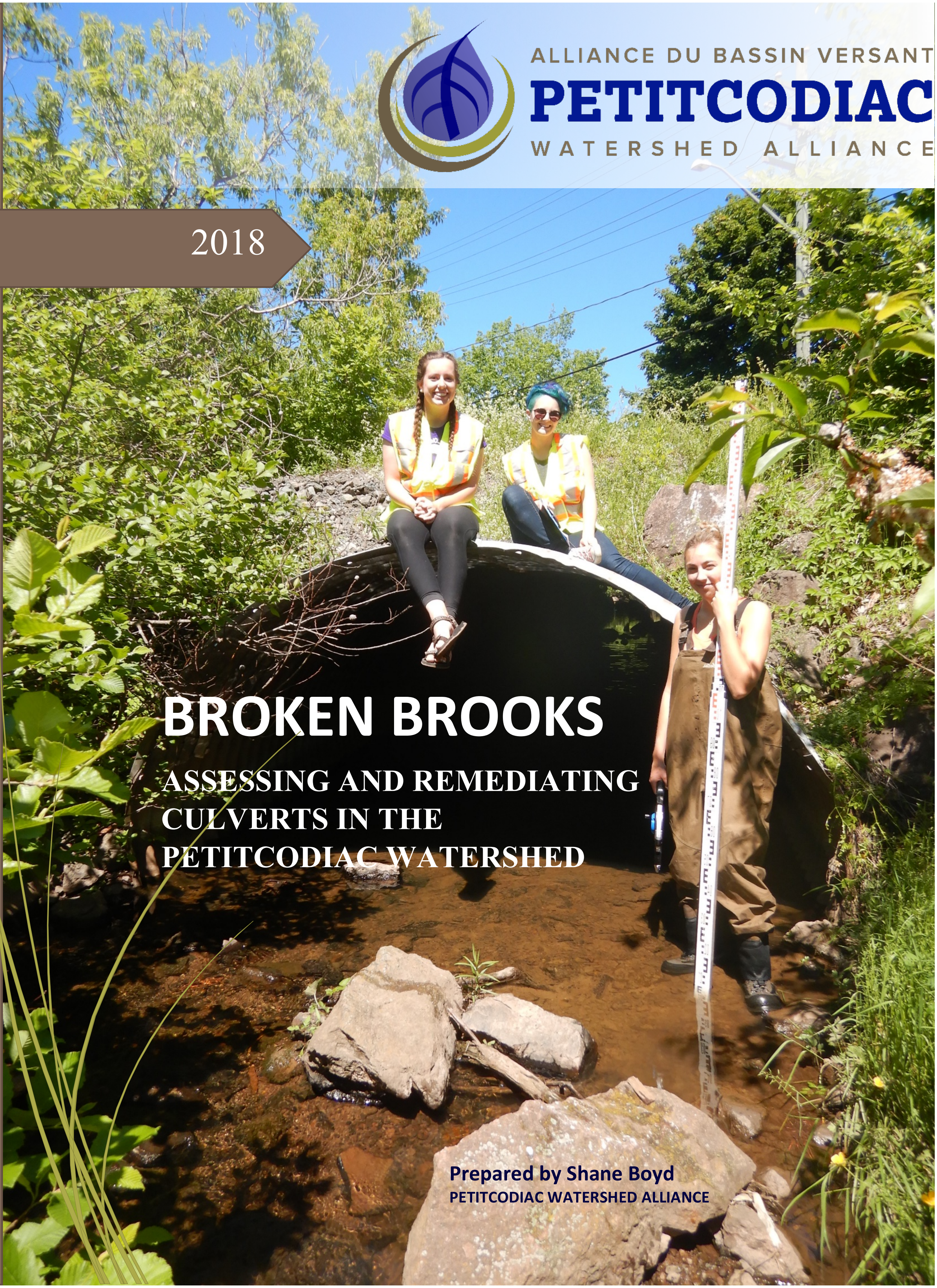
ALLIANCE DU BASSIN VERSANT
PETITCODIAC
WATERSHED ALLIANCE

2018



BROKEN BROOKS

ASSESSING AND REMEDIATING CULVERTS IN THE PETITCODIAC WATERSHED

Prepared by Shane Boyd
PETITCODIAC WATERSHED ALLIANCE

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DISCLAIMER

The **Petitcodiac Watershed Alliance (PWA)** is a non-profit environmental charity who works to protect and improve the ecological systems within the Petitcodiac River Watershed. We use local science to educate community members within the watershed about the ecology within the Petitcodiac River's watershed boundary, and the importance of protecting this unique river system.

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1.0 Table of Contents

List of Figures

List of Tables

Acknowledgements

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We also want to recognize AMEC Foster Wheeler for allowing the PWA to borrow surveying and water quality equipment, thus allowing this project to move forward in its entirety.
Finally, to the entire board of directors and staff of the PWA; we thank you for your help and support.

Executive Summary

Over the five-year span of the Broken Brooks Project, 285 detailed culvert assessments have been completed, and our studies demonstrate that 72.6% of these crossings are either a partial or full barrier to fish passage. Although cost-effective in comparison to other road-watercourse crossings, the environmental impact of these barrier culverts equates to over 500 kilometres of aquatic habitat that is lost or inaccessible to migrating fish species within the Petitcodiac River watershed.

The objective of the Broken Brooks project remains to facilitate fish passage through culverts assessed as barriers, therefore increasing the quantity of aquatic habitat available throughout the Petitcodiac River watershed. To fulfill this objective, remedial work from 2014 to 2018 has been completed at a total of 46 barrier culvert sites, and in doing so, improved fish passage to 120 kilometres of upstream habitat. This remedial work includes debris removals and rock weirs.

The Petitcodiac Watershed Alliance (PWA) has made a concerted effort to expand the Broken Brooks Project beyond our watershed and outside of traditional environmental sectors by forming diverse partnerships with the following government departments and organizations:

- Department of Transportation & Infrastructure (DTI)
- Department of Fisheries & Oceans (DFO)
- Nashwaak Watershed Association
- NSLC Adopt A Stream
- Nature Conservancy of Canada
- New Brunswick Community College (NBCC)

Other highlights from 2018 include: designing the first outflow chutes for NBCC metal processing and construction students to build over the winter and install in the spring, and compiling all road-watercourse crossing data into ArcGIS Online maps. So far, our maps have facilitated communication of project results to our stakeholders and have the potential to increase our capacity to partner with the Department of Transportation & Infrastructure in remediating culverts that are problems from both a public safety and habitat fragmentation perspective.

Résumé general

Au cours des cinq dernières années du projet Broken Brooks, 285 évaluations détaillées de ponceaux ont été complétées, et nos études montent que 72.6% des traversées sont soit des barrières partielles ou complètes au passage du poisson. Bien que rentable par rapport aux autres types de traverses de cours d'eau, l'impact environnementale des ponceaux qui crées des barrières équivaux à plus de 500 km d'habitat aquatique perdu ou inaccessible aux espèces de poissons migrateurs qui essaient souvent d'atteindre des refuges d'eau douce afin de compléter leurs cycles de vie dans le bassin versant de la rivière Petitcodiac.

L'objectif du projet Broken Brooks demeure de faciliter le passage du poisson à travers les ponceaux évalués comme barrières, et en ce fessant, augmenter la quantité d'habitat aquatique disponible à travers le bassin versant de la rivière Petitcodiac. Afin d'accomplir cet objectif, les travaux de remédiation de 2014 à 2017 ont été complétés sur un total de 46 ponceaux évalués comme barrières. Cela a amélioré le passage du poisson sur 120 km d'habitat en amont. Les travaux de remédiation inclus de l'enlèvement de débris et l'installation de ravins de roches.

L'Alliance du Bassin Versant Petitcodiac (PWA) a fait un effort concerté afin d'élargir le projet Broken Brooks au-delà de notre bassin versant et en dehors du secteur environnementale en formant divers partenariats avec les départements gouvernementaux et organisations suivantes :

- Département de Transports et Infrastructure (DTI)
- Département de Pêches & Océans (DFO)
- Nashwaak Watershed Association
- NSLC Adopt A Stream
- Conservation de la Nature Canada
- New Brunswick Community College (NBCC)

D'autres faits saillants de 2018 inclus : la conception des premières goulottes de sortie pour les étudiants au CCNB à construire durant l'hiver et à installer au printemps, et la compilation de l'entièreté des données de traverses de cours d'eau sur les cartes de ArcGIS Online. Jusqu'à date, nos cartes ont facilité les communications par rapport aux résultats du projet avec nos parties prenantes et ont le potentiel d'accroître notre capacité de partenariat avec le Département de Transports et Infrastructure dans la remédiation de ponceaux qui causent des problèmes à la fois d'une perspective de sécurité publique et de fragmentation de l'habitat.

1.0 Introduction

The PWA is a non-profit and non-governmental organization that works to restore and protect the ecological services that the Petitcodiac River watershed provides to the community. The PWA has been a leading organization in actively monitoring the watershed since its inception in 1997. Rigorous annual water quality sampling has resulted in a robust long-term databank encompassing parameters such as pH, dissolved oxygen, temperature, fecal and total coliforms, salinity, total dissolved solids, nitrates, phosphates, and suspended sediment concentrations. These parameters were chosen on the basis of the environment's ability to support life.

