Inverness South Anglers Association

Mull River Habitat Restoration Plan

Assessment of instream habitat and recommendations for Atlantic Salmon Recovery

MacInnis Natural Resource Services Inc.
12/1/2020

Table of Contents

The Mull River Watershed

The Mull River watershed (Figure 1) is located on the western coast of Cape Breton and has a catchment basin of 195 square kilometers. The headwaters of the Mull River begin in the Mabou Highlands and the mouth of the river empties into the Northumberland Strait. The landscape within the Mull River watershed includes a wide variety of landscape types, ranging from steep mountainous tributaries to low gradient tidal habitat. Historically the Mull River supported commercial and Indigenous fisheries with reported returns estimated to be an order of magnitude greater than present estimates. Despite significant declines since European settlement, Atlantic salmon numbers in the Mull River continue to exceed the conservation targets set out by the governing authority the Department of Fisheries and Oceans Canada (DFO) thereby allowing the continuation of recreational fishing and Indigenous harvesting.

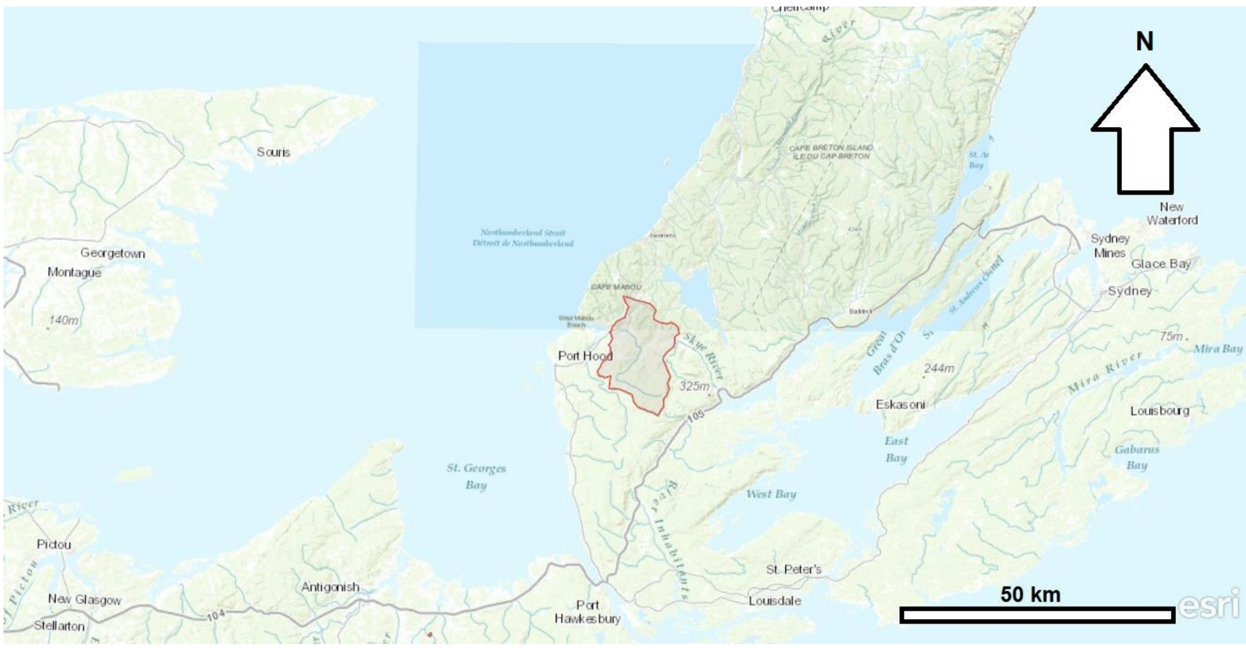

Figure 1: Map of north eastern Nova Scotia. Mull River watershed highlighted in red.

The settlement of European settlers in the early 19th century ushered in a period of landscape-scale change. The first 100 years of settlement in the Mull River had a profound impact on the river's habitat and channel features, eliminating sinuosity and floodplain connection. The extent of this alteration is visible today through the analysis of Lidar imaging and drone surveys. This report concludes that the present condition of the freshwater habitat in the Mull River is much different than the historic conditions which supported an abundance of Atlantic salmon and other important fish species. Habitat assessments completed in 2019 and 2020 found variable levels of habitat quality throughout the entire watershed. Some reaches of stream were in close to pristine condition while others could be characterized as highly degraded. Overall most reaches of channel fell somewhere in between and could benefit from the implementation of river restoration techniques and river management initiatives.

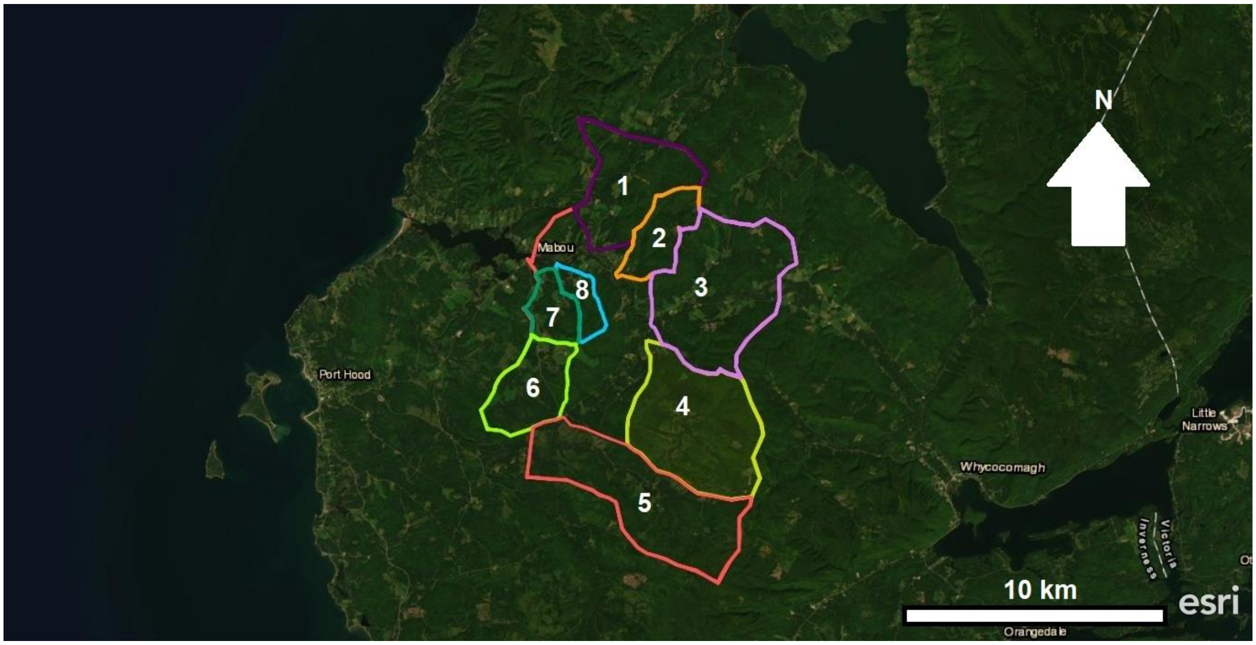

Figure 2: Sub-catchments numbered (clockwise) beginning with (1) Glendyer Brook; (2) Elgin Brook; (3) Sheas Brook; (4) Miramichi Brook; (5) upper Mull River; (6) Southwest Ridge Brook; (7) MacNeils Brook; and (8) Rankin Brook.

Sub-watershed name	**Watershed Size (sq. km)**	**Brief overview**
Glendyer Brook	21.3 sq. km	Most of this brook is quite steep and flows through active farmland. Restoration work was completed in this sub-watershed pre 2010. Bank erosion and siltation.
Elgin Brook	9.7 sq. km	Has a 6 meter falls 300 meters above confluence no potential for meaningful restoration.
Shea's Brook	36.4 sq. km	9 meter channel width design. Lower section has work completed in previous year (pre 2012), upper section has riparian issues erosion and barrier culverts potential for additional restoration and work with farmers. A feeder stream to Sheas Brook, known as Little Sheas has a barrier culvert present near the confluence with Sheas Brook.
Miramichi Brook	34.8 sq. km	Some work in middle section and one tributary, a lot of bedrock, potential for some additional restoration deflectors digger logs in upper regions .
Upper Mull River	36 sq. km	Considerable work needed in culvert remediation, comprises several smaller drainages no restoration done yet considerable potential for crew work.
Southwest Ridge Brook	14 sq. km	No restoration done yet 6 meter channel digger logs deflectors, one upper culvert requires remediation.

Table 1

History of Land-Use Practices

Historical accounts of the natural landscape during the settlement period (1820-1860s) describe a vastly different landscape along in the Mull River watershed. Pre-settlement the Mull River valley floodplain consisted primarily of mature stands of sugar maple forests wherever well-drained alluvial soils were found. The upland hills were characterized by slow-draining clay soils and diverse stands of Acadian forests. In the decades that followed settlement, macro-economic forces and technological developments greatly influenced land-use practices. Initially, strong demand for wool and beef promoted the establishment of pasture land while the early 20th century cash crops such as turnips, potatoes and carrots were grown for the domestic market created by Inverness counties' many coal mines. Cash crops which favor well-drained soils led to the cultivation of the alluvial floodplain soils. The increase in demand for cash crops coincided with a drop in demand for maple syrup, the main product of the Mull River valley's alluvial soil and in a matter of decades much of the floodplain forests were converted to agricultural lands.

The sugar maple floodplain forests were left intact for maple syrup production. Following 1867 (the year of Confederation) sugar became widely available and cheap, eliminating the financial viability of maple syrup production and diminishing its dietary importance. Timber harvesting until the early 1920s was completed primarily as a by-product of agricultural expansion and wood products were used for home heating and building construction. During the early decades of the twentieth century, wide-scale forest harvesting was conducted by the Mersey Pulp Company in the 1920s, with major log drives occurring into the early 1930s. Historical accounts suggest that after this time Atlantic salmon numbers declined significantly with residents believing the residues created by sawmilling and log driving (e.g. bark and sawdust) had "ruined the water, smothered the stream bed and killed most of the fish" (Personal correspondence, Jim St. Clair local historian). Given the scale of logs drives, especially the drive in 1931, it is likely that the influx of materials and the changes to channel morphology would have had long-lasting and devastating impacts on both Atlantic salmon and the entire aquatic ecosystem.

Assessments of current habitat conditions throughout the Mull River and its tributaries over the last three field seasons indicates that the legacy of historical land-use practices continues to negatively affect Atlantic salmon returns to the Mull River. Many of the symptoms of habitat degradation that were observed throughout the watershed can be addressed and mitigated through established river restoration and Atlantic salmon conservation techniques. Issues such as channel simplification (wide, straight and shallow channel) can be addressed by installing large woody debris structures such as digger logs and deflectors while issues such as bank erosion can be addressed through stabilization and tree planting projects. The protection of ecologically sensitive components of the watershed such as buffer zones and wetlands should be promoted through stakeholder and community engagement. This report begins with an overview of river restoration techniques and geomorphological processes followed by the assessment of habitat conditions within the Mull River. The last section of this report will provide detailed recommendations for restoring instream habitat and enhancing Atlantic salmon populations.

River Restoration

River restoration is a broadly used term that represents a variety of actions aimed at modifying or maintaining rivers and adjacent floodplains (Bennett et al., 2011). To some practitioners, river restoration may involve maintaining current channel conditions or floodplain position while to some practitioners river restoration involves restoring river-floodplain connection through the installation of biological structures. River restoration work may also entail the establishment of riparian zone vegetation, fencing livestock out of watercourses as well as restoring fish passage over artificial barriers such as culverts. The goal of river restoration projects is to improve the biological, hydrological and ecological processes found within river systems through the replacement of lost or compromised natural features (Wohl, 2005). Enhancing the stocks of species at risk (SAR) and other culturally important fish species such as Atlantic salmon has been the impetus of hundreds of river restoration projects in Nova Scotia as well as over twenty years of community effort throughout the Mabou Harbour watershed area.

In Nova Scotia, river restoration typically addresses the loss of important instream features such as large woody debris (LWD) as well as the establishment of riparian zones and mitigating bank erosion. These types of projects are aimed at reversing historical impacts such as log-driving and land clearing. In the Mull River watershed human activity over the last two centuries has had a profound influence on the current condition of the river channel. In some reaches the re-establishment of natural features such as riparian zone forests and LWD complexes has initiated the recovery of channel habitat while in other reaches persistent impacts such as those caused by infrastructure (e.g. roads and ditches) and present-day land-use (e.g. clearcutting, riparian zone loss etc) warrant immediate restoration actions. Wherever possible, restoration activities should be structured to improve ‘processes’ such as water retention and debris accumulation rather than addressing symptoms such as bank erosion. The properties bordering the Mull River are primarily privately owned and the successful partnership with landowners is a critical necessity to completing meaningful work. In situations where landowner concerns must be considered a pragmatic approach that incorporates process-based restoration and addresses some landowner concerns (i.e. erosion and flooding) is required.

The assessment of river habitat and the restoration planning process commonly employs terms such as riparian zones, geomorphic processes, channel reaches and many more. Furthermore, the life cycle and habitat requirements for Atlantic salmon are complex and unique for each watershed. Therefore an overview of important terminology is an appropriate starting point for any restoration document. As mentioned above, river restoration broadly aims to improve ecological functions and processes within a specific river or watershed. This is often completed by replacing missing or damaged natural features within the river channel and riparian zone.

Choosing the applicable restoration technique requires assessing the current condition of the river and the influencing factors within the landscape. For the purpose of this document each reach and tributary within the Mull River will be assessed. A river reach is defined as sections of river along which controlling conditions are sufficiently uniform.

Atlantic salmon are an anadromous fish species that occupy a large historic range, previously existing as far south as Virginia (Dunfield, 1985) and as far north as Nunavut. Spawning occurs in the freshwater environment during the fall months (October to December) and tributaries and headwater reaches are often the preferred spawning grounds. Eggs are deposited in redds at the downstream end or riffles or where groundwater upwelling occurs (Sears and DeVries, 2008). Research in a Nova Scotia salmon stream (Brierly Brook) found that Atlantic salmon spawning often occurs in close proximity to embedded LWD (MacInnis et al., 2010). Other important features in the freshwater environment include large holding pools for migrating adult salmon, instream and overhead cover for juveniles, adjacent wetlands and ponds for juvenile over-wintering as well as healthy invertebrate populations.

Stream restoration techniques should be chosen based on the stream classification for each particular reach (Rosgen, 1994). From the headwaters to the inter-tidal zone, river systems can exhibit a wide variety of classifications which must be identified prior to restoration work. David Rosgen has developed a stream classification diagram (Figure 3) that is generally accepted by restoration practitioners as a suitable tool for Atlantic salmon habitat restoration guidance. The stream classification for each reach of river is influenced by the streambed gradient and the floodplain gradient and size. Variance within each classification known as sub-classifications exists as a result of changes in substrate size and composition (e.g. gravel bottom versus clay). Regardless of the specific classification for each reach, habitat quality is determined by the heterogeneity within the river channel, the more complex and diverse the array of features found within each reach, the broader the range of available physical habitat (Fryirs and Brierley, 2013).

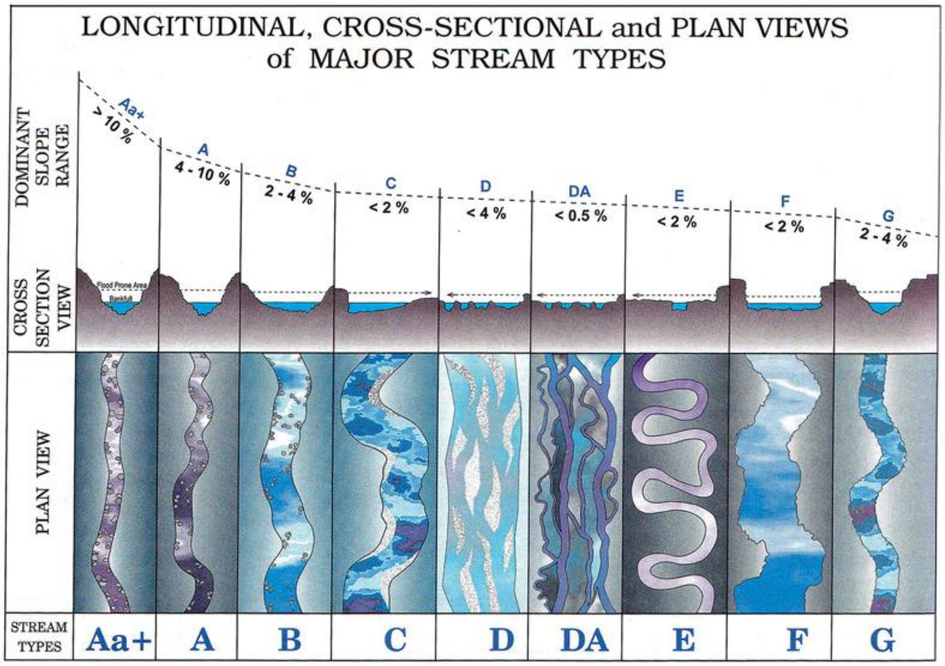

Figure 3: Rosgen's Stream Classification Diagram. (Aa+ and A) represent headwater streams, (B) intermediate streams, (C) and (E) are meandering streams, (D) braided, (F) entrenched and (G) gully (source Rosgen, 1994).

Issues of habitat degradation are often caused by changes to the landscape, impacts known as disturbance events. These events may be caused by climatic changes, rare weather events or anthropogenic events such as land-clearing or dam building. The early history of the Mull River settlers describes one such disturbance events, the logging of the Mull River uplands. In 1931, the Mersey Pulp Company conducted a major tree harvesting operation throughout the Mull River watershed. The Mull River was used to transport logs from the uplands to Mabou Harbor via log driving. While this expansive timber harvest provided local employment, the environmental impact was noted by residents who believed that the bark that had now covered the river bottom in most places had "poisoned the water and killed the fish".