1.1 Overview of the Petitcodiac Watershed

The Petitcodiac River watershed, moving west to east, extends from the Village of Petitcodiac to beyond the boundaries of the city of Dieppe. The rivers and tributaries of the Petitcodiac and Memramcook watersheds run through roughly 2,400 square kilometres of land spanning multiple municipal jurisdictions, while supporting the most densely populated area of the province (approximately 160,000 people). The aquatic systems in this watershed are likely stressed, as 2012 water quality reports state that most parameters necessary for life are not being met. Additionally, increasing anthropogenic stressors over the past five decades have drastically altered the river's hydrology, morphology, and ability to support life. Current pressures affecting watershed health include: increased development and industrialization as urban communities expand; continued agricultural and forestry land use stress; and probable development of natural gas extraction in rural areas.

1.2 Overview of the Broken Brooks Project

As anthropogenic expansion and development increases, instances of river crossings and alterations also increase. Culverts are commonly installed to divert water under roads, rail beds, and driveways to avoid pooling. The problem that often arises with culvert installation is the alteration of a river's morphology, negatively affecting fish and other aquatic fauna. For example, culverts can change water velocity, river hydrology and often create full barriers to fish passage due to debris build up. Because of this, a river may be conceptualized as being broken into segments.

The PWA established an aquatic connectivity program in the Petitcodiac watershed in 2014 with the objective to identify road-watercourse crossings (including bridges, culverts, dams, causeways, and fording sites) that were barriers to fish passage. To date, 680 road-watercourse crossings have been identified throughout our watershed as one of the following:

- Bridge
- Fording Site
- Dam
- Crossing removed
- Not accessible
- Not Fish Habitat
- Culvert

Over the last four years, detailed measurements have been taken of 285 culverts located on fish bearing streams. Measurements taken with surveying equipment and a measuring tape enables a crossing to be labeled as 'Passable', a 'Partial Barrier' or a 'Full Barrier' to fish passage. The most common barriers to migrating aquatic species are steep culvert slopes, the presence of an outflow drop, and deteriorating infrastructure. The information gathered during the assessment process allows remedial work to be prioritized, through which the amount of aquatic habitat availability is increased.

In 2016, the Atlantic Canadian Culvert Assessment Toolkit (ACCAT) was created and uploaded to the PWA's website, providing any organization wishing to complete culvert assessments in their area with all of the necessary datasheets and tutorial videos required to do so.

1.3 Study Area

This year, the PWA focused culvert assessment efforts on the Halls Creek sub-watershed, spanning from Ammon to Irishtown and connecting to the Petitcodiac River at the Riverfront Park in Downtown Moncton. This was the first year that culvert assessments took place in the city, where road-watercourse crossings are more highly concentrated. Additionally, the Pollett River Run site remains within the scope of this project.

2.0 Methods

The methods outlined in this section include how culverts are assessed, how remedial actions are chosen, and how barrier culverts are prioritized for remediation.

2.1 Culvert Assessment Procedure

Within our watershed are a number of smaller rivers and streams that flow into the Petitcodiac River. The first step was to prioritize these smaller sub basins based on water quality and the presence of abundant fish populations, most notably the target fish species: brook trout (*Salvelinus fontinalis*). In an attempt to improve and increase aquatic habitat for the target fish species, the first year of connectivity assessments were focused within the Pollett and Little River basins, where healthy populations of brook trout are known to exist.

This year, the Halls Creek sub-watershed was selected for an aquatic connectivity analysis to generate a baseline understanding of freshwater habitat connectivity and availability in the Halls Creek watershed. Results from our 2018 field work will be shared with DFO, DTI, and other stakeholders.

Having prioritized and selected a watershed to be assessed for aquatic connectivity, ArcGIS software was used to create a map the area of study. The locations of potential culvert sites were identified by plotting a symbol at each instance where a road intersected a watercourse. Google Maps was also used to help verify the presence or absence of a crossing. Once maps were completed, field assessments were conducted using the ACCAT protocol. Coordinates from the maps were used to locate each site on the field. The equipment required for each watercourse crossing assessment is outlined in Table I.

Table I: List of field equipment

Materials/Supplies	Equipment	Safety/Personal
Pencil	60m measuring tape	Hip/Chest waders
Eraser	Automatic level	Rubber boots / Rain gear
Pencil sharpener	Tripod	Cell phone / flashlight
Topographic map	Level rod	Field first aid kit
Batteries	Metre stick	Reflective vests
Data sheets (on waterproof paper)	Clipboard	Water bottle
Mileage record	GPS	PFD (working in swift water)
	Camera	Hat, sunscreen, insect repellant

Upon arrival at each road-watercourse crossing site, the first section of the datasheet (titled "Crossing Data"), was completed, and the crossing type was observed as one of the following:

- Bridge
- Fording Site
- Dam
- Culvert Removed
- Not Accessible
- Not Fish Habitat
- Culvert

For every culvert located on a fish-bearing stream, a more detailed assessment was completed by filling out the 'Photos', 'Structure', and 'Elevation' sections of the assessment sheet (Appendix A: Atlantic Canadian Culvert Assessment Toolkit Watercourse Crossing Datasheet). A description of each of the parameters in the datasheet can also be found in Appendix D: Description of Full Assessment Parameters.

Using the information gathered in the datasheet, culverts were classified as 'Passable', a 'Partial Barrier', or a 'Full Barrier' based on the culvert slope and outflow drop (Table II). In general, the greater the slope and outflow drop of a culvert, the more difficult it becomes for a fish to pass through it and access upstream habitat.

Table II: Table of culvert conditions determining fish passability

Barrier Type	Criteria
Passable	No outflow drop AND culvert slope < 0.5%
Partial Barrier	Outflow drop < 10 cm OR culvert slope between 0.5% and 2.5%
Full Barrier	Outflow drop > 10 cm OR culvert slope > 2.5%

In combination with the table above, the illustration below was consulted to accurately measure each assessed culvert's ability to pass fish (Figure 1).

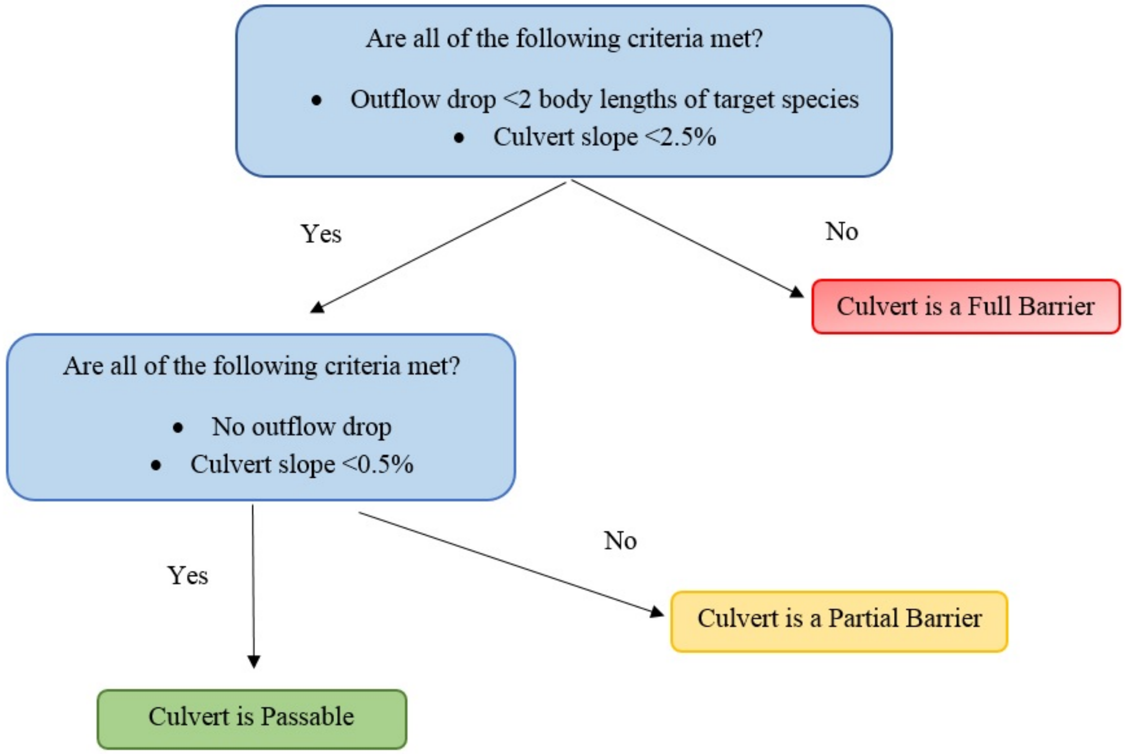

Figure 1: Flowchart of culvert conditions determining fish passability

2.2 Selecting a Remedial Action

Many culverts deemed to be a barrier had more than one issue contributing to their inability to pass fish. Remedial options were derived from *Guidelines for the design of fish passage for culverts in Nova Scotia* (Fisheries and Oceans Canada, 2015). The PWA first learned of these remedial techniques from NSLC Adopt A Stream during the ACCAT Steering Committee Meeting in 2016 (Table III).