The goal of this project is to restore instream fish habitat by replacing missing or damaged habitat features in the Mull River watershed by using established restoration techniques. Structures such as digger logs and deflectors can improve ecological function and promote the recovery of instream habitats. Measuring the success of this project (i.e. achieving goals) will be completed using established fish habitat monitoring protocols. Monitoring the results of restoration work is an important component to all restoration projects and should focus on measuring changes to water temperature, biological activity (redd counts) and physical habitat (habitat suitability index). A successful project will result in improved habitat, decreased summer water temperature, narrower channels and an increase in biological activity. A detailed monitoring plan is found in the following section of this report.

Figure 4: Aerial photo (looking upstream) of Shea's Brook near the Shea's - Mull River confluence.

Restoration Techniques

Digger logs are large logs placed across the stream and attached with rebar. They are designed with a rock ramp on the upstream side that captures gravel substrate and creates salmon and trout spawning area. The log is placed on an angle both horizontally and vertically. This angle pushes water to one side, restoring the natural meander of the stream. The plunging water creates a pool on the downstream side of the structure, creating resting areas and cover for salmon parr and adult trout due to depth and a blurring of the surface due to high turbulence at the surface and unembedded cobble.

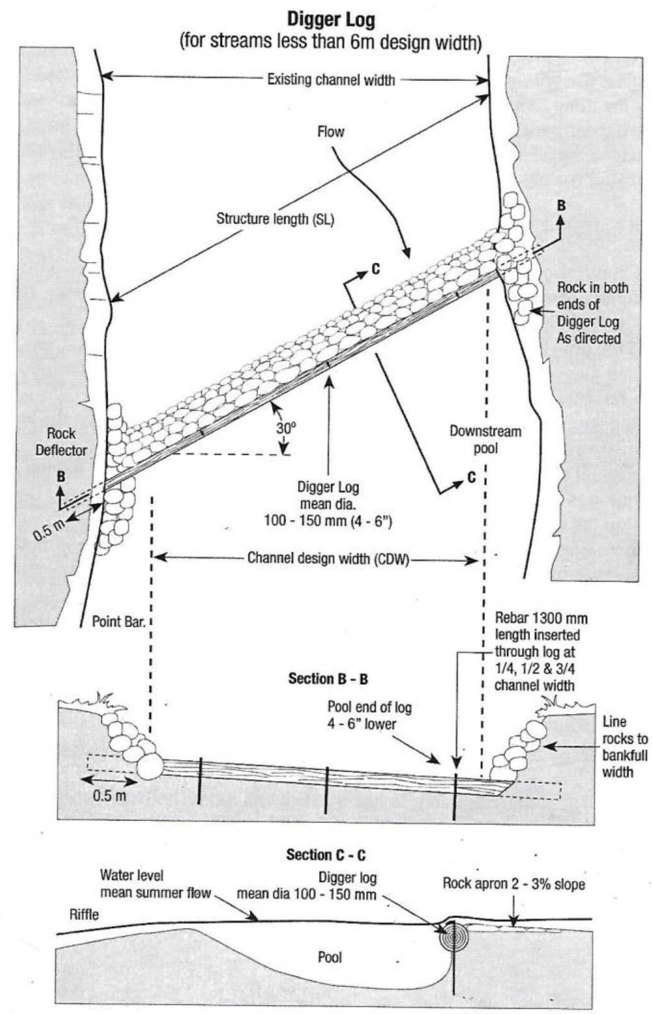

Figure 5: Conceptual drawing of a digger log

Log sills are similar to digger logs, but the log is placed at less of a vertical angle. They are used to build up the bed of an incised stream and connect it with its floodplain. Installing a log sill or rock sill will stop the river from cutting further down and decrease velocities in high flows as the water will be able to spill over into the floodplain. The log sills will also capture any gravels coming downstream to provide insect habitat, spawning habitat, and rearing cover for juvenile salmonids. These are used as control structures at both the crest of a riffle and the head of the pool.

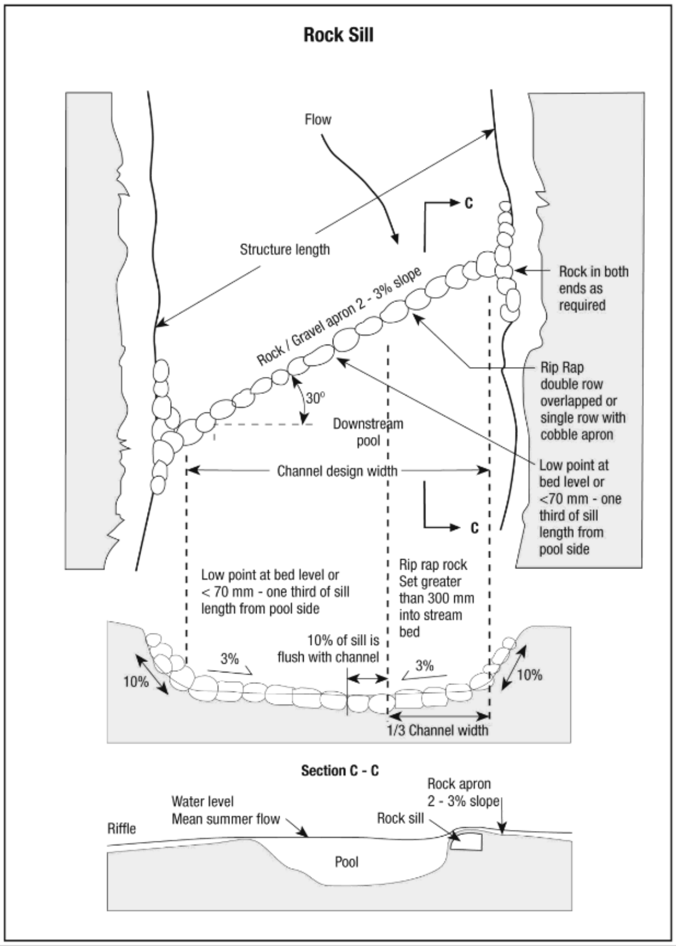

Figure 6: Basics of a rock sill used at the head of a pool.

Deflectors are triangular structures that extend out from the banks of the stream. They are intended to help narrow up an overwidened channel to its natural width and meander. This increases the depth of the thalweg by concentrating flow, improving fish passage and rearing. Deflectors are often paired with digger logs.

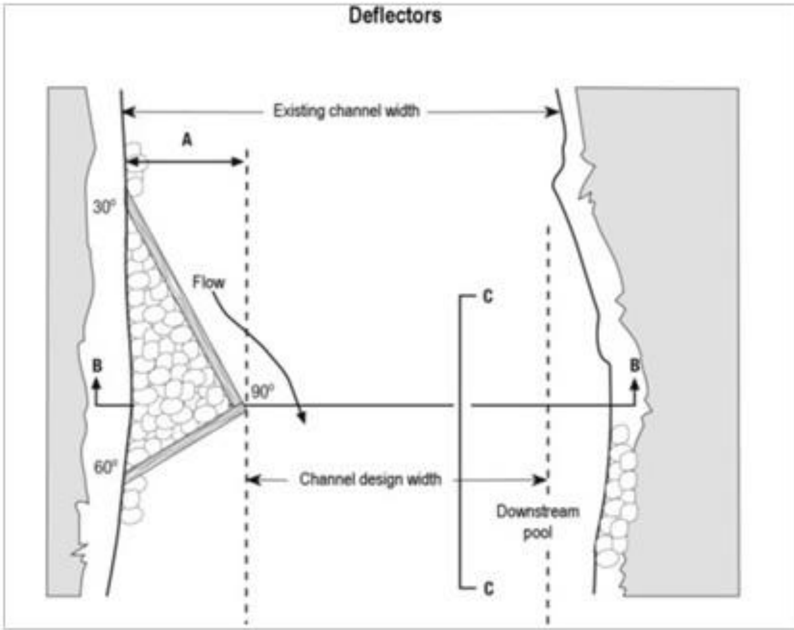

Figure 7: Conceptual drawing of a log framed deflector (source DFO 2008)**.**

Undercut bank structures are designed to simulate an undercut bank and are usually constructed out of logs. They provide hiding and escape cover for fish of all sizes. They can also protect stream bank from scour or erosion.

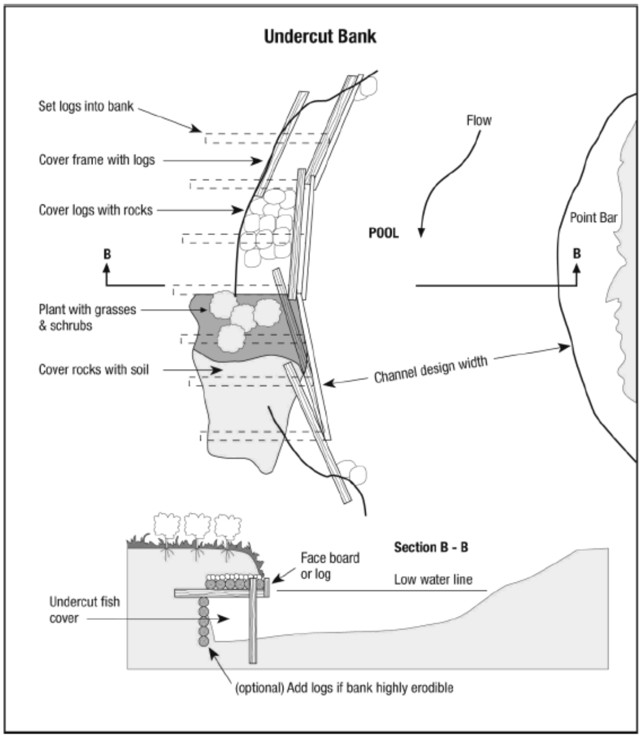

Figure 8: Diagram of an undercut bank structure

Riparian planting helps to re-establish vegetation, creating shade for the stream and stabilizes the banks. Log structures will be used to protect eroding banks.

Reaches with confined channels and no flood plains that are now incised holding more than the one in one hundred year flow will need log sills installed to raise the bed to a level that will allow the one in one hundred year flow to be the bank full flow. This will allow gravel to build up on the bed providing habitat. Reaches with some flood plain will have channels designed depth and width to handle the flow that cannot be safely handled on the small flood plain and incised channels will have log sill structures designed to maintain and capture gravel substrates. Reaches with suitable flood plains to handle the flood flows will have digger logs, deflectors, and undercut bank structures to form pools, spawning areas, and large overhead cover for adult salmon and trout

Instream Assessment of Fish Habitat

Issues of habitat degradation were identified throughout the Mull River watershed, including tributaries. The most common issues included streambank erosion, channel bottom embeddedness, an over-widened channel and an absence of large-woody-debris (LWD). These factors are limiting the productive capability of Atlantic salmon by reducing spawning habitat (quantity and quality) and destroying juvenile rearing and adult migration habitats. Signs of channel recovery were observed throughout the river system but the rate of recovery appears to be quite slow. This plan proposes to restore fish habitat in the Mull River by implementing a watershed-scale restoration plan that systematically addresses shortcomings in habitat features (e.g. absence of LWD etc) by using established-restoration techniques such as digger logs, bank stabilization and riparian zone planting, log deflectors and rock sills. The selection of techniques will depend on habitat features and upstream catchment size for each restoration site. Work in the main channel is expected to focus on using larger structures such as rock sills and log deflectors while work in the tributaries will focus on digger logs, deflectors and hand-rocking banks. This project also proposes significant community and landowner consultation and education in hopes of reducing harmful activities within the floodplain such as land-clearing, specifically near important buffer zones.

The Mull River watershed occupies a variety of landscapes and geologies as well as a variety of land uses. For the purposes of restoration planning the watershed can be divided into manageable sections or in geomorphic terms landscape units and reaches. Landscape units, sometimes referred to as sub-watersheds, contain similar topography, have similar landform patterns and may contain numerous channels and feeder streams. Each landscape unit will contain multiple reaches of stream. Reaches are defined as sections of river along which controlling conditions are sufficiently uniform. Given the variability in habitat features between reaches and landscape units, this plan will prescribe restoration actions on a reach by reach basis.

It is important to note that not all reaches are suitable for restoration activity, reaches with less than 4.0 square kilometers in upstream watershed area or with stream gradients greater than 3% are not deemed suitable for the work proposed in this document. The recovery of habitats outside these specifications is best achieved through natural processes. ISAA can promote the natural recovery of these reaches through community engagement and education. Typically steep slopes are found within confined valley bottoms and intrusion by human activities is not common. Reaches with steep gradients (<3%) are best managed and improved by promoting less harmful land-use practices in the adjacent floodplain. Streams with smaller drainage areas lack the hydrological force required for digger logs and other structures to influence instream habitats. The calculation of available habitat for restoration only counted habitat that was suitable for instream restoration.

ISAA completed tributary restoration projects throughout many tributaries of the Mull River, however as a result of high intensity rainfall events in 2010 and 2014 many of the restoration structures have been destroyed beyond repair. Part of this proposed work will focus on restoring these sections of stream and removing remnant structures. As a result of past work in the watershed, ISAA has developed a working relationship with some landowners as well as created a strong rapport within the community. Having a strong reputation within the community will help ISAA obtain landowner access to restoration sites. The findings of the habitat assessment and the recommendations for restoration have been divided into four sections (Table 2 below).

Section Name	Watershed Size	Available Habitat for Restoration	Applicable Techniques	Downstream Coordinates
Headwaters	21.22 square kilometers	53,873 square meters	Digger logs and deflector and tree planting. Hand rocking banks.	61°20′37.6″W 45°58′44.5″N
Upper	51.61 square kilometers	57,657 square meters	Deflectors and digger logs and tree planting.	61°22′9″W 45°59′56.7″N
Mid	69.10 square kilometers	86,615 square meters	Digger logs and deflectors, tree planting bank stabilization, rock sills and deflectors.	61°19′25.4″W 46°02′6.8″N
Lower	150 square kilometers	207,180 square meters	Log deflectors, bank stabilization, rock sills and deflectors and tree planting.	61°23′12.4″W 46°04′4.3″N
Total Restoration Potential	405,325 square meters of potential instream restoration.			

Table 2: Summary of watershed sections and restoration information.

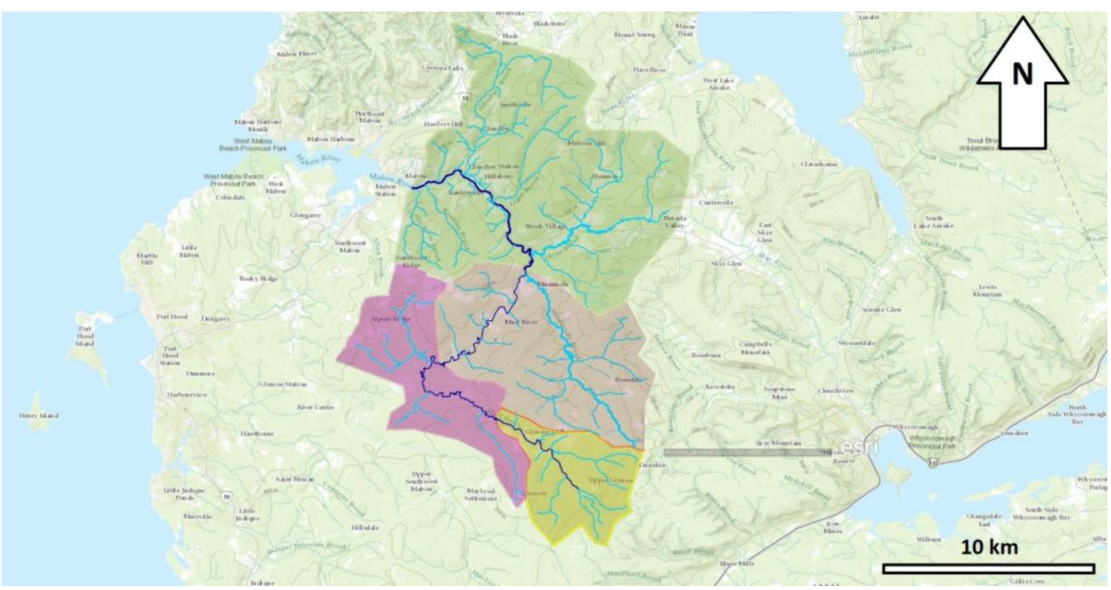

Figure 9: Color coded map displaying the landscape planning units. The main branch of the Mull River is highlighted in dark blue.

Section Specific Details

This report has divided the Mull River into four sections; headwaters, upper, middle and lower. Planning units were developed based on topography, upstream watershed size and applicable restoration tools..

Headwaters: Assessment of Instream Habitat and Restoration Recommendations

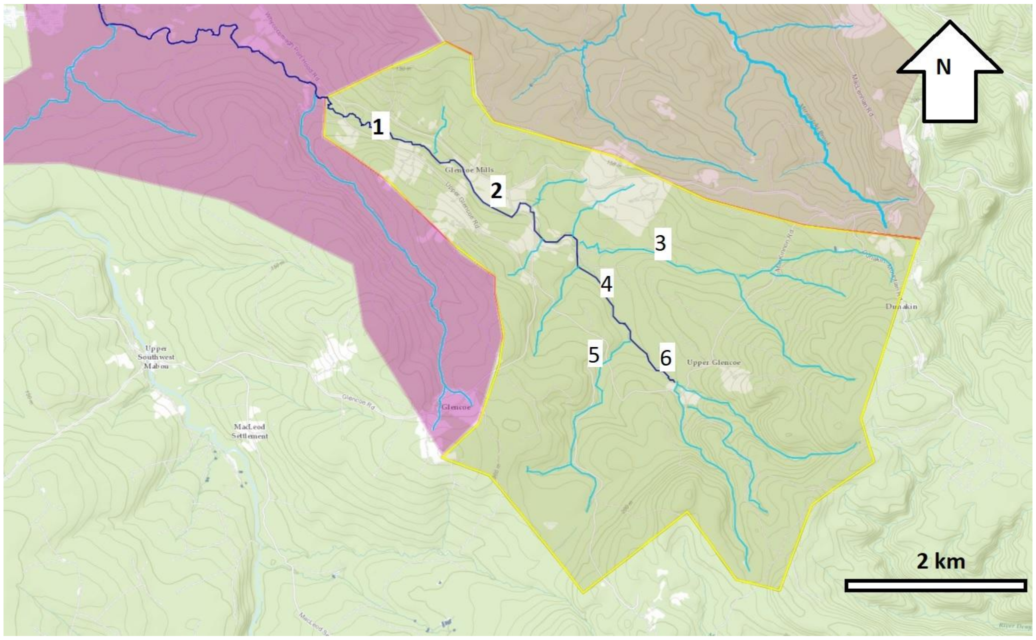

Figure 10: Map of the headwater section of the watershed with the individual reaches identified.