Table III: Remedial options for culverts classified as either a partial or full barrier

Culvert Measurements	Remedial Option
Outflow drop less than 15 cm	Rock weir
Outflow drop less than or equal to 25 cm	Outflow chute
Outflow drop between 25 cm and 40 cm	Outflow chute with downstream weirs
Outflow drop greater than 40 cm	Mini-fishway
Slope greater than 0.5%	Baffles

2.3 Prioritizing and Remediating Barrier Culverts

There are many factors to consider when not only prioritizing remediation of barrier culverts, but also choosing a remediation technique. First, once the data has been compiled, culverts are sorted by upstream habitat gain in a descending order. Next, culverts with natural bottoms, outflow drops between 0 and 40 centimetres, and/or severe erosion are filtered out from the list. As a result, only culverts on which remedial work would be successful remain. Finally, images taken during fieldwork are used to verify the culverts' conditions in order to better judge the feasibility of remediation. It is recommended that each site be revisited and remeasured before plans for remedial work begin. One or more remedial techniques are chosen based on the conditions detailed in Table III and Figure 1.

2.3.1 Debris Removals

Woody debris, leaf litter, and sediment are natural and normal components of a stream ecosystem. However, a restrictive and narrow culvert can cause large debris to catch on the inflow. As a result, an accumulation of debris may occur, leading to a blockage at the inflow of the culvert and impeding fish passage upstream. Therefore, in order to maintain proper fish passage and adequate water depth, debris removals took place when blockages were encountered during culvert assessments.

2.3.2 Rock Weirs

On culverts assessed to have an outflow drop of 15 centimetres or less, a rock weir can be installed to increase the height of the existing plunge pool. By installing this type of structure, water levels are raised in the plunge pool, and the barrier outflow drop is effectively reduced or eliminated. Although no rock weirs were constructed this year, plans are being made for the construction of five rock weirs at high-priority sites in 2019.

2.3.3 Outflow Chutes

An outflow chute is a preferred remediation structure for when a culvert exhibits an outflow drop of up to 25 centimetres, ideally between 15 and 25 centimetres, as an outflow drop of under 15 centimetres can usually be eliminated with a rock weir on its own. However, both a rock weir and an outflow chute may be installed at a single site to eliminate an outflow drop of up to 40 centimetres. This year, five outflow chutes have been designed, two of which will be built by NBCC metal processing and construction students over the winter and installed in spring 2019.

3.0 Results and Discussion

Results from the 2018 Broken Brooks project have been divided into 2018 field data followed by a total of all culvert and crossing work that has been conducted since the inception of the Broken Brooks project in 2014. Remedial efforts through barrier culverts that have taken place over the last five years are also outlined in this section. All assessment and remedial work has been integrated into ArcGIS Online maps and has greatly increased our capacity to not only share data with stakeholders, but also track habitat remediation work. A more detailed discussion of how connecting to other organizations, both in and outside of the environmental sector, has allowed us to continually grow the culvert program each year also appears in this section.

3.1 Results from 2018 Fieldwork

During the 2018 field season, PWA staff identified a total of 74 road-watercourse crossings throughout the Halls Creek sub-watershed. Originally, 88 crossings had been identified by previous staff using ArcGIS. An additional 12 crossings had been discovered during fieldwork. However, many of the crossings identified were found to be a single culvert spanning multiple roads. For example, multiple instances involved a double-lane highway and its ramps or service roads crossing a watercourse. Although this appears as three or four individual crossings on ArcGIS, oftentimes these crossings were in reality one large culvert. As a result, the total number of crossings was reduced after fieldwork. In addition to the 24 culverts assessed in the Halls Creek sub-watershed, a total of 24 bridges, two Fording Sites, seven crossings situated on streams considered not to be suitable for fish habitat, and 11 sites that were not accessible due to poor road condition or private property, and two dams were found (Table IV). There were no instances of crossings having been removed due to discontinued use of the road.

Table IV: 2018 watercourse crossing totals for the Halls Creek sub-watershed

Crossing Type	Number of Crossings	Percent (%)
Culverts Assessed	28	37.8
Bridges	24	32.4
Fording Sites	2	2.7
Not Fish Habitat	7	9.5
Not Accessible	11	14.9
Crossing Removed	0	0.0
Dams	2	2.7
Total	**74**	**100.0**

Table V further classifies the 28 detailed culvert assessments within the Halls Creek sub-watershed on fish passability. The majority of the culverts (83.3%) were measured as either partial (43.3%) or full barriers (40.0%) to fish passage, whereas only five (16.7%) of the assessed culverts were classified as passable with respect to fish species attempting to access upstream habitat. Although this is a low rate of passability compared to past results, the Halls Creek sub-watershed has proportionally twice as many bridges, which are considered as passable watercourse crossings.

Table V: 2018 Culvert assessment results for the Halls Creek sub-watershed

Passability	Number of Culverts	Percent (%)
Passable	5	16.7
Partial Barrier	13	43.3
Full Barrier	12	40.0
Total	**30**†	**100.0**

† As double and triple culverts often have different levels of passability within the same site, the two double culverts in the Halls Creek sub-watershed are considered to be four single culverts to better represent the proportions of passability in the sub-watershed. This results in a total of 30 culverts instead of the assessed 28 culvert sites.

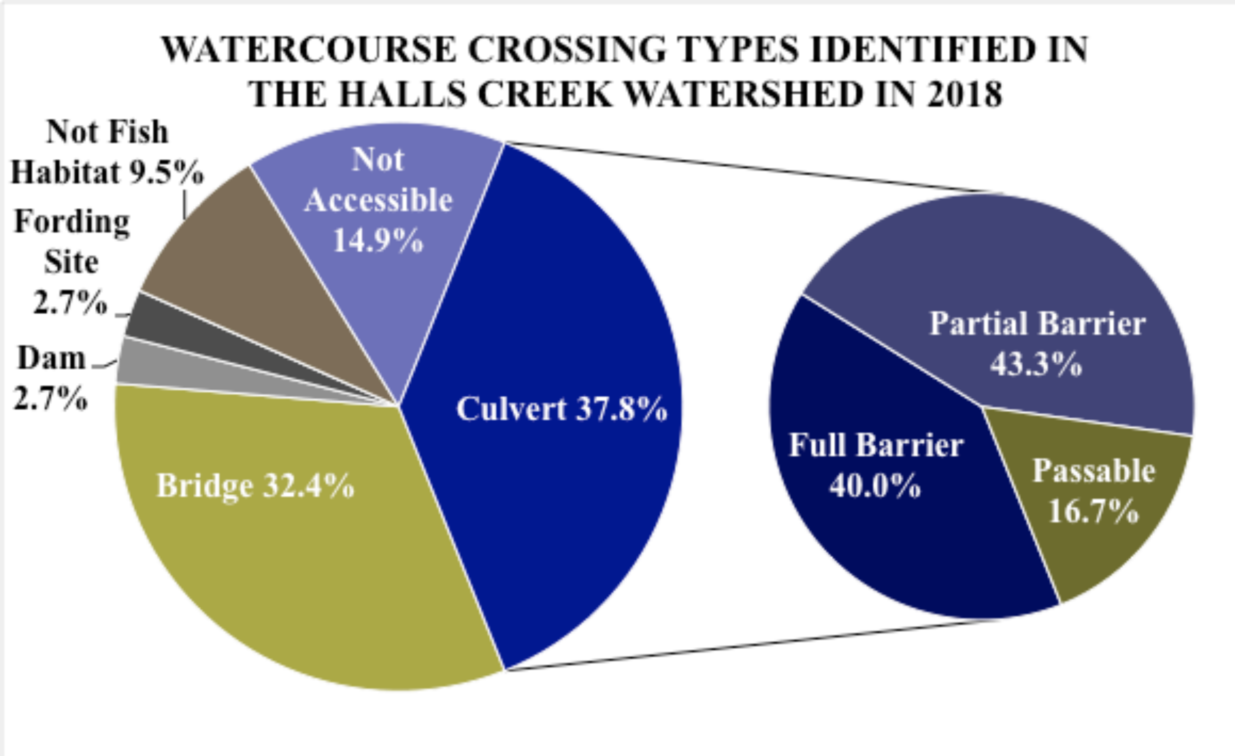

Figure 2: Watercourse crossing types identified in the Halls Creek watershed in 2018

3.2 Total Project Results from 2014 to 2018

Over the course of the last five field seasons, our assessments have covered the following sub-watersheds:

- Pollett River
- Little River
- Lower Turtle Creek
- Bannister Brook
- Stoney Creek
- Weldon Creek
- North River
- Anagance River
- Memramcook River
- Hall's Creek

Throughout the above-listed sub-watersheds we have identified a total of 680 road-watercourse crossings and have completed a grand total of 285 detailed culvert assessments. Table VI outlines the number of each crossing type encountered and its corresponding percent value.