Reach	Available Habitat for restoration	Watershed size	Downstream coordinates
1	24,330 square meters	21.2 square kilometers	61°20′45.9″W, 45°58′50.4″N
2	10,218 square meters	17.62 square kilometers	61°19′3.7″W, 45°58′9.4″N
3	5,984 square meters	4.9 square kilometers	61°18′31.4″W, 45°57′56.5″N
4	7,800 square meters	10.2 square kilometers	61°18′32″W, 45°57′52.5″N
5	2,841 square meters	4.02 square kilometers	61°18′4.3″W, 45°57′20.4″N
6	2700 square meters	4.5 square kilometers	61°18′0.9″W, 45°57′19.2″N
Total	53,873 square meters		

Table 3: Overview of headwaters section of Mull River.

Reach #1: Headwaters

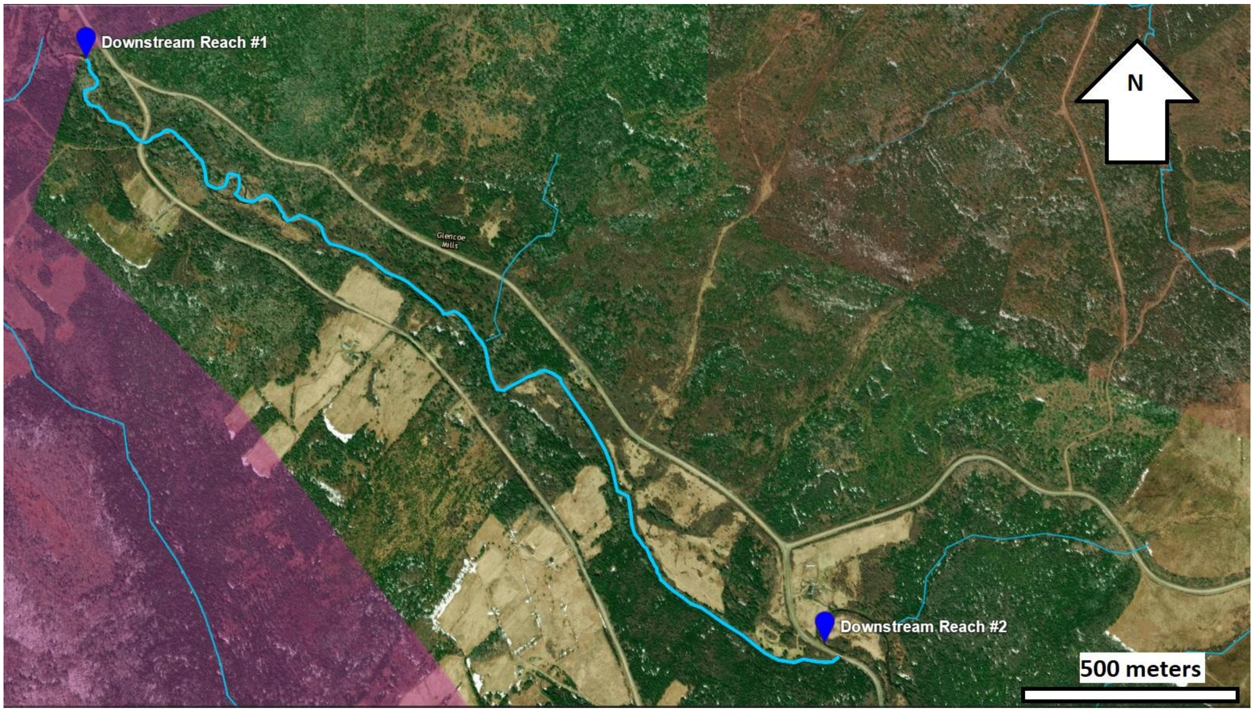

Figure 11

Reach #1 is the lowest downstream reach in the headwaters section of the Mull River and the quality of habitat has been negatively impacted by historic land use and resource extraction related activities (e.g. sawmills and grist mills). Instream surveys found that much of the channel through this section was over-widened (10-12 meter wide) and lacked sufficient pool habitat.

Site Specific Details			
Reach #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
`1	8.11 meters	3000 meters	24,330 sq. meters

Table 4: Restoration potential and stream width calculations.

Reach #1 begins where the Mull River flows underneath the Glencoe Rd. It appears that this reach of stream has been channelized, likely to align the stream perpendicular to the road. The first 120 meters of stream has been pushed against the left bank (looking downstream) and has downcut the substrate to the underlying bedrock. The bedrock transitions to a gravel – cobble substrate 120 meters below the bridge below a small bedrock falls (figure 12). Addressing this particular issue is difficult as a dwelling is located in the floodplain adjacent to the bedrock outcropping. Beginning 50 meters downstream the habitat substrate becomes conducive to instream restoration techniques such as deflectors and possibly digger logs. The channel below the bedrock outcropping is straight and lacks a meander pattern (visible in figures 13 and 14).

Figure 12: Bedrock outcropping at the bottom of a re-aligned channel in reach #1.

Figure 13: Looking upstream towards the bedrock outcropping. As the river moves away from the steep embankment the channel is allowed to dissipate energy and deposit instream materials.

Figure 14: Looking downstream from the bedrock outcropping. The dwelling that has encroached on the flood plain is visible on right side of the photo.

Restoration through this reach can be completed using digger logs and deflectors for the first 2200 meters of stream. The construction of bank cribbing using logs and instream material should be completed at two sites (61°20′17.4″W, 45°58′39″N) identified in figure 16 below.

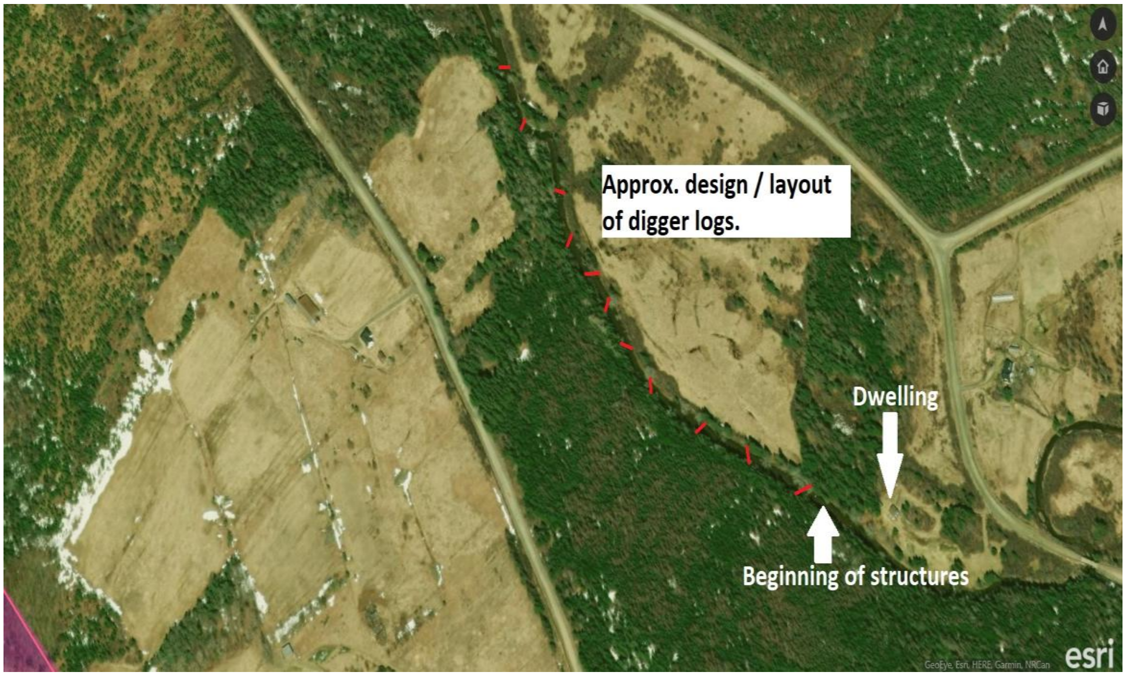

Figure 15: Red lines denote approximate location and design of digger log structures.

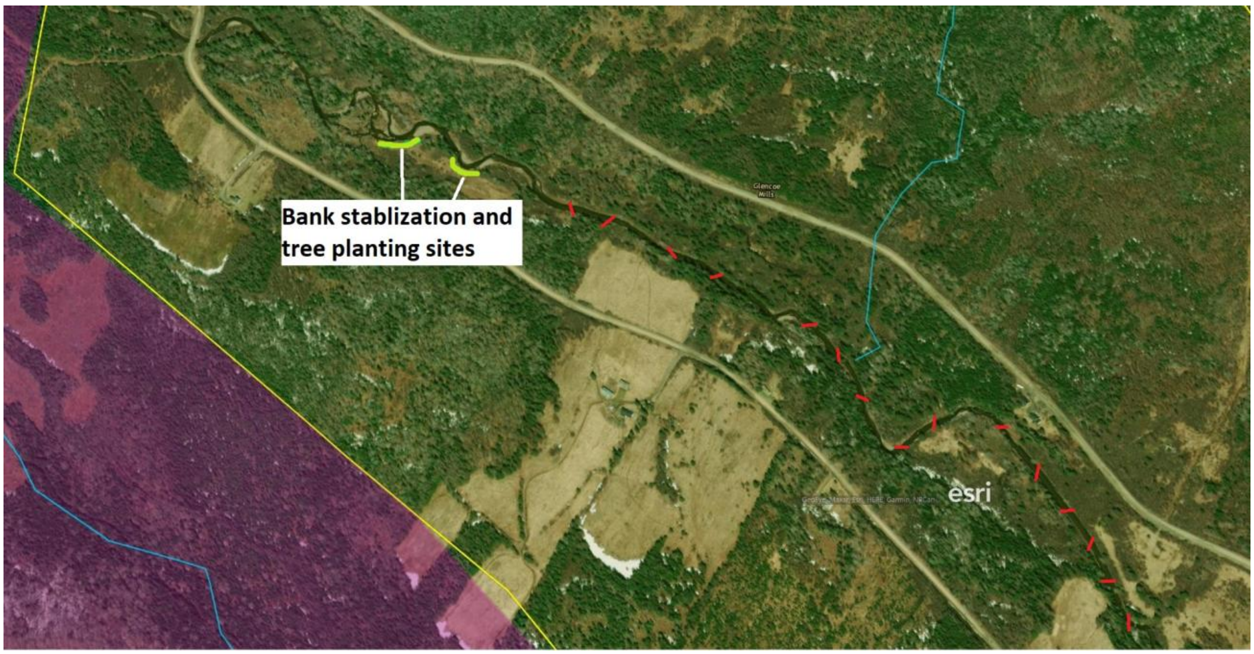

Figure 16: Approximate layout of instream restoration structures. Digger logs denoting in red.

The floodplain topography surrounding the lower 800 meters is much wider and has a much greater degree of sinuosity and contains a major debris complex that has divided the channel into multiple threads. As this section of channel may further migrate within the floodplain, the most suitable technique for restoration would be alternating deflectors.

Figure 17: Lower sites on reach #1. Deflectors are most appropriate technique.

Figure 18: Orange and blue markings denote locations of historic channels, signifiying a great degree of changes over time.

Figure 19: Lower extent of reach #1 in the headwater section.

Figure 20: Aerial photo of debris complex and multi-thread channel development.

Reach #2: Headwater Section

Site Specific Details			
Reach #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
`2	7.86 meters	1300 meters	10,218 sq. meters

Table 5: Headwaters reach #2 details and information.

Reach #2 begins below the confluence of the upper branches (61°18′34.6″W, 45°57′57.6″N) and ends at the bridge on Upper Glencoe Rd. The majority of this reach flows through abandoned and semi active pasture land. A combination of digger logs, deflectors and bank logs can be used to improve instream habitat conditions through this reach. Tree planting should accompany any bank stabilization work if an intact riparian zone doesn't exist. The potential for restoration in this reach is 10,218 square meters and can be completed using primarily crew work. The lower-most turn in this reach, located just upstream from the Upper Glencoe Bridge may benefit from armour rocking. There appears to be machine access to this site, therefore bank stabilization can be completed using armour stone. There is beaver activity scattered throughout this reach with an established dam (Figure 24) about 300 meters above the Upper Glencoe Rd bridge. Where naturally occurring features such as debris jams and beaver dams exist, those structures should be left intact whenever possible. Landowner education on the benefits of natural structures could be a worthwhile expenditure of effort.

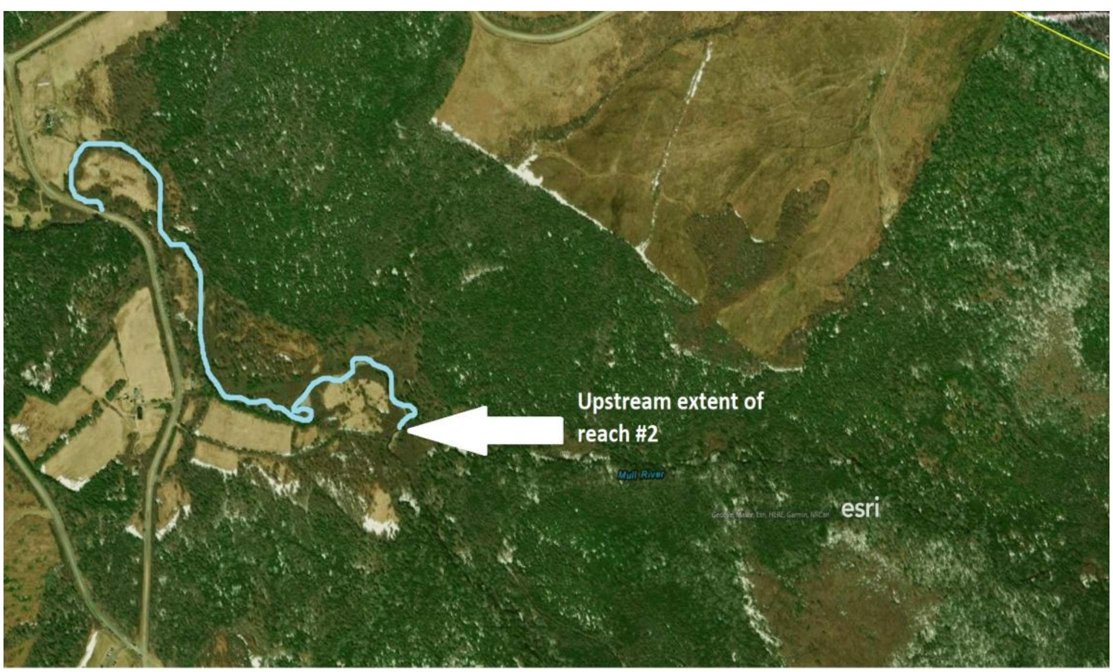

Figure 21: The channel of reach #2 is highlighted in light blue.

Figure 22: Lower portion of reach #2.

Figure 23: Bank erosion issues on the left. Restoration work should include tree planting and bank stabilization.

Figure 24: Beaver dam in headwaters reach #2

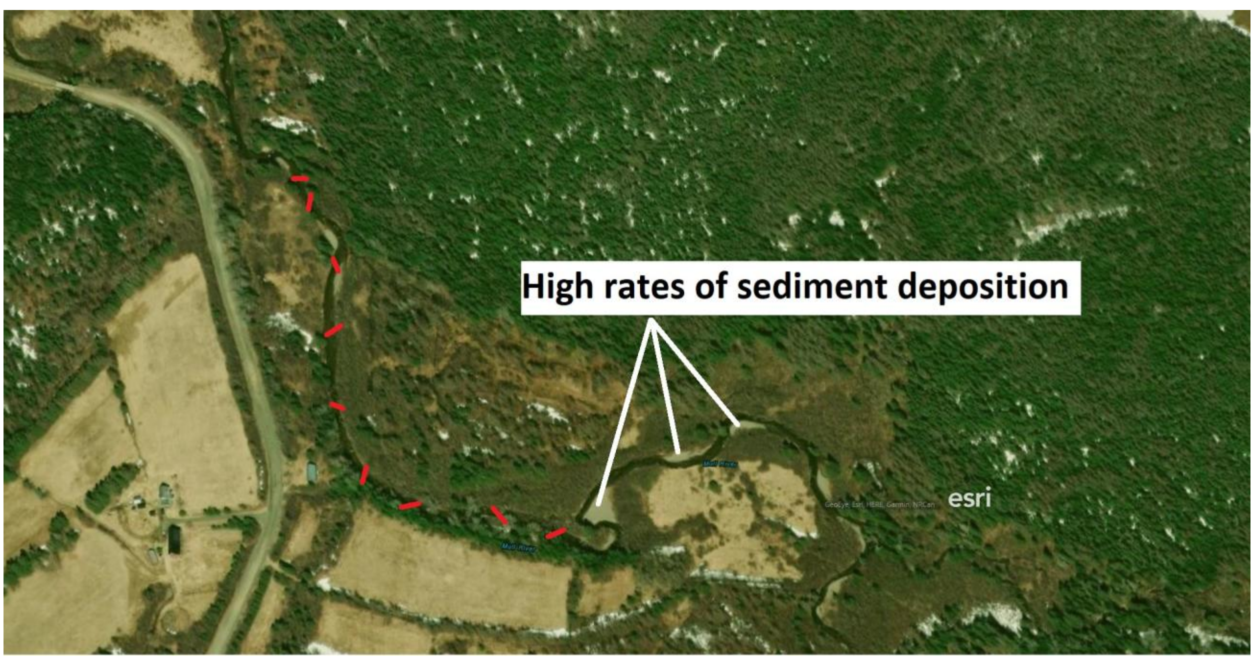

Figure 25: Red lines indicate approximate location of digger logs.

Figure 26: Showing deposition of gravels and fines along inside of meander.

Figure 27: Showing accumulation of fines. Large woody debris providing overhead cover.

Reach #3: Headwater Section

Site Specific Details			
Reach #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
`3	5.44 meters	1100 meters	5,984 sq. meters

Table 6

Reach #3 is an unnamed tributary to the Upper Mull River that drains from the northern portion of the watershed. This tributary contains over one kilometer of suitable habitat for instream restoration. The uppermost sections of this tributary are spread out of three smaller branches which contain fish habitat but are not suitable for restoration. The most effective restoration technique for this reach would be the installation of digger logs with deflectors. The bankfull width in this reach is 5.44 meters and the structures should be installed every 32.64 meters on average. This particular reach is the most remote reach in the watershed and may require clearing access trails (foot paths only) in order to bring equipment and materials into the site. A review of topographic maps and sattelitte images showed the presence of old logging roads. Ground truthing will be required to determine whether or not those trails still provide any access for vehicles or the restoration crew.

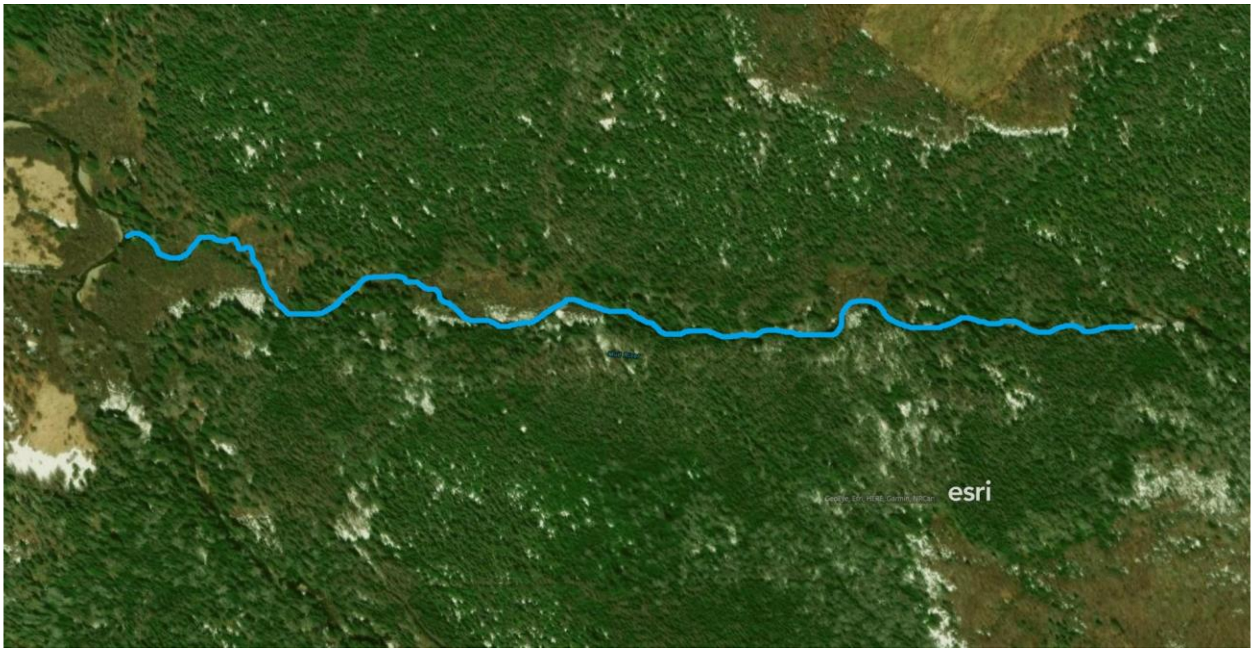

Figure 28: Headwater reach #3 highlighted in blue.

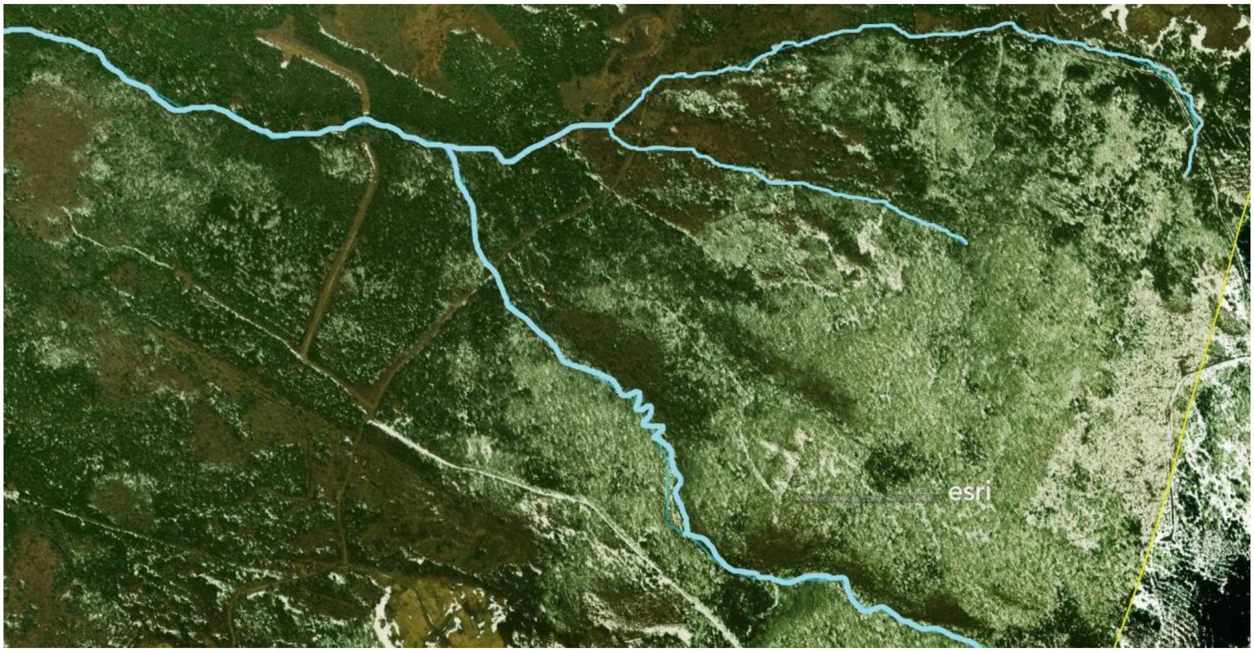

Figure 29: Satellite image of the upper branches that drain into reach #3 in the headwater section.

In the headwater section of the Mull River there are two watercourses (reach 5 and 6) that enter the river from the south. Below these watercourses there is a 1400 meter reach of stream that contains 7800 square meters of potential habitat (see table below). This reach runs parallel to MacKinnon Rd but will require the creation of a 400-500 meter access trail in order for the crew to bring in materials and equipment.

Reach #4: Headwater Section

Site Specific Details			
Reach #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
4	6.73 meters	1.4 km	7,800 sq. meters

Table 7

Restoration of this reach will be done using digger logs and deflectors spaced at approximately 40 meters between structures. There is potentially enough stream length through this reach to require the installation of 35 digger log structures.

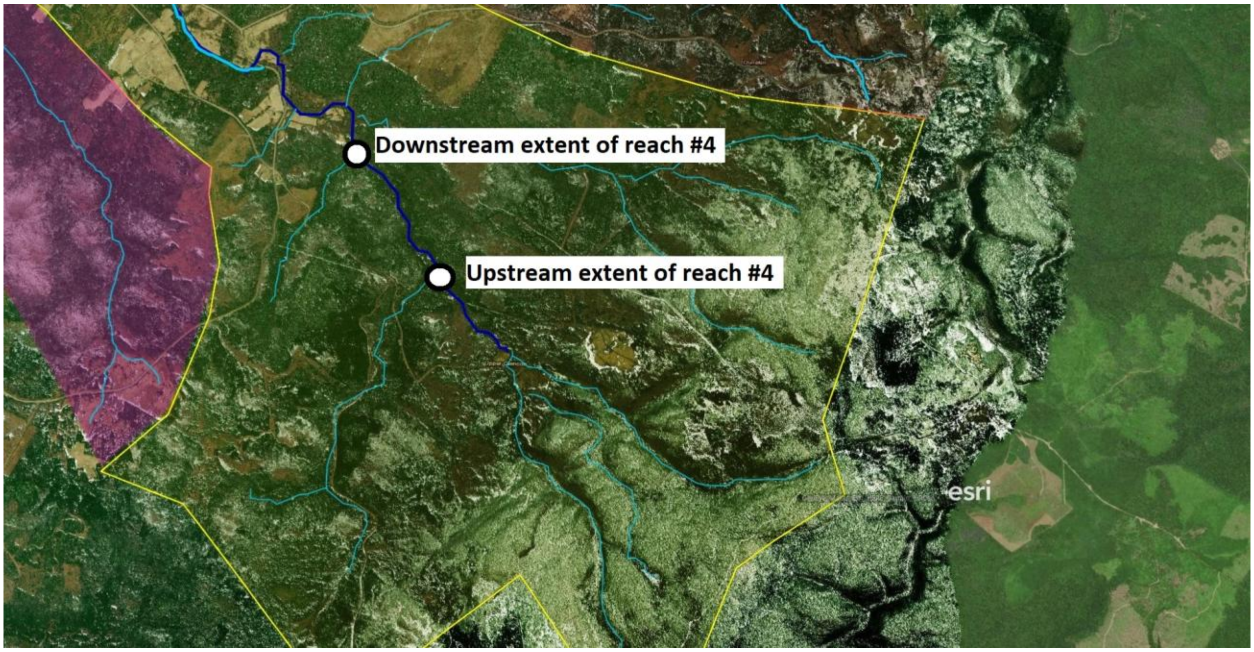

Figure 30: Satellite image displaying reach #4 in relation to the rest of the headwater section.

Figure 31: Typical channel condition in reach #4 of the headwaters.

Reach #5 & #6: Headwater Section

Site Specific Details			
Reach #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
5	5.14 meters	553 meters	2,842 sq. meters
6	5.31 meters	508 meters	2,702 sw. meters

Table 8

Reach 5 and Reach six are similar in watershed size, stream gradient and restoration potential. Reach six splits into two smaller watercourses that both contain trout and salmon habitat. The productivity of both reaches has been diminished by habitat fragmentation caused by improperly installed highway culverts (figures 33 – 36). The habitat in both reaches has been impacted to some extent by historical land use practices such as farming, clear-cutting and road construction. The installation of digger logs at approximately 32 meter structure spacing should facilitate the recovery of spawning habitat and pool habitat.

Figure 32: Downstream of the barrier culvert in reach 5. Brook trout and salmon parr were observed during site visit in October 2020.

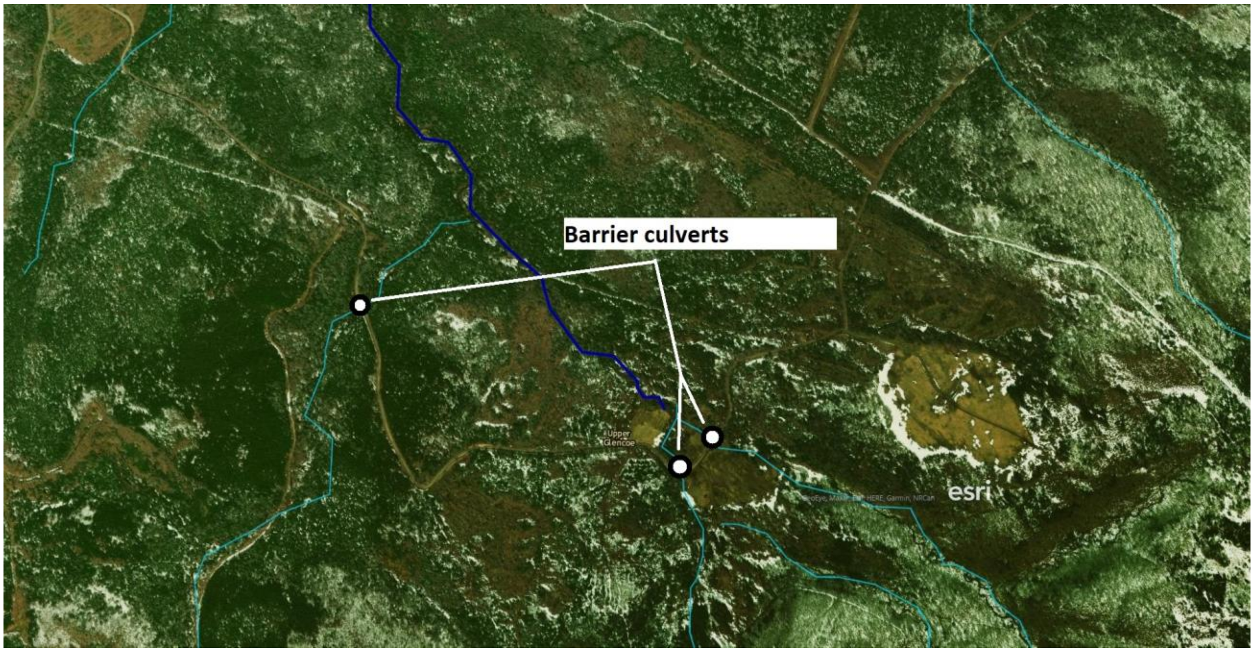

Figure33: Satellite map showing the locations of the three barrier culverts in the headwaters section.

Figure 34: Barrier culvert on MacKinnon Rd on reach 5 (61°18′16″W , 45°57′12.9″N).

Figure 35: Partial-to-complete fish passage barrier on reach 6 MacKinnon Rd crossing (61°17′38.2″W, 45°56′60″N).

Figure 36: Complete barrier to fish passage on north branch of reach 6 - MacKinnons Rd (61°17′33.3″W, 45°57′3.4″N).

Upper Section Habitat Assessment and Restoration Recommendations

The upper section of the Mull River can be divided into six reaches, including a tributary which is labeled as reach #1 for this section (see figure 37). This section of the watershed was historically settled for farming in the 1800s and in the early 1900s the river channel was heavily impacted by the presence of sawmill and grist mills. Both aerial and instream assessments throughout this section indicated that the channel habitat is recovering in recent decades. The recovery of habitat in the upper section of the Mull River appears to be occurring at a faster rate than the habitat found in both the headwater section and mid and lower sections. This can most likely be attributed to the topography in that section of stream which is low lying floodplain habitat with numerous overflow channels. Much of the historic farm land in this section has been abandoned and many old pastures have been colonized by alders and willows. Beaver dams were located in a couple of locations in this section of stream, providing important over-wintering habitat for salmonids as well as providing flood-mitigation features to the channel design.

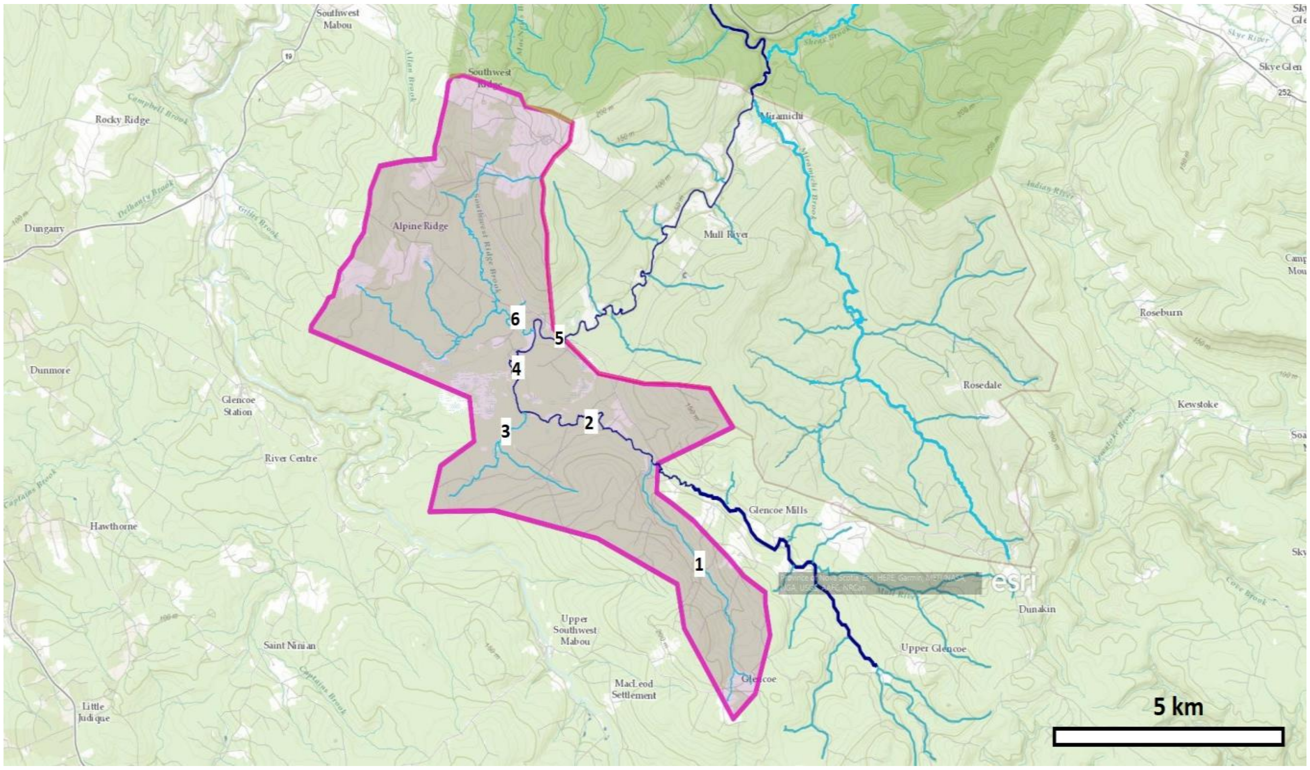

Figure 37: Topographic map of the upper section (highlighted in purple).