Table VI: 2014–2018 Watercourse crossing totals throughout the Petitcodiac watershed

Crossing Type	Number of Crossings	Percent (%)
Culverts Assessed	285	41.6
Bridges	100	14.7
Fording Sites	11	1.6
Not Fish Habitat	150	22.1
Not Accessible	128	18.8
Culvert Removed	2	0.3
Dams	8	1.2
Total	**680**	**100.0**

Of the 285 culverts assessed between 2014 and 2018, 27.4% were evaluated as Passable, 24.2% were Partial Barriers and 48.4% were Full Barriers to fish passage (Table VII).

Table VII: 2014–2018 Culvert assessment results throughout the Petitcodiac watershed

Passability	Number of Culverts	Percent (%)
Passable	78	27.4
Partial Barrier	69	24.2
Full Barrier	138	48.4
Total	285	100.0

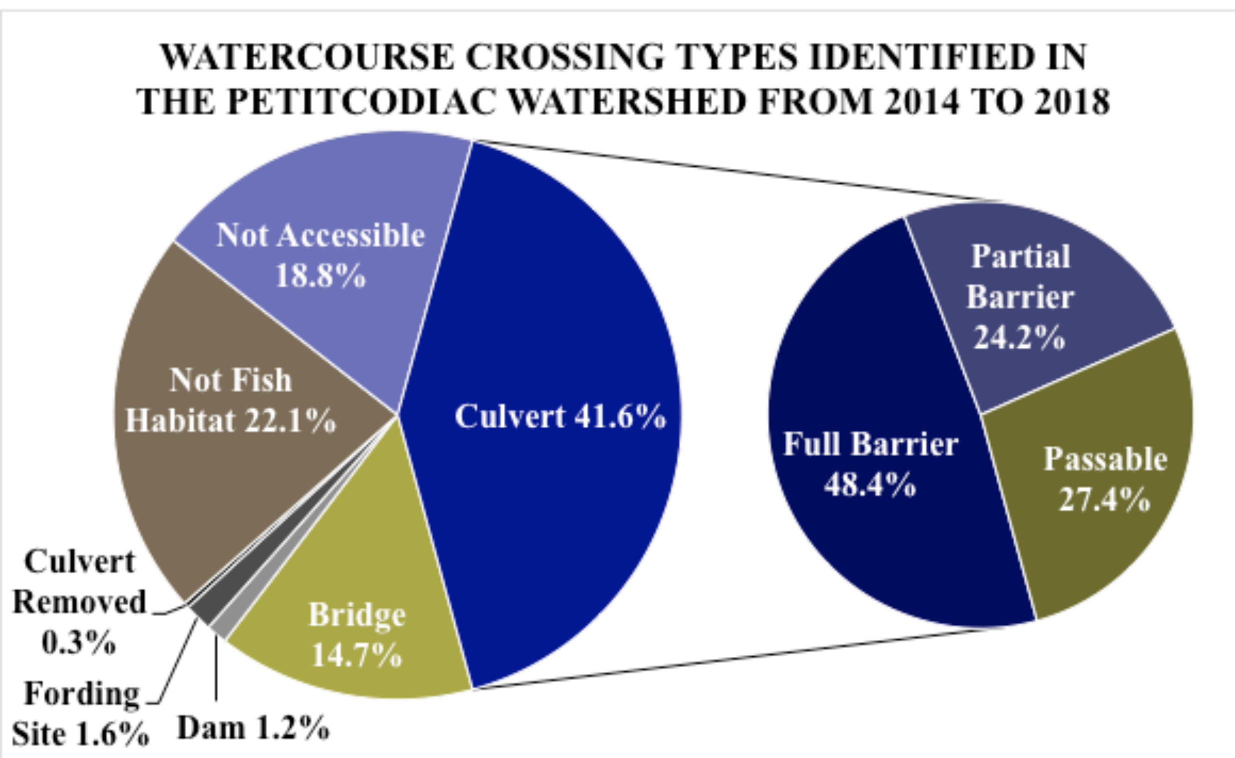

Figure 3: Watercourse crossing types identified in the Petitcodiac watershed from 2014 to 2018

3.3 Remedial Efforts

Remedial efforts include debris removals, rock weir construction, and outflow chute installations.

3.3.1 Debris Removals

Seven debris removals were conducted in the Halls Creek sub-watershed, resulting in a total of 4.36 kilometres of upstream habitat gain.

Table VIII: Debris removals completed as part of 2018 fieldwork

Crossing ID	Basin	Upstream Habitat Gain (km)	Latitude	Longitude
C-259	Ogilvie Brook	0.47	46.13477°	-64.75799°
C-260	Ogilvie Brook	0.01	46.13513°	-64.75790°
C-261	Ogilvie Brook	2.39	46.12957°	-64.79554°
C-262	Gorge Brook	0.11	46.14180°	-64.86400°
C-263	Gorge Brook	0.29	46.15080°	-64.86952°
C-265	Gorge Brook	0.69	46.15707°	-64.87748°
C-268	Rabbit Brook	0.40	46.11030°	-64.81650°

3.3.2 Outflow Chutes

This is the first year that outflow chutes have been designed for installation on culverts in New Brunswick. Thanks to the PWA's partnership with NBCC, two outflow chutes will be constructed by students each winter at low cost.

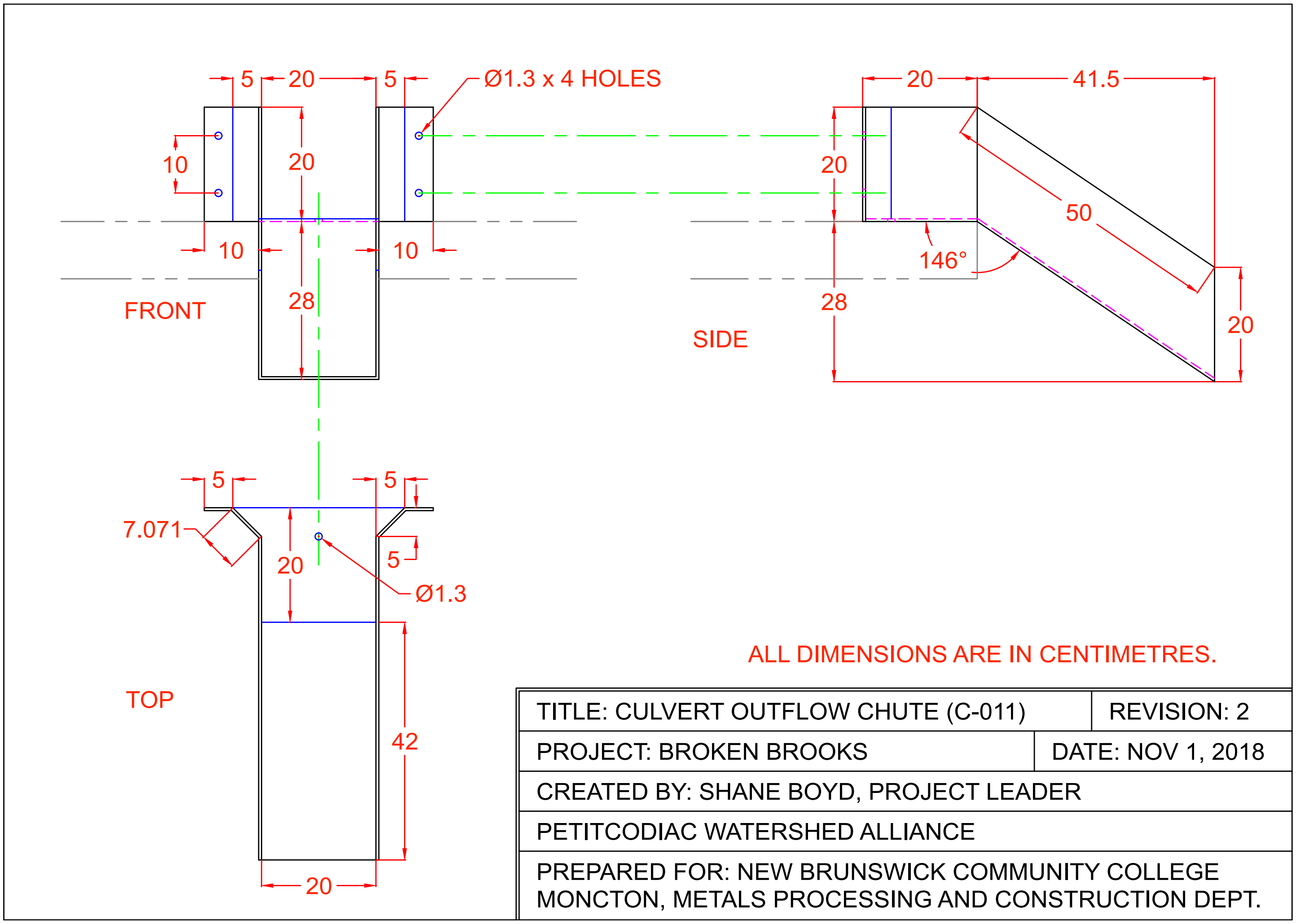

Figure 4: Front, top, and side views with dimensions of outflow chute for culvert C-011