Despite the faster rate of recovery found in the upper section this report still recommends the implementation of instream restoration, in particular deflectors, bank logs and digger logs where applicable. Increased summer water temperatures and extremely low summer flows are common issues that have been observed by local anglers and the ISAA restoration crew. The issues with water temperature and baseflow conditions can be attributed to historical channel re-alignments (channelization for agriculture and timber drives) which have caused the Mull River to drain the groundwater tables in the adjacent floodplains. Historical accounts of this section of stream describe a much different floodplain ecosystem than is presently found. Low lying areas were inundated by sweeping meanders, abandoned channels, oxbow lakes and wetlands. Above the immediate floodplain area were stands of mature maples and oaks. The removal of these important features resulted in widespread habitat degradation and without human intervention (e.g. restoration) the full recovery of these habitats may take centuries. The restoration structures that are proposed for this section are designed to mimic the channel response to large woody debris, creating pools and spawning habitat. Siltation was also observed through this section of stream resulting in the embeddedness of stream bed substrate which reduces spawning success and lowers the productivity of primary producers (i.e. invertebrates).

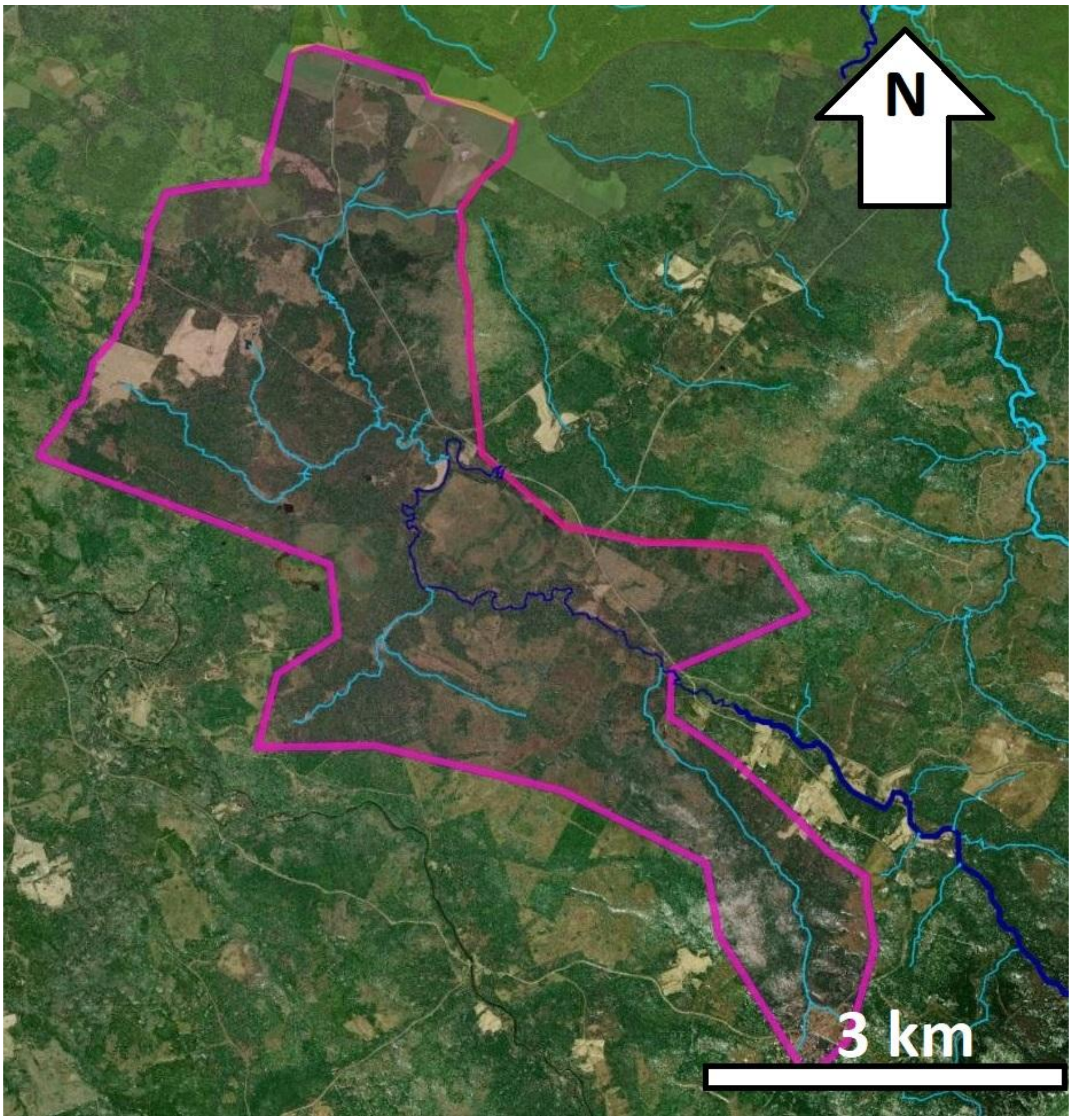

Figure 38: Satellite image with the upper section highlighted in purple.

Overview of upper section – Mull River			
Reach	**Available Habitat for restoration**	**Watershed size**	**Downstream Coordinates**
1	**1,632 square meters**	**4.9 square kilometers**	**61°20′53.8″W, 45°58′52.9″N**
2	**34,003 square meters**	**30 square kilometers**	**61°22′45.2″W, 45°59′19.5″N**
3	**1,813 square meters**	**4.1 square kilometers**	**61°22′44.9″W, 45°59′18.2″N**
4	**21, 318 square meters**	**36.1 square kilometers**	**61°22′35.2″W, 46°00′2″N**
5	**10,860 sq. meters**	**53.5 square meters**	**61°22′9.1″W, 45°59′57.4″N**
6	**5,173 square meters**	**14.1 square kilometers**	**61°22′38.5″W, 46°00′2.7″N**
Total	**74,799 square meters of potential restoration habitat**		

Table 9

Reach #1: Upper Section

The upper section of the Mull River begins with a tributary that enters on the south side of the watershed and meets the Mull River at 61°20′53.8″W, 45°58′52.9″N. This stream drains a 4.9 square kilometer watershed and contains 300 meters of stream that would be suitable for instream restoration. Moving further upstream on this watercourse the potential for restoration is limited due to inaccessibility and steep gradient stream bed.

Figure 39: Small tributary with a 4.9 square kilometer watershed.

The lower 300 meters of channel could be restored by installing digger logs every 32.6 meters. The logs will be installed at alternating angles to create a serious of left and right side pools.

Reach Specific Details			
Reach #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
1	5.44 meters	300 m	1,632 sq. meters

Table 10

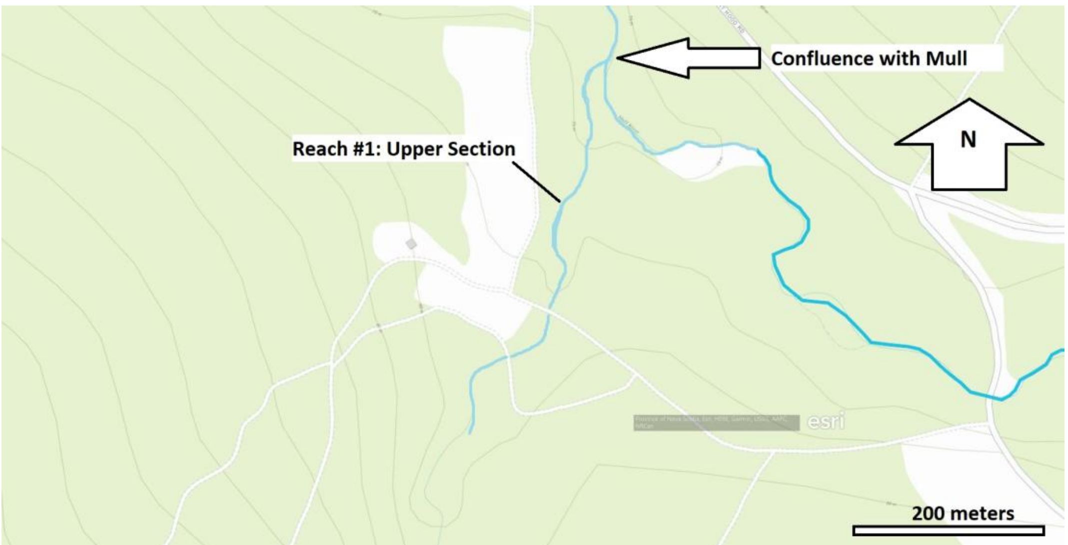

Figure 40: Topo map of reach #1 – upper section.

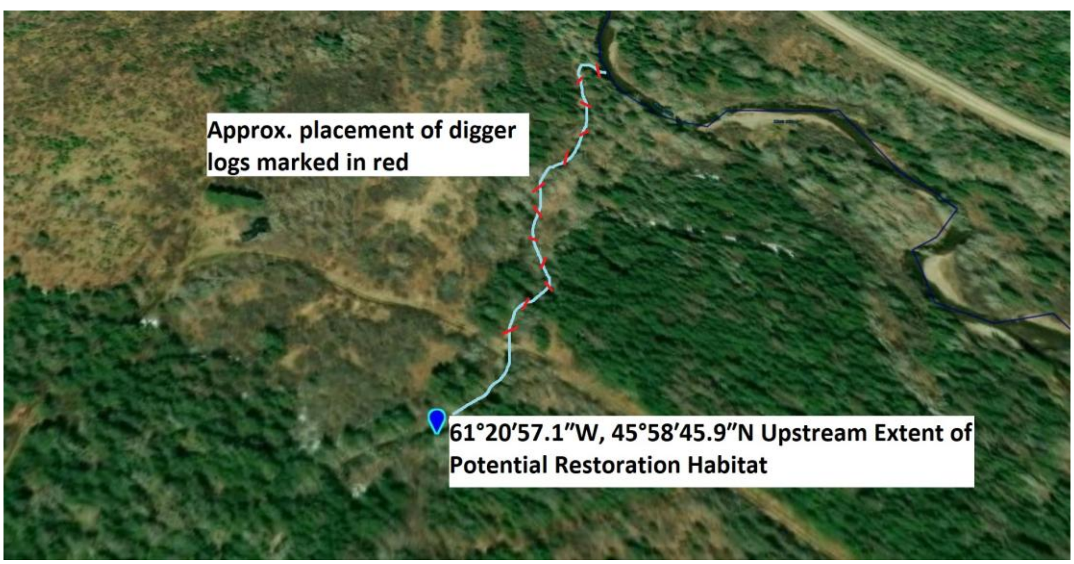

Figure 41: Satellite image showing approximate location and sequence of digger logs.

Reach #2: Upper Section

The second reach in the upper section covers approximately 3700 meters of channel making it the longest reach in the upper section. The channel within this reach should have a calculated bankfull width of 9.19 meters, however surveys of this reach during the fall of 2019 and 2020 found that the channel was over-widened (10-14 meters wide) and that in recent years the meanders have begun to widen out (e.g. greater sinuosity). This is evident by the accumulation of large gravel bars forming on the inside of all meanders (Figure X). Historical accounts of the land-use surrounding this reach describe a functioning grist mill at the location of the current bridge on Upper Glencoe Rd. The riparian vegetation was also cleared in the 1860s and the ground cover was converted to pasture land. This changes to the hydrology in this reach caused severe habitat degradation, primarily through the straightening of the channel and removal of organic materials and streamside vegetation. Satellite imagery on this reach clearly shows where had been straightened, following the abandonment of the pasture land sometime in the last century, this reach has begun to recover its meander pattern.

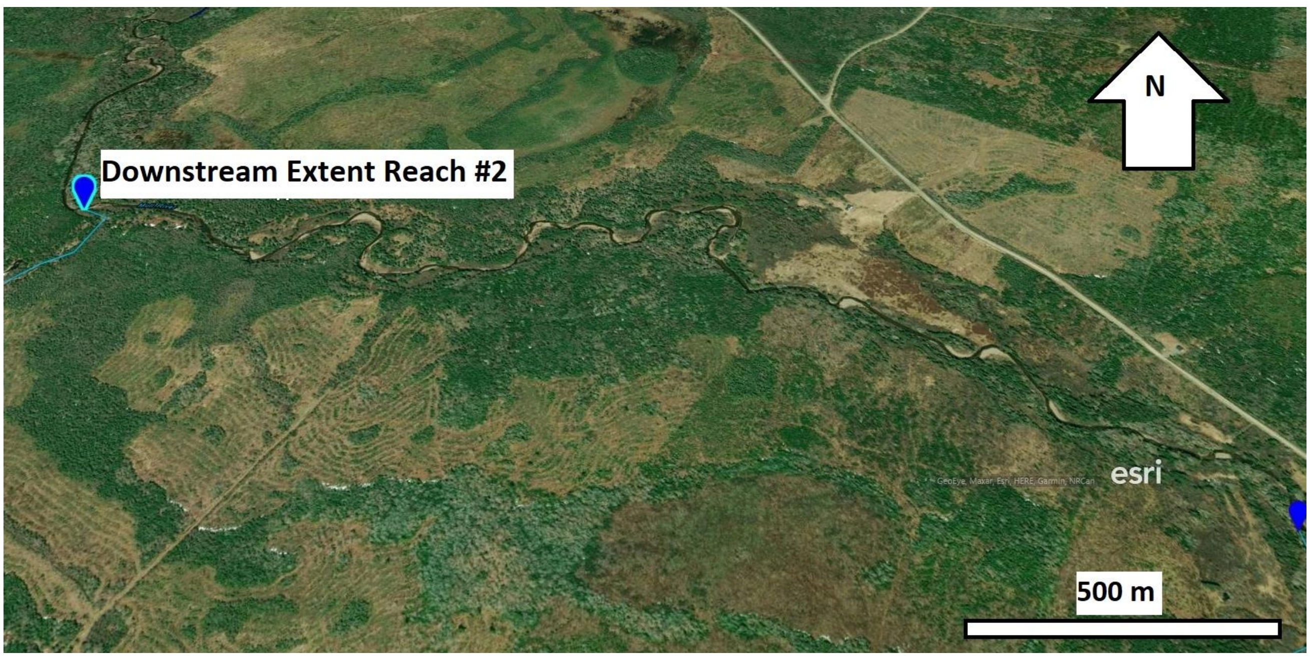

Figure 42: Satellite image of reach #2 in the upper section.

Restoration of fish habitat in this reach can be achieved by installing log deflectors to encourage meander formation and pool creation. Deflectors that are installed upstream from the newly forming gravel bars will reduce flood and ice scouring by pushing the flow towards the thalwag of the channel. Reducing the pressure on these newly formed bars will promote the establishment of permanent vegetation. Gravel bars that are allowed to vegetate help retain groundwater, reduce the transport of fine sediments and eventually provide shade as pioneer tree species such as alders and willows establish. Tree planting along some banks sites in this reach is recommended to help jump-start the re-establishment of slow growing trees such as sugar maple.

Reach Specific Details			
Reach #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
2	9.19 meters	3.7 km	34,003 sq. meters

Table 11

Figure 43: Aerial photo from reach #2 below the Upper Glencoe Bridge showing the accumulation of gravel on the inside of the meander.

Log deflectors will be built to encourage channel habitat recovering, primarily through the deepening of pools, narrowing of channel width and by allowing gravel bars to develop. Deflectors will be spaced out at approximately 50 to 65 meter intervals in alternating directions. Two sites were identified for tree planting (see figure 45) and two sites were identified for bank stabilization through the construction of log framed cribs. Depending on site conditions during the time of structure installation, the log cribs could be constructed to include an artificial over-hanging bank.

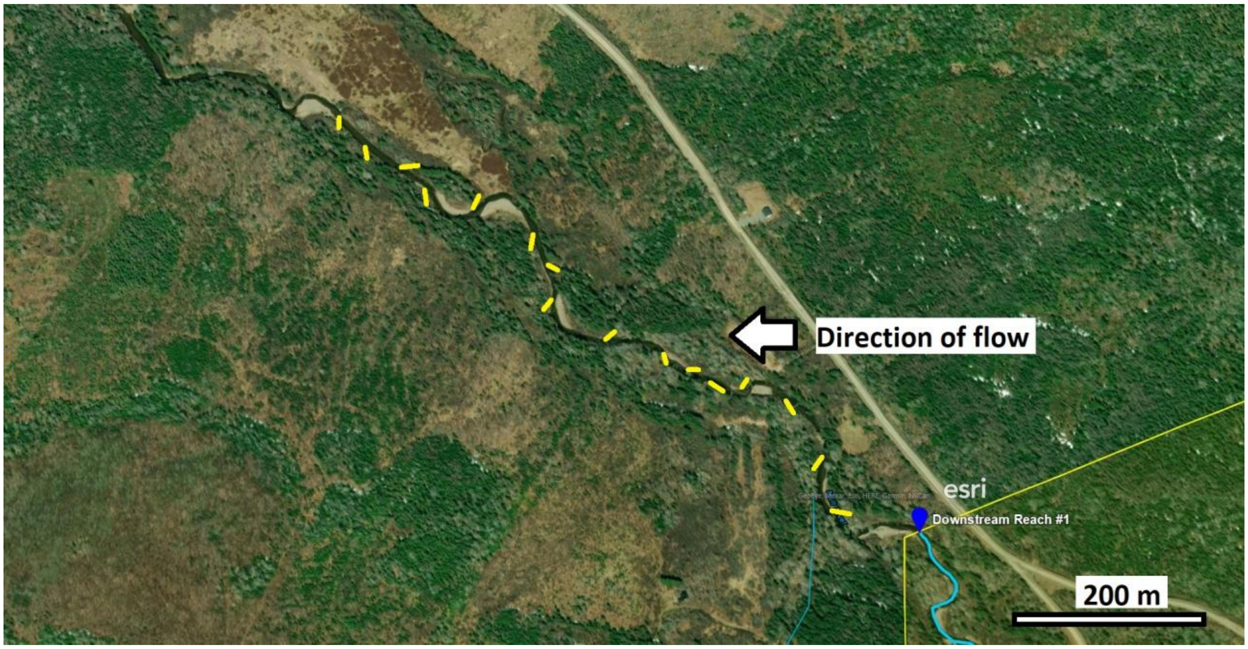

Figure 44: Approximate placement of deflector structures in upper section reach #2.