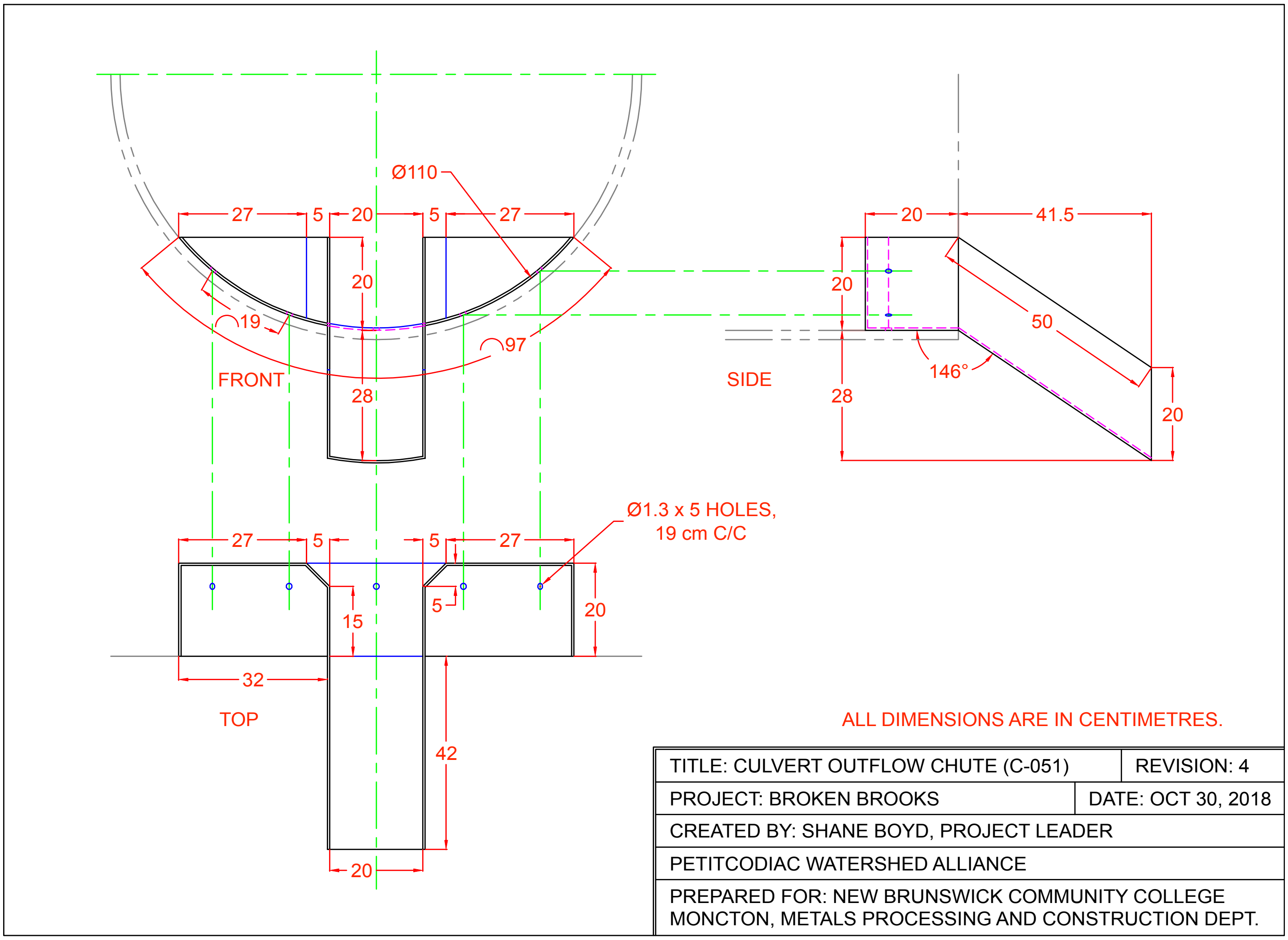

Figure 5: Front, top, and side views with dimensions of outflow chute for culvert C-051

3.3.3 Pollett River Run Restoration

This year, the culvert and road used to access the Pollett River mud bog site were removed. The PWA advertised the changes on social media and reached over 31,500 people. Overall, this event went from having over 3,000 participants in 2017 to less than 300 participants in 2018. Many vehicles used for the mud run were towed due to lack of proper registration. Although we could not measure the amount of sedimentation entering the Pollett River, we believe that the collaborative effort of our organization and partners have greatly reduced the impact on the river in 2018.

In addition, we did not collect as much garbage as previous years because there was almost none on the ground. We also gave away free garbage bags to people descending the Pollett River in rafts, while conducting outreach on species at risk at the same time. We decided not to plant many trees because we want to ensure that vehicles are no longer able to access the property before planting. We also decided not to install signs at the site due to the likliness of them being vandalized. We are collaborating with these partners again in 2019 for the Pollett River Run.

4.0 Conclusion

Culverts are the most common structure used to enable anthropogenic transportation across waterways, and in the case of those culverts assessed in the Petitcodiac watershed, are a barrier to fish passage 72.6% of the time. The 207 culverts that made up these partial and full barriers restrict access to over 500 km of aquatic habitat for various species attempting to migrate upstream to fulfill their life cycles.

Fortunately, an integral part of this project has been to restore barrier culverts where expertise and resources allow. Although restoration techniques have been limited to debris removals and rock weir installations prior to this year, fish passage has been improved to approximately 120 km of upstream habitat through the remediation of 53 barrier culverts over the past five years.

This year, our capacity to share road-watercourse crossing information and track past, present and future culvert remedial work has increased through ArcGIS online mapping.

The PWA continues to expand our aquatic connectivity program by connecting with a diverse network of organizations. Discussions with NSLC Adopt A Stream have identified opportunities to expand the PWA's current culvert remedial techniques over the past year. Furthermore, a partnership with NBCC Moncton is allowing trades outside of the environmental sector to apply their skills in reversing habitat fragmentation. In doing so, students will experience the gratification that comes with conservation work and potentially carry this initiative into their respective trades. Finally, data analysis to be collected from the Nature Conservancy of Canada's barrier prioritization tool will more accurately inform which barrier sites should be prioritize to maximize habitat remediation efforts in the upcoming field season.

5.0 References

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Appendix A: Atlantic Canadian Culvert Assessment Toolkit Watercourse Crossing Datasheet

Crossing Data				
Observers				
Crossing ID		**Date Observed**		
Road Type	□ Public □Rail Bed ROW □ Private □ Logging Road			
Road Name		**Crossing Condition**	□ New □ Old □ Eroding □ Rusted □ Collapsing	
Stream Name				
Upstream Habitat Gain				
Tidal Site	Yes □ No □ Unknown □			
Crossing Type	□ Bridge □ Ford □ Dam □ Removed □ Inaccessible □ Not Fish Habitat □ Culvert # ____			
GPS Coordinates	LAT	LONG		
Beaver dam present	□ Yes □ No	**Fish observed**	□ Upstream □ Downstream	
Evidence of erosion	**□ Upstream (□ Left bank □ Right bank □ Fill slope)** **□ Downstream (□ Left bank □ Right bank □ Fill slope)**	**Estimated area of active erosion (m^2)**		

Photo IDs			
Upstream		Downstream	
Inlet		Outlet	
Other		Other	

Structure 1					
Debris blockage present	□Yes □No	**Description of debris**			
Culvert material	□ Concrete □ Corrugated Metal Pipe □ Corrugated Plastic □ Smooth □ Wood □ Other				
Culvert shape	□ Round □ Pipe Arch □ Open bottom arch □ Box				
Culvert bottom	□Unnatural □Natural	**Culvert dimensions (m)**	Width	Height	Length
Backwatered	□ 0% □ 25% □ 50% □ 75% □ 100%		**Baffles**	□ Present	□ Absent
Water depth in crossing matches that of stream: yes no (significantly deeper) no (significantly shallower)					
Water velocity in crossing matches that of stream: yes no (significantly faster) no (significantly slower)					
Embedment	□ from upstream □ from downstream	**Length of Culvert with Embedment**	□0%□ 25%□ 50%□75%□100%		

Elevations (m)						
Station	**BS**	**HI**	**FS**	**Elevation (HI – FS)**	**Distances (m)**	**Tailwater Control Bankfull Width:** **Distance from Tailwater Control to Second Riffle:**
Inflow						
Outflow						
Tailwater Control						
Left Bankfull at Tailwater						
Right Bankfull at Tailwater						
Second Riffle						

Culvert Slope (%) (Inflow-Outflow)/Culvert length*100		**Outflow Drop** (outflow – tailwater control)	
Downstream Slope (Tailwater Control – Second Riffle/distance from tailwater control to second riffle			

Structure 2

Debris blockage present	□Yes □No	**Description of debris**			
Culvert material	□ Concrete □ Corrugated Metal Pipe □ Corrugated Plastic □ Smooth □ Wood □ Other				
Culvert shape	□ Round □ Pipe Arch □ Open bottom arch □ Box				
Culvert bottom	□Unnatural □Natural	**Culvert dimensions (m)**	Width	Height	Length
Backwatered	□ 0% □ 25% □ 50% □ 75% □ 100%	**Baffles**		□ Present	□ Absent
Water depth in crossing matches that of stream: yes no (significantly deeper) no (significantly shallower)					
Water velocity in crossing matches that of stream: yes no (significantly faster) no (significantly slower)					
Embedment	□ from upstream □ from downstream	**Length of Culvert with Embedment**	□0% □ 25%□50%□75%□100%		