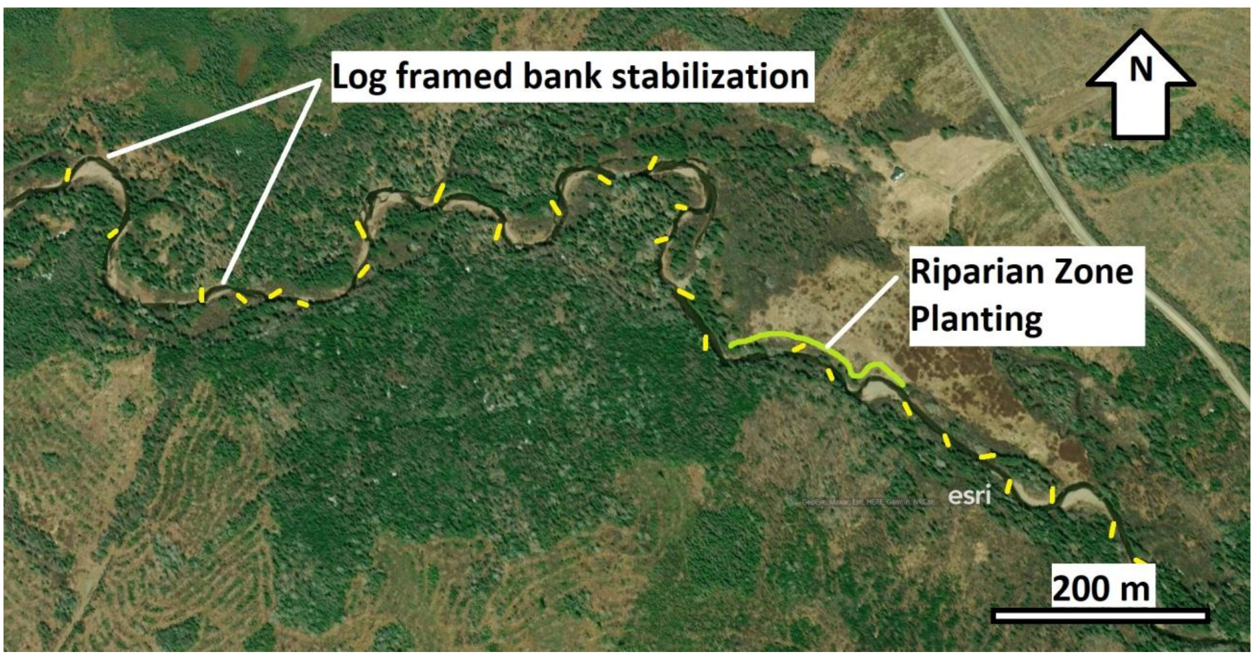

Figure 45: The lower extent of reach #2 (upper section).

Reach #3: Upper Section

The third reach in the upper section is a highly degraded tributary that flows south to north, emptying into the Mull River at the downstream extent of reach #2. This 4.9 square kilometer sub-watershed has been fragmented by forestry activities and historical land clearing for farming. The upper portion of this reach is a series of wetland ponds connected by 2-3 meter wide channels. As a result of the historical land-uses in this reach, the headwater wetlands are disconnected during summer months due to low water. Options for remediation include digger logs in the lower 300 meters of stream, however addressing the disappearance of surface water will require the installation of gradient controls which could include the installation of log sills or artificial beaver dams. The potential impact of restoration on this reach will depend on the landowner's willingness to restore connectivity throughout this reach by restoring the wetlands and increasing water retention. There a number of logging roads that intersect the channel throughout this section, assessing these crossing for fish passage is recommended in 2021. Recent forest harvesting activity was observed in the upper portion of these reach. Meeting with the landowner to discuss their plans and willingness to allow restoration is required before starting any restoration.

Reach Specific Details			
Reach #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
3	5.18 meters	350 m	1,813 sq. meters

Table 12

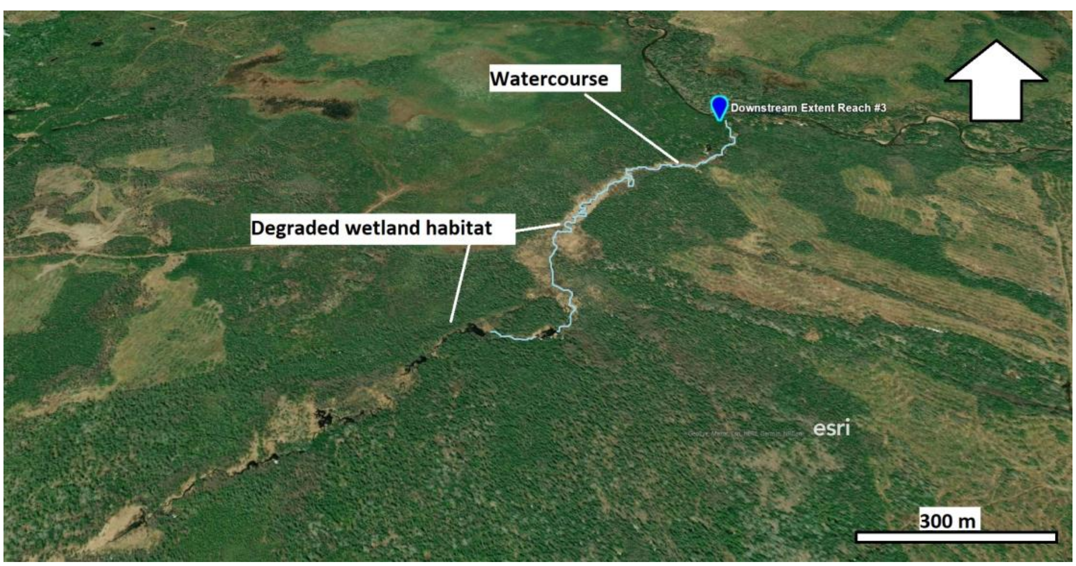

Figure 46: Upper Reach #3

Reach #4: Upper Section

Reach #4 in the upper section begins at the confluence of reach #3 and the Mull River and continues for about one kilometer to the confluence of Southwest Ridge Brook and the Mull River. The adjacent floodplain in reach #4 contains both active and abandoned farmland as a couple of dwellings. Streambed sediment was observed throughout much of this section and the distance between pools (e.g. the meander length) was greater than the hydrological data would suggest. Both these issues can be addressed by installing deflectors which will help to sort substrate and promote the delivery of fines and silts into the floodplain. To the east of this reach a 110 hectare plot of land was clearcut around the year 2000, this could be a contributor to the siltation observed throughout reach #4. After reviewing both drone footage and satellite images it appears that all environmental guidelines (e.g. buffer zones) were adhered to. Regardless, clearcutting can negatively affect adjacent streams by reducing the capacity of soils to retain water, thus decreasing baseflow conditions during the summer months.

Reach Specific Details			
Reach #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
4	9.69 meters	2200 m	21,318 sq. meters

Table 13

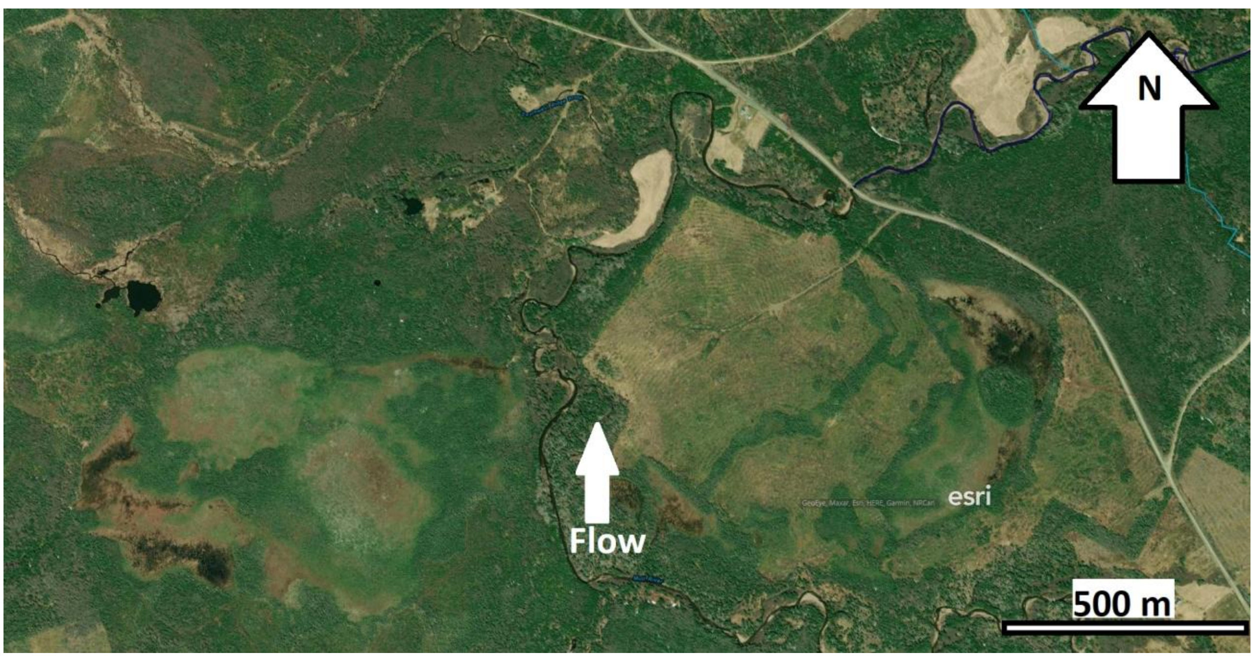

Figure 47: Satellite image showing reach #4 upper section.

Restoration through this section will be completed by installing alternating series of log deflectors. This reach can be divided into two sections, beginning upstream this reach flows through a channelized section of stream and has been completely straightened. Installing deflectors will help recover the natural meander pattern. Approximate location of each deflector is marked with a yellow dash in figures 49-52.

Figure 48: The lower extent of reach #4 above the Southwest Ridge Brook confluence.

Figure 49: Approximate location of log deflectors.

Figure 50: Approximate location of deflectors.

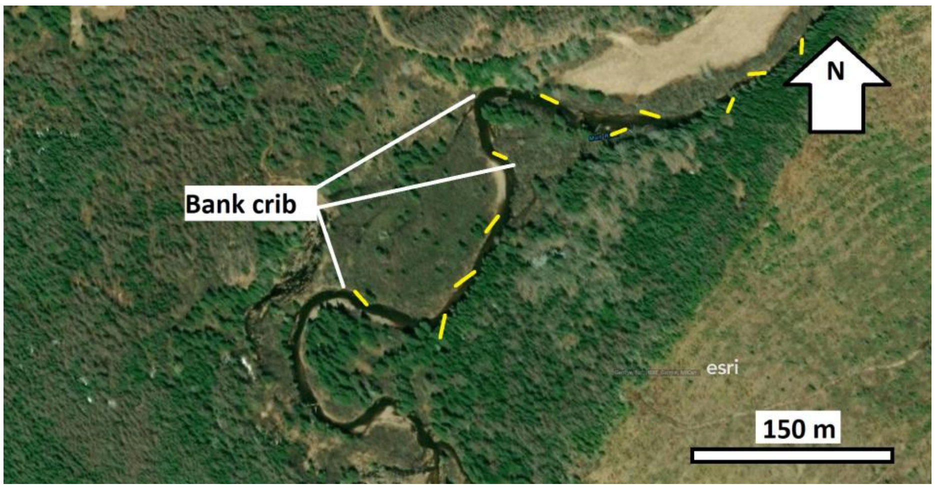

Figure 51: Approximate location of deflectors and bank cribbing.

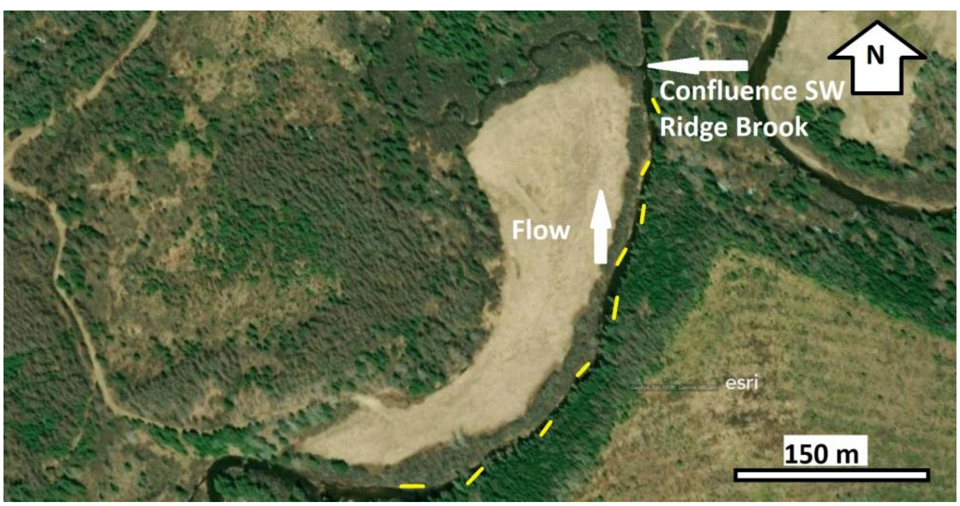

Figure 52

Reach #5: Upper Section

Reach #5 in the upper section of the Mull River begins at the confluence of the Southwest Ridge Brook and the Mull River and ends at the Whycogomah-Port Hood Rd crossing. The total watershed area above this bridge is 53.5 square kilometers. This reach contains several holding pools and an active beaver dam (figure 53) approximately 100 meters upstream from the bridge. It appears the beaver dam is creating habitat for fish and mitigating flood water damage so restoration work will begin upstream from the dam. Measurements of the channel in 2020 indicate that the channel is over-widened by 30% and could benefit from the installation of deflectors. By narrowing the channel the deflectors will enhance the depth of the holding pools. Tree planting should also be completed along a 110 meter section of bank that currently lacks a riparian zone (figure 54 and 55).

Reach Specific Details			
Reach #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
5	10.86 meters	1000 m	10,860 sq. meters

Table 14

Figure 53: Aerial photograph looking downstream on reach #5 (above the Whycogomah-Port Hood Rd Bridge.

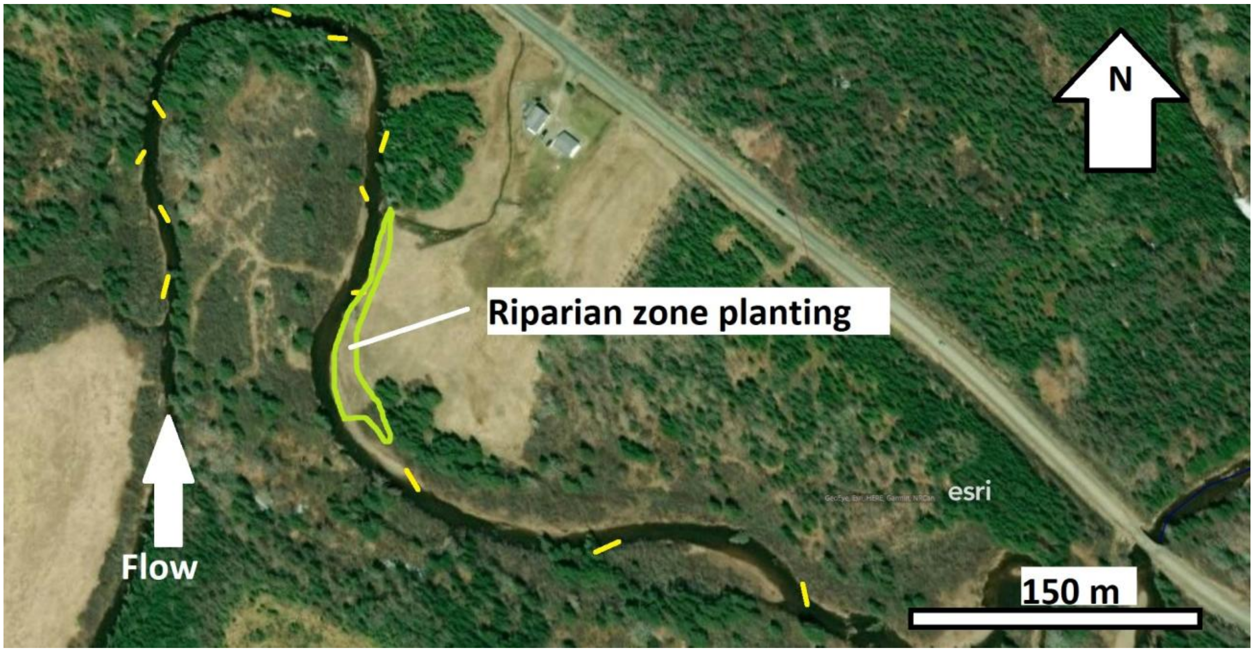

Figure 54: Approximate location of deflectors marked with yellow dash.