Elevations (m)

Station	BS	HI	FS	Elevation (HI – FS)	Distances	
Inflow						**Tailwater Control Bankfull Width:**
Outflow						
Tailwater Control						**Distance from Tailwater Control to Second Riffle:**
Left Bankfull at Tailwater						
Right Bankfull at Tailwater						
Second Riffle						

Culvert Slope (%) (Inflow-Outflow)/Culvert length*100		**Outflow Drop** (outflow – tailwater control)	
Downstream Slope (Tailwater Control – Second Riffle/distance from tailwater control to second riffle			

Structure 3

Debris blockage present	□Yes □No	**Description of debris**			
Culvert material	□ Concrete □ Corrugated Metal Pipe □ Corrugated Plastic □ Smooth □ Wood □ Other				
Culvert shape	□ Round □ Pipe Arch □ Open bottom arch □ Box				
Culvert bottom	□Unnatural □Natural	**Culvert dimensions (m)**	Width	Height	Length
Backwatered	□ 0% □ 25% □ 50% □ 75% □ 100%	**Baffles**		□ Present	□ Absent
Water depth in crossing matches that of stream: yes no (significantly deeper) no (significantly shallower)					
Water velocity in crossing matches that of stream: yes no (significantly faster) no (significantly slower)					
Embedment	□ from upstream □ from downstream	**Length of Culvert with Embedment**	□0% □ 25%□50%□75%□100%		

Elevations

Station	BS	HI	FS	Elevation (HI – FS)	Measurements	
Inflow						**Tailwater Control Bankfull Width:**
Outflow						
Tailwater Control						**Distance from Tailwater Control to Second Riffle:**
Left Bankfull at Tailwater						
Right Bankfull at Tailwater						
Second Riffle						

Culvert Slope (%) (Inflow-Outflow)/Culvert length*100		**Outflow Drop** (outflow – tailwater control)	
Downstream Slope (Tailwater Control – Second Riffle/distance from tailwater control to second riffle			

Appendix B: Atlantic Canadian Culvert Assessment Toolkit French Translation of Watercourse Crossing Datasheet

Informations du croisement			
Observateurs			
ID du croisement		**Date de l'observation**	
Type de route	□ Publique □ Chemin de fer □ Privée □ Exploitation forestière		
Nom de la route		**Condition du ponceau**	□ Neuf □ Âgé □ Érodé □ Rouillé □ S'écroule
Nom du ruisseau			
Gain d'habitat en amont			
Site de Marée	Oui □ Non □ Inconnu □		
Type de croisement	□ Pont □ Gué □ Barrage □ Ponceau retiré □ Inaccessible □ N'est pas habitat de poissons □ Ponceau # __		
Coordonées GPS	LAT	LONG	
Présence de barrage de castor	□ Oui □ Non	**Poissons observés**	□ En amont □ En aval
Signes d'érosion	**□ En Amont (□ Rive gauche □ Rive droite □ Talus de remblai)** **□ En Aval (□ Rive gauche □ Rive droite □ Talus de remblai)**	**Zone estimée d'érosion active (m^2)**	

ID des photos			
En amont		En aval	
Tuyau d'arrivée		Tuyau d'évacuation	
Autre(s)		Autre(s)	

Structure 1					
Présence de blocage	□ Oui □ Non	**Description du débris**			
Matériel du ponceau	□ Béton □ Tuyau de métal ondulé □ Tuyau de plastic ondulé □ Tuyau lisse □ Bois □ Autre				
Forme du ponceau	□ Circulaire □ Arquée □ Hémispherique à sol ouvert □ Rectangulaire				
Fond du ponceau	□ Non naturel □ Naturel	**Dimensions du ponceau (m)**	Largeur	Hauteur	Longueur
Eau stagnante	□ 0% □ 25% □ 50% □ 75% □ 100%	**Déflecteurs**		□ Présents	□ Absents
Profondeur d'eau dans le croisement correspond à celle du ruisseau: □ oui □ non (plus profonde) □ non (moins profonde)					
Débit d'eau dans le croisement correspond à celui du ruisseau: □ oui □ non (plus rapide) □ non (plus lent)					
Ponceau encastré	□ D'amont □ D'aval	**Longueur de l'encastrement**	□0% □25% □50% □75% □100%		

Élévations (m)						
Station	**CAR***	**HI****	**CAV*****	**Élevation** (HI – CAV)	**Distances (m)**	**Largeur du niveau de débordement du seuil de contrôle:** **Distance du seuil de contrôle au deuxième seuil:**
Tuyau d'arrivée						
Tuyau d'évacuation						
Seuil de contrôle						
Rive gauche du SC						
Rive droite du SC						
Deuxième seuil						
Pente du ponceau (%) (Tuyau d'arrivée-Tuyau d'évacuation)/Longueur du ponceau*100			**Chute d'évacuation** (Tuyau d'évacuation – tailwater control)			
Pente en aval (Seuil de contrôle – Deuxième seuil)/distance du seuil de						

contrôle au deuxième seuil	

Structure 2

Présence de blocage	◻ Oui ◻ Non	**Description du débris**			
Matériel du ponceau	◻ Béton ◻ Tuyau de métal ondulé ◻ Tuyau de plastic ondulé ◻ Tuyau lisse ◻ Bois ◻ Autre				
Forme du ponceau	◻ Circulaire ◻ Arquée ◻ Hémispherique à sol ouvert ◻ Rectangulaire				
Fond du ponceau	◻ Non naturel ◻ Naturel	**Dimensions du ponceau (m)**	Largeur	Hauteur	Longueur
Eau stagnante	◻ 0% ◻ 25% ◻ 50% ◻ 75% ◻ 100%		**Déflecteurs**	◻ Présents	◻ Absents
Profondeur d'eau dans le croisement correspond à celle du ruisseau: ◻ oui ◻ non (plus profonde) ◻ non (moins profonde)					
Débit d'eau dans le croisement correspond à celui du ruisseau: ◻ oui ◻ non (plus rapide) ◻ non (plus lent)					
Ponceau encastré	◻ D'amont ◻ D'aval	**Longueur de l'encastrement**	◻0%◻ 25%◻ 50%◻75%◻100%		

Élévations (m)

Station	CAR*	HI**	CAV***	Élevation (HI – CAV)	Distances (m)	
Tuyau d'arrivée						**Largeur du niveau de débordement du seuil de contrôle:**
Tuyau d'évacuation						
Seuil de contrôle						
Rive gauche du SC						**Distance du seuil de contrôle au deuxième seuil:**
Rive droite du SC						
Deuxième seuil						

Pente du ponceau (%) (Tuyau d'arrivée-Tuyau d'évacuation)/Longueur du ponceau*100		**Chute d'évacuation** (Tuyau d'évacuation – tailwater control)	
Pente en aval (Seuil de contrôle – Deuxième seuil)/distance du seuil de contrôle au deuxième seuil			

Structure 3

Présence de blocage	◻ Oui ◻ Non	**Description du débris**			
Matériel du ponceau	◻ Béton ◻ Tuyau de métal ondulé ◻ Tuyau de plastic ondulé ◻ Tuyau lisse ◻ Bois ◻ Autre				
Forme du ponceau	◻ Circulaire ◻ Arquée ◻ Hémispherique à sol ouvert ◻ Rectangulaire				
Fond du ponceau	◻ Non naturel ◻ Naturel	**Dimensions du ponceau (m)**	Largeur	Hauteur	Longueur
Eau stagnante	◻ 0% ◻ 25% ◻ 50% ◻ 75% ◻ 100%		**Déflecteurs**	◻ Présents	◻ Absents
Profondeur d'eau dans le croisement correspond à celle du ruisseau: ◻ oui ◻ non (plus profonde) ◻ non (moins profonde)					
Débit d'eau dans le croisement correspond à celui du ruisseau: ◻ oui ◻ non (plus rapide) ◻ non (plus lent)					
Ponceau encastré	◻ D'amont ◻ D'aval	**Longueur de l'encastrement**	◻0% ◻25% ◻50% ◻75% ◻100%		

Élévations (m)

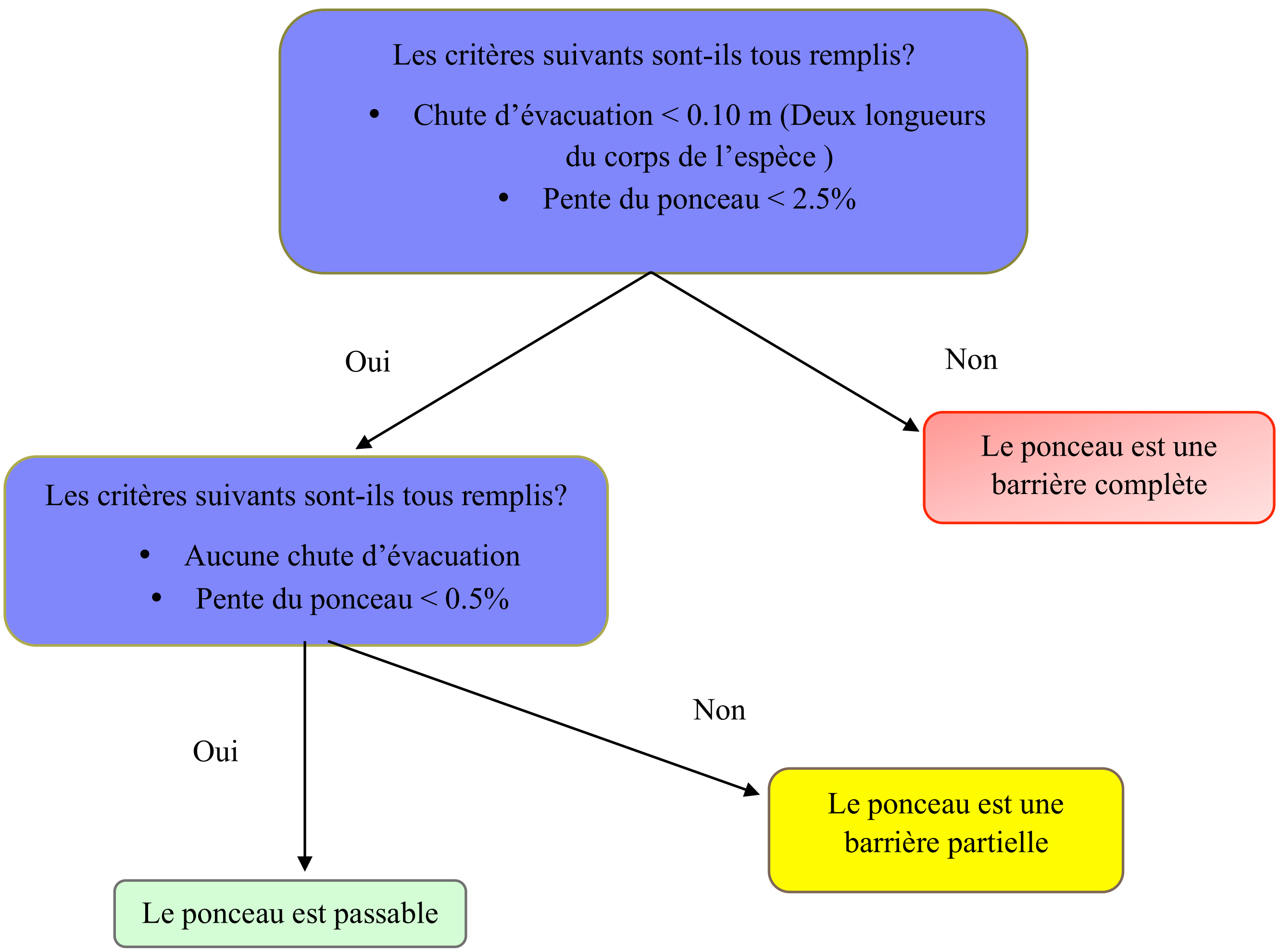
Station	CAR*	HI**	CAV***	Élevation (HI – CAV)	Distances (m)	
Tuyau d'arrivée						**Largeur du niveau de débordement du seuil de contrôle:**
Tuyau d'évacuation						
Seuil de contrôle						
Rive gauche du SC						**Distance du seuil de contrôle au deuxième seuil:**
Rive droite du SC						
Deuxième seuil						

Pente du ponceau (%) (Tuyau d'arrivée-Tuyau d'évacuation)/Longueur du ponceau*100		**Chute d'évacuation** (Tuyau d'évacuation – tailwater control)	
Pente en aval (Seuil de contrôle – Deuxième seuil)/distance du seuil de contrôle au deuxième seuil			

*CAR = Coup Arrière **HI = Hauteur de l'instrument ***CAV = Coup Avant

Appendix C: French Translation of ACCAT Barrier Classification System and Flow Chart

Type de barrière	Critères
Passable	Les critères suivants doivent êtres remplis: Aucune chute d'évacuation Pente du ponceau < 0.5%
Barrière partielle	Au moins un des critères suivants est rempli: Chute d'évacuation < 10 cm Pente du ponceau entre 0.5% - 2.5%
Barrière complète	Au moins un des critéres suivants est rempli: Chute d'évacuation > 10 cm Pente du ponceau > 2.5%



Appendix D: Description of Full Assessment Parameters

Variable	Units	Description
Crossing Data		
Researchers		Assessors collecting the data
Culvert ID		An identification code unique to each crossing
Date Observed		
Road Type		Indicate whether the crossing is located on a public road, rail bed, private property or logging road
Road Name		Ability of watercourse to support fish
Stream Name		Name of watercourse the structure is located on
Upstream Habitat Gain		The distance of upstream habitat from the current site to the next barrier or un-assessed water crossing
Tidal Site		Date the culvert assessment began
Crossing Type		Select one of the following: bridge, fording site, dam, inaccessible, not fish habitat or culvert (# of culverts present)
Crossing Condition		Indicate one of the following: new, old, eroding, rusted, collapsing
GPS Coordinates		Location of the culvert using latitude and longitude
Beaver activity present		Indicate if there are any signs of beaver activity including a beaver dam or lodge
Fish Observed		The observation of any fish observed. Include type, number & approximate size
Evidence of erosion		If erosion is present in the crossing area indicate whether it is occurring upstream, downstream, left bank, right bank and/or fill slope
Estimated area of active erosion	m^2	Estimate the area of active erosion if indicated in the previous category
Photo IDS		
Photos		Photos of watercourse crossing site (U/S-upstream, Inflow, D/S-downstream, outflow, other) and corresponding id number as indicated on camera
Structure 1 (complete section when a culvert is located on a fish bearing stream)		
Debris blockage present		Indicate whether debris has built up either at the culvert inflow or within the stream
Description of debris		Describe what the debris blockage is composed of (large woody debris, deteriorating culvert material, garbage, etc)
Culvert material		Indicate that material the culvert is composed of: concrete, corrugated metal pipe, corrugated plastic, smooth, wood or other
Culvert shape		Indicate whether the shape of the culvert is round, pipe arch, open bottom arch, or box
Culvert bottom		Indicate whether the culvert bottom is natural (similar to the surrounding stream substrate) or unnatural
Culvert dimensions	m	Measure the culvert width, height and length with a measuring tape in meters
Backwatered	%	Surface of outflow pool extending back into the culvert negating the problematic slopes. Recorded as 25%, 50%, 75%, or 100% backwatered.
Baffles		Indicate the presence of baffles in a culvert
Water depth in crossing matches that of stream		Indicate whether the water depth in the culvert is deeper, more shallower or similar to that of the stream

Water velocity in crossing matches that of stream:		Indicate whether the water velocity in the culvert is faster, slower or similar to that of the stream
Embedment		If the culvert is embedded into the stream substrate, indicate if occurs upstream or downstream
Length of Culvert with Embedment	%	If embedment was indicated in the above category, indicate what percentage of the pipe was embedded.
Elevations		
Culvert Inflow	m	Elevation measurement taken at the bottom of the inflow of a structure
Culvert Outflow	m	Elevation measurement taken at the bottom of the outflow of a structure
Tailwater Control	m	Elevation measurement taken in the thalweg at end of outflow pool or at an identified location downstream of the structure
Left Bankfull at Tailwater	m	Elevation measurement of the left bankfull width of watercourse taken downstream of structure
Right Bankfull at Tailwater	m	Elevation measurement of the right bankfull width of watercourse taken downstream of structure
Second Riffle	m	Elevation measurement taken at the next riffle immediately downstream of the tailwater control point
Tailwater Control Bankfull Width	m	Measure the bankfull width at the tailwater control
Distance from Tailwater Control to Second Riffle:	m	Measure the distance between the tailwater control and second riffle
Culvert Slope (%)	%	Slope of the culvert calculated by: (Inflow-Outflow)/Culvert length*100
Outflow Drop	m	Distance between the bottom of the culvert outflow and that thalweg of the tailwater control. Calculated by subtracting the tailwater elevation from the outflow elevation
Downstream Slope	%	Natural slope of the streambed calculated by: (Tailwater Control – Second Riffle/distance from tailwater control to second riffle)
Structure 2 and/or Structure 3 Complete these sections if a double or triple culvert is present		

Appendix E: Culvert Assessment Equipment Checklist

Materials

- ☐ Clipboard
- ☐ Data Sheets (on waterproof paper)
- ☐ Pencils, Eraser, Sharpener
- ☐ GPS
- ☐ Topographic Map
- ☐ Camera
- ☐ Extra Batteries
- ☐ Data Sheets
- ☐ Mileage Record

Equipment

- ☐ 60 m measuring tape
- ☐ Meter Stick
- ☐ Surveying: Automatic Level, Tripod & Level Rod

Safety

- ☐ Hip or Chest Waders
- ☐ Rain Gear
- ☐ Flashlight
- ☐ Field First Aid Kit
- ☐ Reflective Vests
- ☐ Insect Repellant, Sun Screen, Hat, Water Bottle
  PFD (working in swift water)

Appendix F: Automatic Level Survey Procedures for Culvert Assessments

The automatic level survey is an optical instrument that provides a height of reference from which you can determine changes in elevations, and in doing so the slope, from one location to another. The equipment required to conduct surveying are outlined below (must have a minimum of 2 people):

1. **Tripod**: as indicated in its name, the tripod has 3 ‘legs’ that are adjustable for height. The automatic level will be secured onto the top of the tripod for the duration of the surveying procedure.
2. **Automatic Level**: Elevation measurements are taken by reading the staff through the lens of the automatic level.
3. **Staff**: 5 meter long measuring stick, divided into meters and centimeters. Readings are measured to the nearest centimeter.