Figure 55: Looking upstream on reach #5 of the upper section. The right-side of the stream should be planted.

Reach #6: Upper Section

Reach #6 consists of the lower 700 meters of Southwest Ridge Brook, a tributary that enters the Mull River from the north side of the river. Southwest Ridge Brook drains a watershed of 14.1 kilometers and should have an average channel width of 7.39 meters. Instream surveys were conducted in the fall of 2020 and found that the channel was over-widened and it lacked pools and instream cover. Improving the quality of fish habitat in this reach can be accomplished by installing a series of digger logs and deflectors. The digger logs will dig pools on the downstream side of the structure which will improve the downstream meander pattern as well as providing important instream cover for trout and juvenile salmon. On the upstream side of the digger log the formation of spawning habitat will occur as cobble and gravel substrate deposit above the log.

Reach Specific Details			
Reach #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
6	7.39 meters	700 m	5,173 sq. meters

Table 15

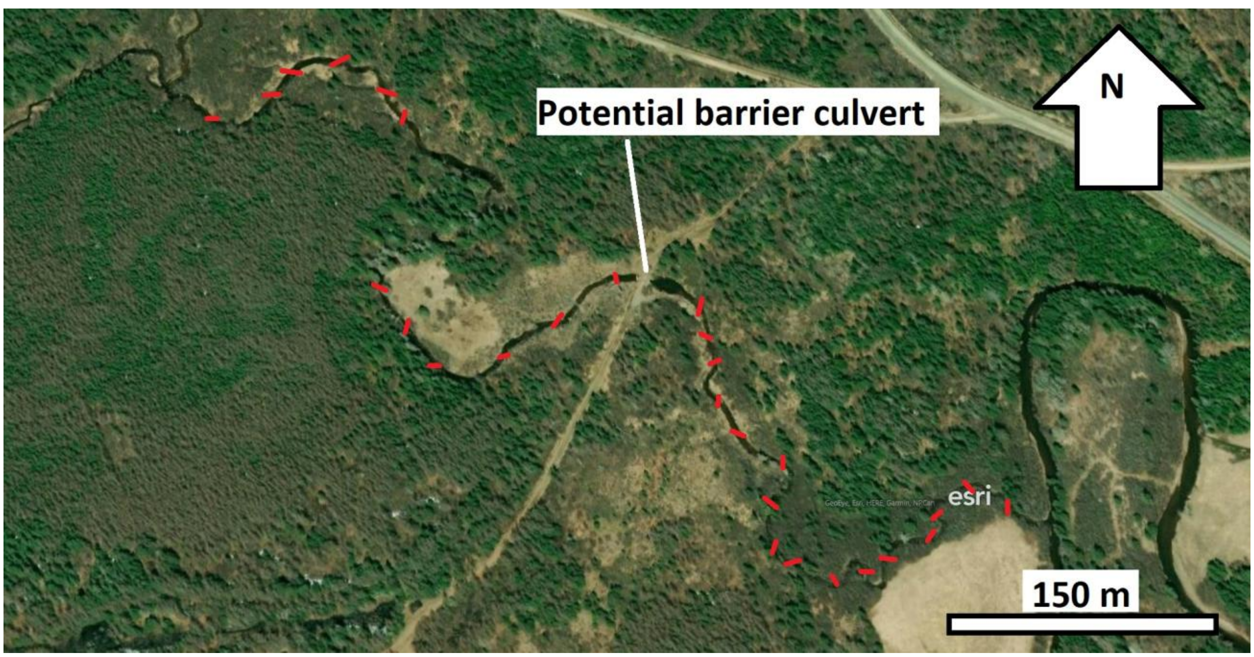

Figure 56: Approximate location of digger logs marked in red.

Mid Section

The mid section of the Mull River watershed contains a mix of degraded and recovering habitats that have been significantly altered through the first century and a half of European settlement in the area. LiDar imaging was reviewed to analyze historic channels locations within the floodplain which confirmed the accounts of local historian James St. Clair. During the late 1800s and early 1900s, in an effort to increase agricultural output and to facilitate log drives large-winding meanders were removed. This process of straightening resulted in a 40-50% reduction in overall stream length and available habitat. The mid section begins below the Whycogomah-Port Hood Road and the downstream extent is above the Miramichi Brook – Mull River confluence. The surrounding landscape in this section of the watershed is predominantly farm land in the low-lying and flat terrain areas. The south side of the river is less developed, likely as a result of the steep terrain that borders the river. There has been some forest harvesting on the north side of the Mull River through this section but overall it appears the land-use patterns have remained relatively stable over the past fifty years.

Figure 57: The north (left) and south (right) sides of the Mull River in the mid section

The mid section of the Mull River consists of three reaches and contains 7600 meters of channel and has a potential area for restoration of 86,615 square meters of habitat. Restoration work in this section can be achieved through the installation of log deflectors, bank stabilization work and larger rock structures such as rock sills, deflectors and groynes. The scope of restoration work will be dependent on the adjacent landowner's priorities – restoration work could also include establishing buffer zones through tree planting. Establishing buffer zones usually requires displacing agricultural production, it is important to make allowances for commercial losses if they occur. Farmers may be willing to establish buffer zones if they are compensated or receive something in return which could include building fences or livestock watering set-ups.

Overview of the mid section – Mull River			
Reach	**Available Habitat for restoration**	**Watershed size**	**Downstream Coordinates**
1	**35,584 square meters**	**58.40 square kilometers**	**61°20′57.2″W, 46°00′31.4″N**
2	**31,584 square meters**	**66.20 square kilometers**	**61°20′3.8″W, 46°01′9″N**
3	**19,873 square meters**	**69.12 square kilometers**	**61°19′25.6″W, 46°02′3″N**
Total	**74,799 square meters of potential restoration habitat**		

Table 16

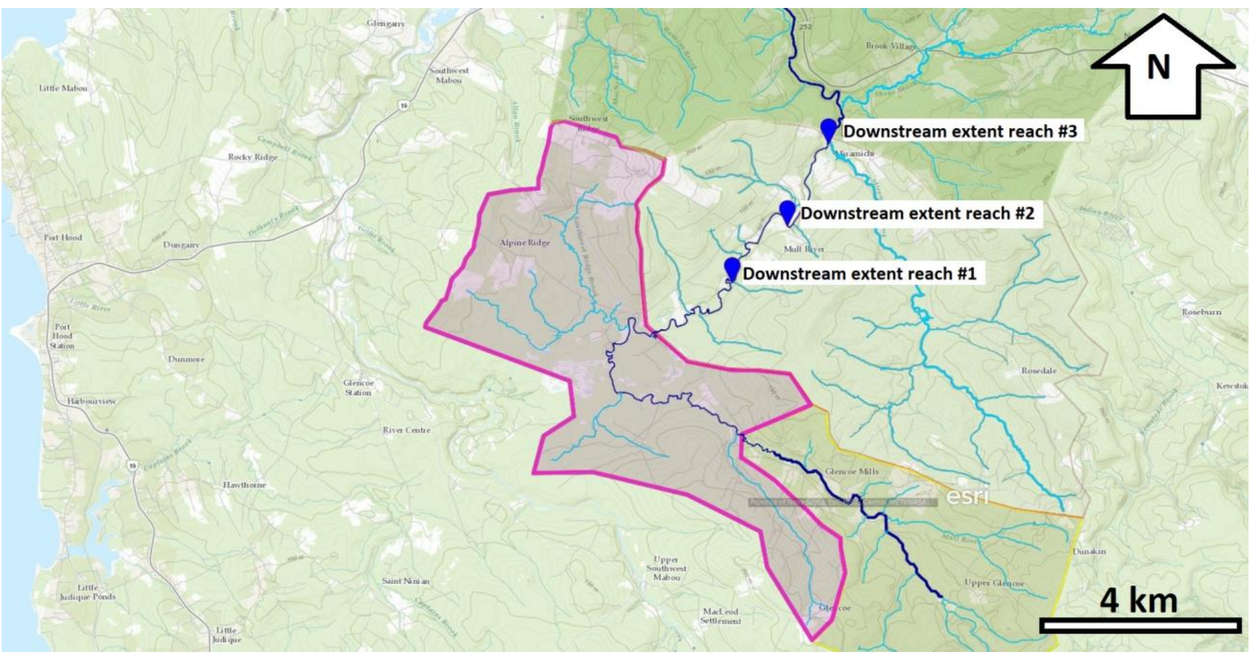

Figure 58: Topographic map of the mid section of the Mull River watershed.

Reach #1: Mid Section

Mid Section - Reach Specific Details			
Reach #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
1	11.12 meters	3200 m	33,584 sq. meters

Table 17

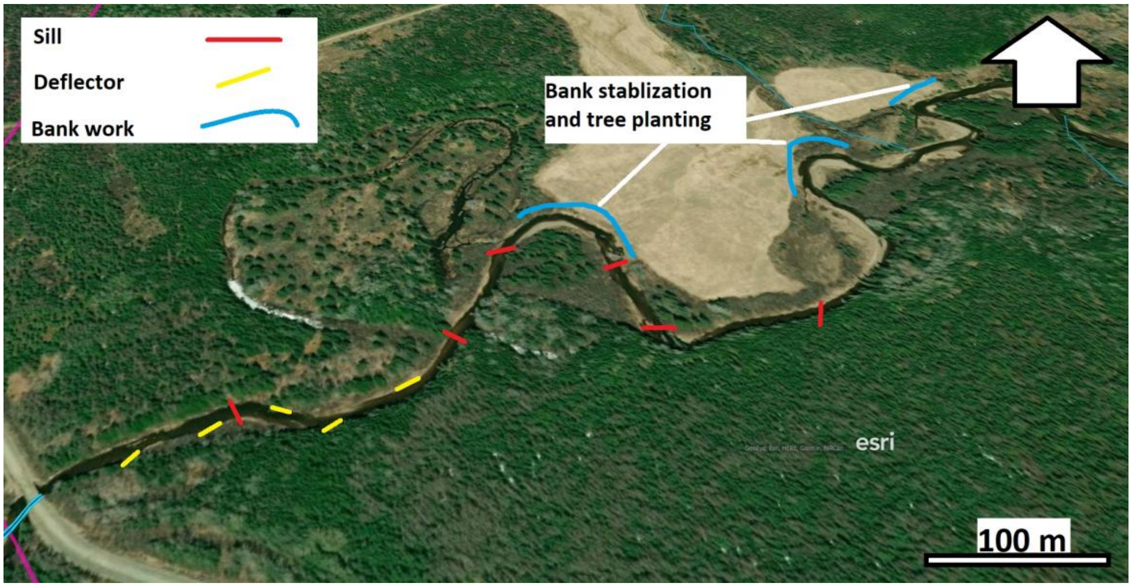

Figure 59

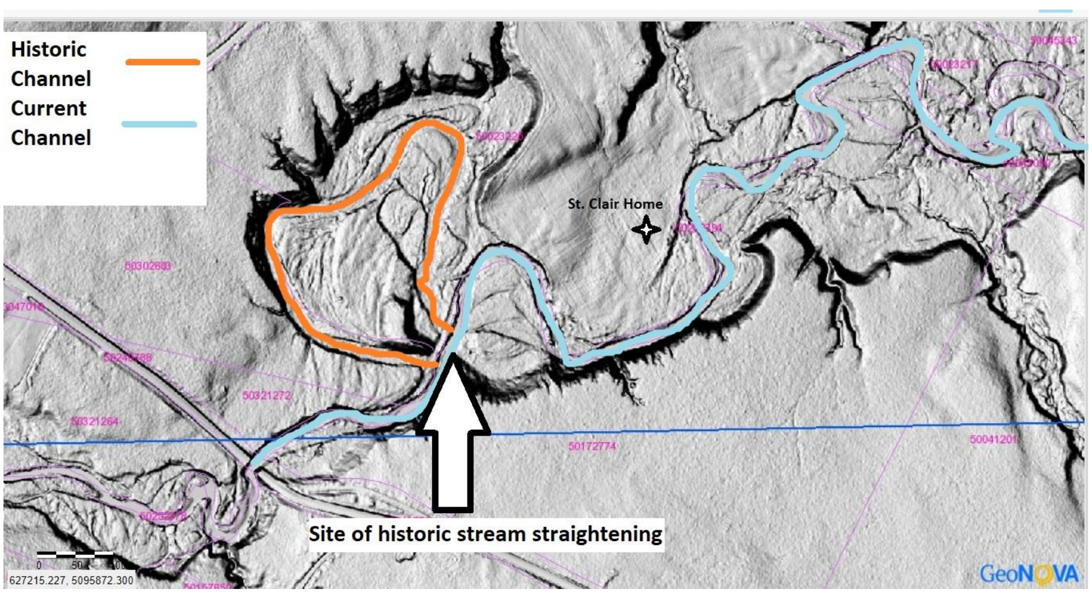

Figure 60: A local historian recalls the story of his grandfather taking the bend out of the river circa 1900.

Figure 61: Aerial photo of the historic channel bend.

The removal of "the bend in the river" around the year 1900 resulted in the loss of 1 kilometer of channel and over 11,000 square meters in fish habitat. It is quite likely that similar projects were completed by farmers during that area of settlement and as a result the channel has been forced to adjust to an entirely different flow regime. Evidence of this can be seen in figure 63 below.

Figure 62: Aerial photo of reach #1 in the mid section of the Mull River.

Figure 63: Lower half of reach #1 mid section Mull River.

Figure 64: Looking downstream from the top half of reach #1 mid section Mull River.

Reach #2 and #3: Mid Section

Mid Section - Reach Specific Details			
Reach #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
2	11.54 meters	2700 m	31,148 sq. meters
3	11.86	1700	19,872 sq. meters

Table 18

Figure 65: Approximate structure layout for reach #2 mid section Mull River.

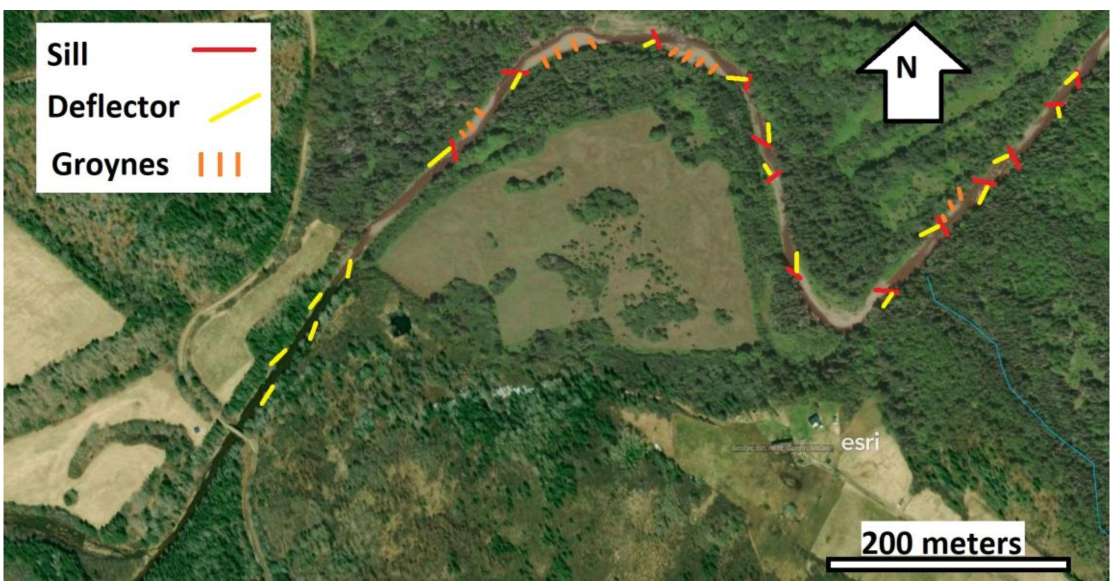

Figure 66: Approximate structure layout for reach #3 mid section Mull River.

Lower Section Mull River

The lower section of the Mull River contains a number of productive, yet degraded tributaries as well as several large holding pools for adult Atlantic salmon and brook trout. Parts of this section flow through a steep ravine, including bedrock falls at a pool known locally as “the salmon pool”. Much of the habitat through this section is over-widened, shallow and lacks a natural meander sequence. The streambed is also embedded, likely as a result of upstream siltation run-off. Restoration in this section should target existing holding pools where enhancement of habitat can be achieved. Rock sills, groynes and rock deflectors can be installed using heavy equipment where access is possible. Log deflectors can be used in sites where machine access is limited. The confluences of several important tributaries enter the Mull River in the lower section, therefore this section will provide assessment and recommendations for three reaches and three tributaries; Sheas Brook, Miramichi Brook and Glendyer Brook.