Figure 8: Pictures of the 3 pieces of equipment required for surveying: the tripod (left), the automatic level (center) and the staff (right) (Photographs of surveying equipment, n.d.).

Terminology:

Height of Instrument (HI): arbitrary elevation from which all other elevations will be calculated.

Elevation: The goal of level surveying is to determine the elevation of each location. For culvert assessments, the elevations of the following locations must be calculated:

1. First Riffle
2. Culvert Inflow
3. Culvert Outflow
4. Pool Depth
5. Tailwater Control

6. Second Riffle
7. Tailwater Control Horizontal Cross-Section

With the elevations of these locations, the slope of the following stream characteristics can be calculated:

1. Upstream Slope
2. Culvert Slope
3. Downstream Slope
4. Bankfull Height and cross-section of the Tailwater Control

Foresight (FS): The first measurement taken of the staff. If the tripod location does not change, the HI will remain static and only FS readings will be taken at each station. At the very most, only two formulas are needed throughout the procedure. The first is to find elevation:

$$\boldsymbol{Elevation = HI - FS}$$

Backsight (BS): If the tripod has to be moved, the staff must stay at the same location while it is being repositioned. Once relocated, the person at the tripod can take a BS reading from the staff and calculate the new HI.

$$HI_{new} = Elevation + BS$$

Procedure

If at all possible, set up the tripod in a location where the all of the following can be observed:

1. First Riffle
2. Culvert Inflow
3. Culvert Outflow
4. Pool Depth
5. Tailwater Control
6. Second Riffle
7. Tailwater Control Horizontal Cross-Section (minimum of 5 locations)

Once the tripod is set up at a comfortable height and relatively level, place and secure the automatic level onto the tripod head. Use the three leveling screws to bring the bubble within the circle on the spherical level. Once the bubble is centered staff readings can be taken.

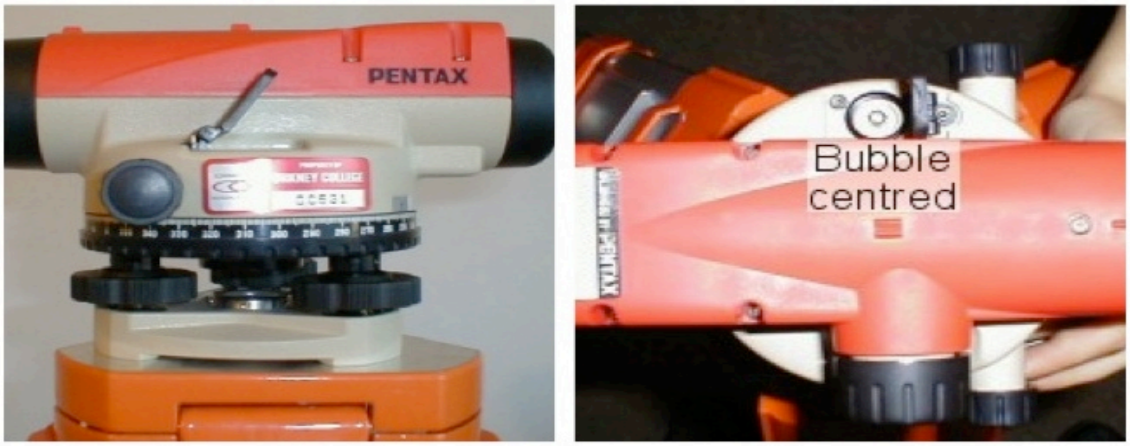


Figure 9: The automatic level must be secured onto the tripod head (left) before using the 3 leveling screws to bring the bubble within the circle on the spherical level (right). Once the bubble is centered, staff readings can be taken (Photographs of surveying equipment, n.d.).

After the tripod is set-up, look through the lens and rotate the level until the staff is visible. Focus the eyepiece and read the numbers (to the nearest centimeter) on the staff where the horizontal and vertical crosshairs meet.

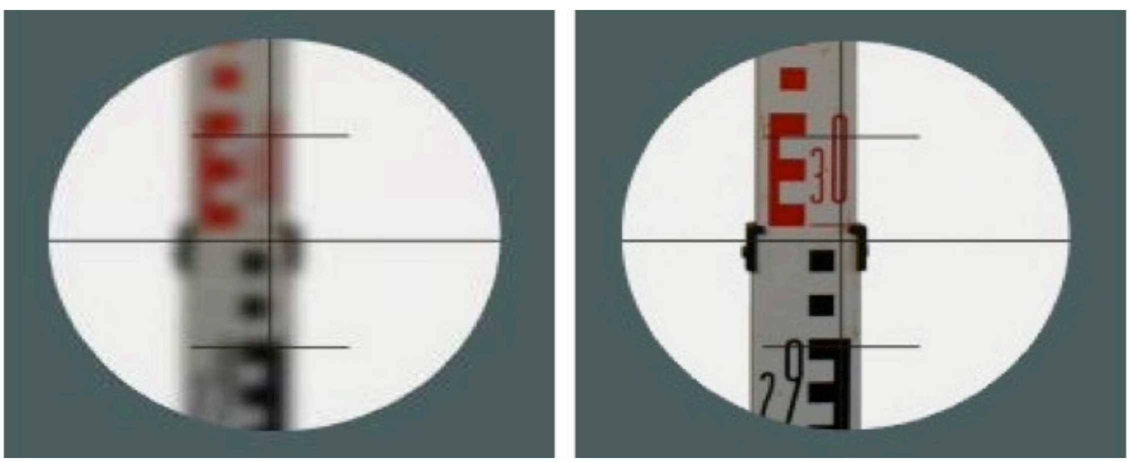


Figure 10: Pictures of the staff while looking through the automatic level before (left) and after (right) the lens is focused. The staff reading in this example is 2.99 m (Photographs of surveying equipment, n.d.).

In the example below (Table 11), the tripod location is static and only FS readings were taken. Each FS reading was recorded on the data sheet and subtracted from the HI to determine the relative elevation of each station.

Table IX: Example of staff measurement readings in a situation where the tripod remains in the same location throughout the surveying process.

Station	HI	FS (-)	BS (+)	Elevation (m)
First Riffle	10.00	3.67		6.33
Culvert Inflow	10.00	3.77		6.23
Culvert Outflow	10.00	3.82		6.18
Pool Depth	10.00	4.09		5.91
Tailwater Control	10.00	4.18		5.82
Second Riffle	10.00	4.21		5.79

If it is not possible to view all stations from one tripod location, backsight readings will be required to determine the new height of instrument (HI_{new}). In the example below (Table 12), after taking a FS reading of the *First Riffle* and *Culvert Inflow*, the tripod was relocated to enable a *Culvert Outflow* reading. It is critical that the staff is held in place at the *Culvert Inflow* station.

At this point, a BS reading of 1.71 m was taken and added to the elevation calculated at the *Culvert Inflow* (6.78 m) for a *Culvert Outflow* HI of 8. 49 m:

$$HI_{at\ Culvert\ Outflow} = Culvert\ Inflow\ Elevation + Culvert\ Inflow\ BS$$
$$HI_{at\ Culvert\ Outflow} = 6.78\ m + 1.71\ m$$
$$HI_{at\ Culvert\ Outflow} = 8.49\ m$$

The next FS reading was taken at the Culvert Outflow (2.74 m) and is subtracted from the latest HI of 8.49 m for a Culvert Outflow elevation of 5.75 m:

$$Elevation\ of\ Culvert\ Outflow = HI - FS$$
$$Elevation\ of\ Culvert\ Outflow = 8.49\ m - 2.74\ m$$
$$Elevation\ of\ Culvert\ Outflow = 5.75\ m$$

The tripod was also moved after the Tailwater Control, changing the HI again to 7.77 m.

Table X: Example of surveying in a situation where the location of the tripod must be moved in order to obtain staff readings from each station.

Station	HI (m)	FS (-)	BS (+)	Elevation (m)
First Riffle	10.00	3.67		6.33
Culvert Inflow	10.00	3.22	1.71	6.78
Culvert Outflow	8.49	2.74		5.75
Pool Depth	8.49	3.01	2.29	5.48
Tailwater Control	7.77	2.86		4.91
Second Riffle	7.77	2.90		4.87

Slope was calculated by measuring the distance between each station and using a simple rise over run formula. For example, to find the slope of the culvert in Table 19, the following values were used:

$$Slope\ of\ Culvert = \frac{\Delta\ elevation}{\text{distance}}\ x\ 100$$

$$Slope\ of\ Culvert = \frac{culvert\ inflow - culvert\ outflow}{distance\ between\ inflow\ and\ outflow} x\ 100$$

$$Slope\ of\ Culvert = \frac{6.78\ \text{m} - 5.75\ \text{m}}{18\ \text{m}} x\ 100$$

$$Slope\ of\ Culvert = 5.72\%$$