Overview of the Lower Section – Mull River			
Reach	**Available Habitat for restoration**	**Watershed size**	**Downstream Coordinates**
1	**11,457 square meters**	**100 square kilometers**	**61°19′14″W, 46°02′27″N**
2	**42,840 square meters**	**137.6 square kilometers**	**61°20′30.7″W, 46°03′42.7″N**
3	**26,791 square meters**	**150 square kilometers**	**61°21′28.1″W, 46°04′17.7″N**
Total	**81,088 square meters of habitat restoration potential**		

Table 19

Tributaries of Mull River			
Tributary Name	**Available Habitat for restoration**	**Watershed size**	**Downstream Coordinates**
Miramichi Brook	**32, 884 square meters**	**34.8 square kilometers**	**61°19′25.2″W, 46°02′5.5″N**
Sheas Brook	**74,306 square meters**	**36.4 square kilometers**	**61°19′14″W, 46°02′27″N**
Glendyer Brook	**18,902 square meters**	**21.7 square kilometers**	**61°21′35″W, 46°04′23.3″N**
Total	**126,092 square meters of potential restoration habitat**		

Table 20

Reach #1: Lower Section

Lower Section Mull River - Reach Specific Details			
Reach #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
1	13.02 meters	880 m	11,457 sq. meters

Table 21

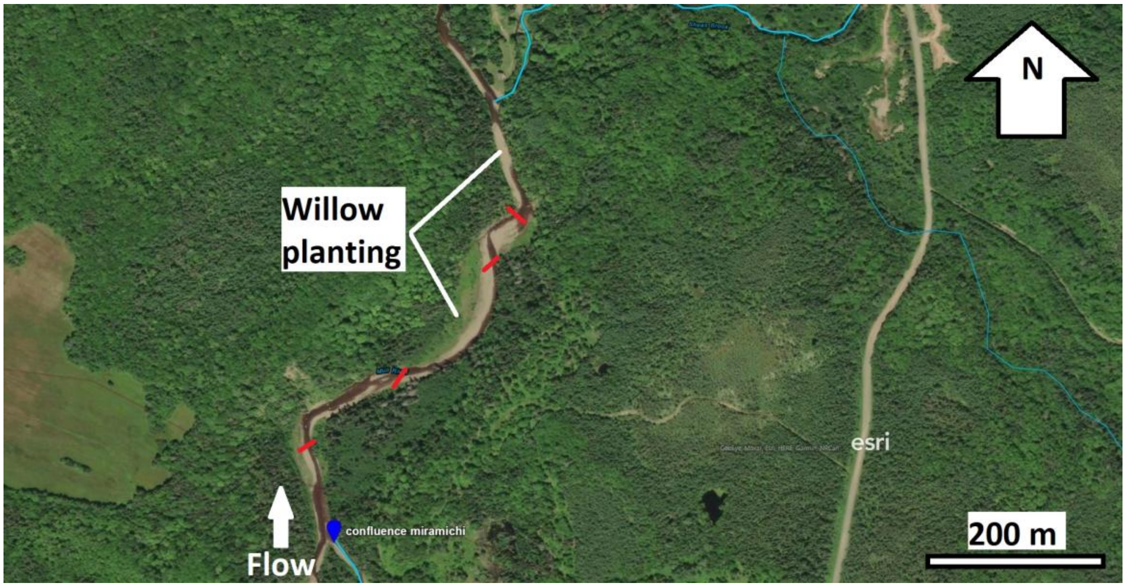

Figure 67: Approximate structure layout in reach 1 of the lower section.

Figure 68: Looking upstream from above the Sheas Brook confluence.

Reach #2: Lower Section

Lower Section Mull River - Reach Specific Details			
Reach #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
2	14.28 meters	3000 m	42,840sq. meters

Table 21

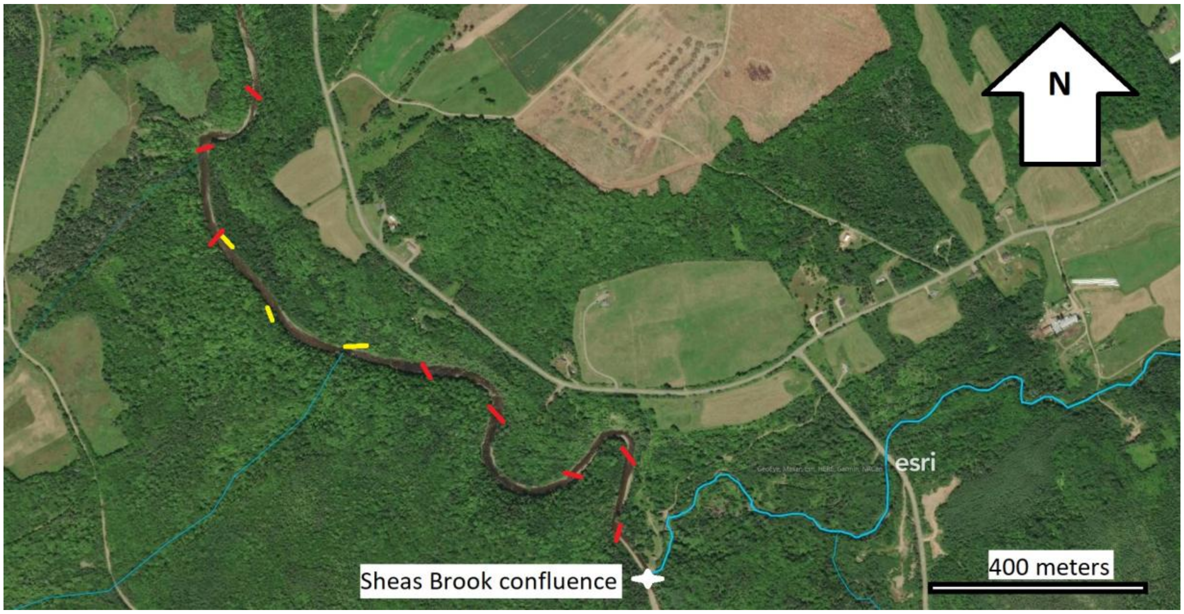

Figure 69: Approximate structure layout for the upstream half of reach #2 in the lower section of Mull River.

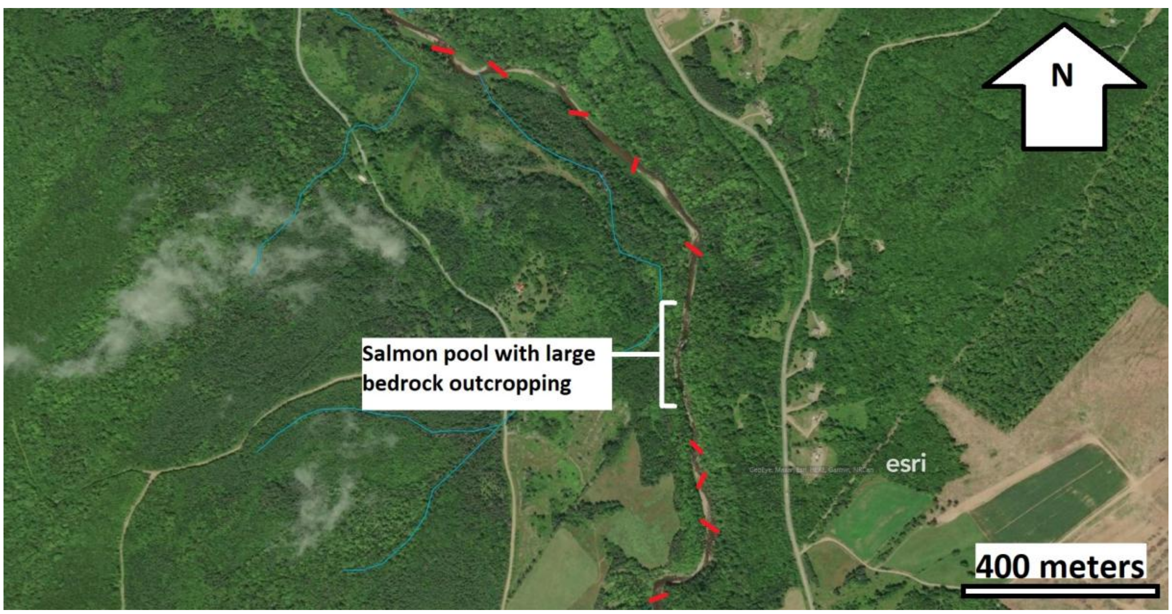

Figure 70: Downstream half of reach #2 on the Lower Mull.

Figure 71: Looking downstream towards the tail end of the salmon pool. Atlantic salmon were observed here in Oct. 2020.

Figure 72: The head of the salmon pool (61°19′59.5″W, 46°03′14.1″N).

Reach #3: Lower Section

Lower Section Mull River - Reach Specific Details			
Reach #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
3	14.64 meters	1400 meters	20,496 sq. meters

Table 22

The final reach of the main stem of the Mull River spans approximately 1400 meters and should have a bankfull width of 14.64 meters. Instream assessments through this reach indicate that some sites contain bankfull widths of 20 to 25 meters wide. Directly below the Murray Hill Bridge is a site with significant bank erosion caused by historical channel re-alignment during the early 1900s. The upstream side of the Murray Hill bridge was once a logging dam which likely caused the alteration of the stream further upstream (figure 74). As a result of the channel straightening the downstream habitat has been impacted by increased water flow demonstrated by the severe bank erosion in figure 75. This reach can be restored by installing sills, deflectors and completing bank stabilization work. Tree planting and establishing a buffer zone along the lower portion of these reach will help prevent future erosion caused by the absence of a riparian zone (figure 76).

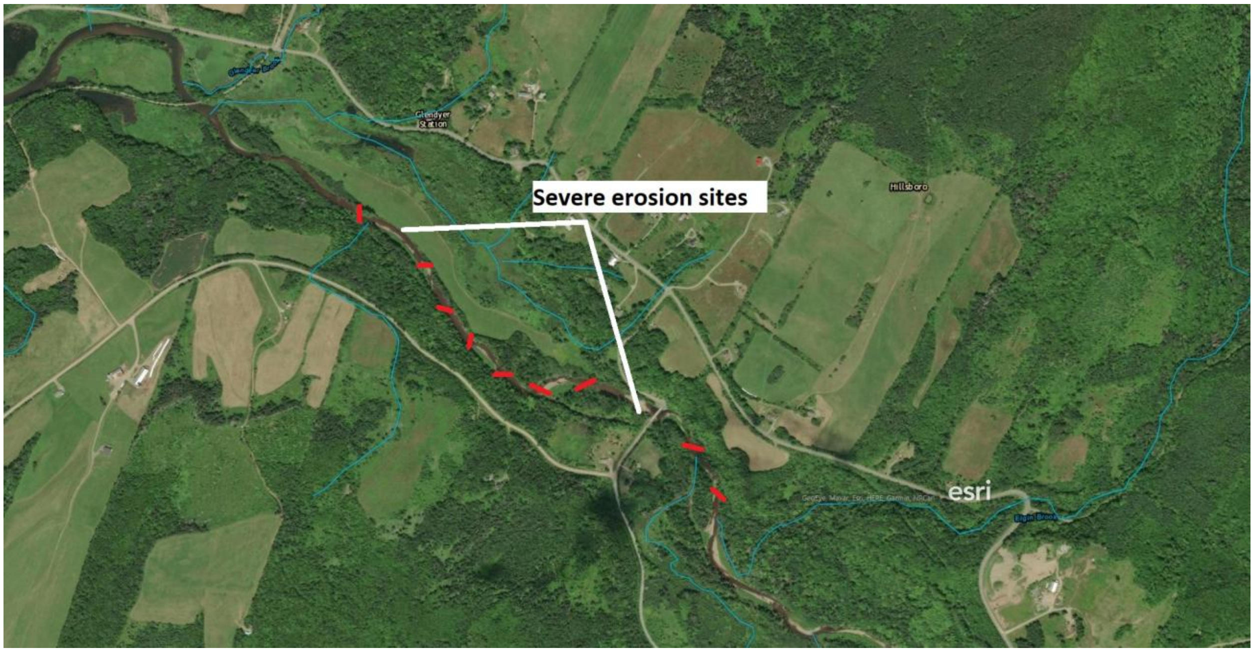

Figure 73: Approximate layout of structures. Bank stabilization work will be required to address erosion issues.

Figure 74: Aerial photo looking upstream from Murray Hill Bridge. Historic channels are visible to the right.

Figure 75: Aerial photo looking downstream from Murray Hill Bridge.

Figure 76: Erosion site at the lower extent of reach #3 of the lower section of the Mull River. Bank stabilization and tree planting are recommended here.

Miramichi Brook

Miramichi Brook drains 34.8 square kilometers of the southern extent of the Mull River watershed. Restoration work was completed in the headwaters of Miramichi Brook where it flows through the Rosedale mountains. While work has been completed in the past there is still ample room for continued work (figure 77).

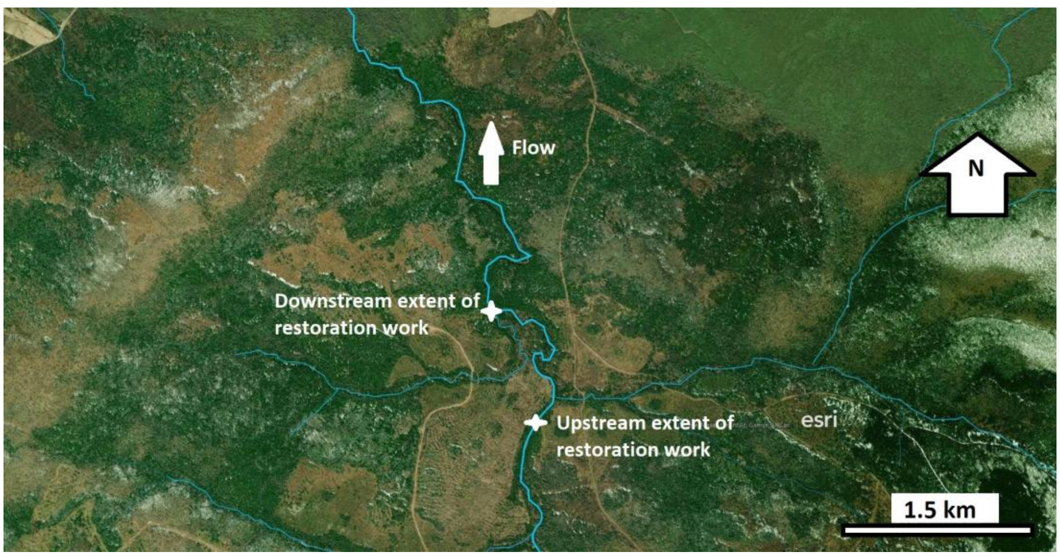

Figure 77: Satellite map showing previous restoration efforts.

Figure 78: Aerial photo of existing digger log in Miramichi Brook

Site Information	**Miramichi Brook – Site Specific Information**		
Site #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
1	5.58 meters	1600 meters	8,928 sq. meters
2	7.42 meters	800 meters	5,936 sq. meters
3	9.01 meters	2000 meters	18,020 sq. meters
Total Restoration Potential	32, 884 square meters of potential instream habitat restoration.		

Table 23

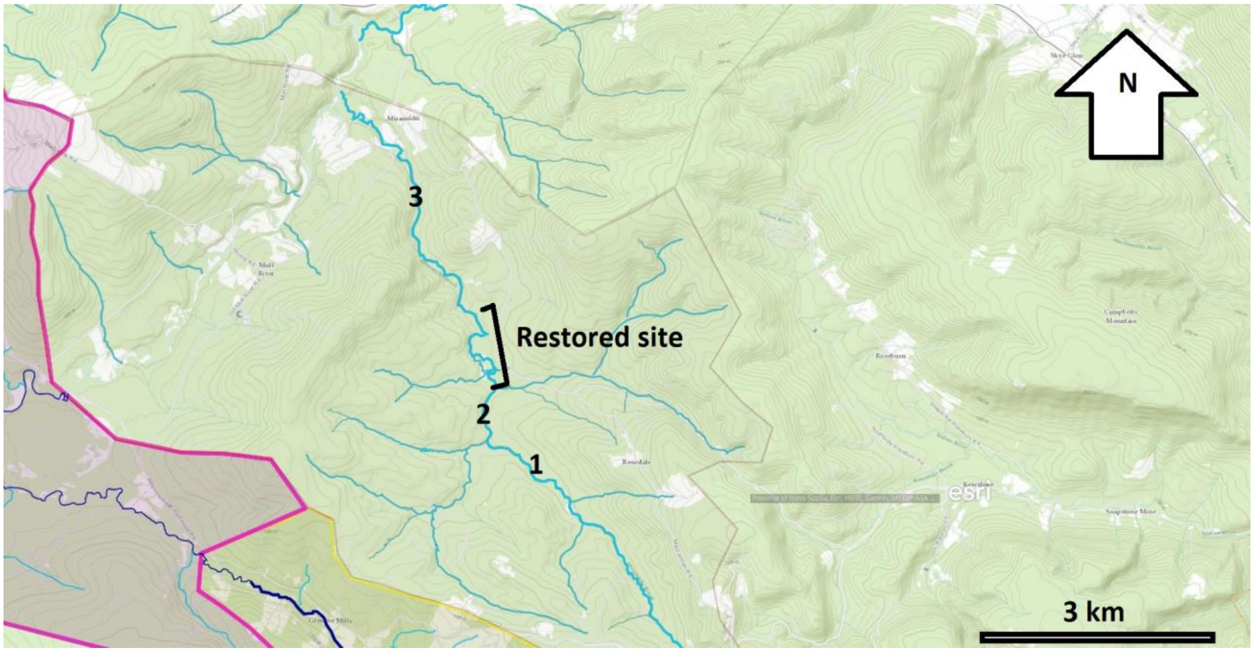

Figure 79: Topographic map showing 3 potential restoration sites in the Miramichi Brook watershed. Site numbers correspond to Table 23.

Figure 80: Potential restoration site #2 in Miramichi Brook.

Sheas Brook

Sheas Brook is the largest tributary of the Mull River, draining an area of over 36 square kilometers. Previous restoration work has been completed throughout the Sheas Brook watershed but the success of these efforts appears to have been undermined by significant heavy rain events in 2010 and 2014. Instream habitat assessments throughout Sheas Brook indicate that the rainfall events have altered most reaches of the river system and the remaining structures are no longer performing their intended functions. Restoration work within Sheas Brook should begin by reviewing all remaining structures and removing those that are no longer helping the channel recover. Overall the Sheas Brook system contains lots of spawning and rearing habitat for Atlantic salmon and contains an abundance of trout pools. New restoration work should focus on installing deflectors throughout the main stem of Sheas and installing digger log structures throughout Brook Village Brook (known locally as Little Sheas) and the upper reaches of the main stem. Sheas Brook can be divided into three sites as shown in table 24 and figure 81 below.

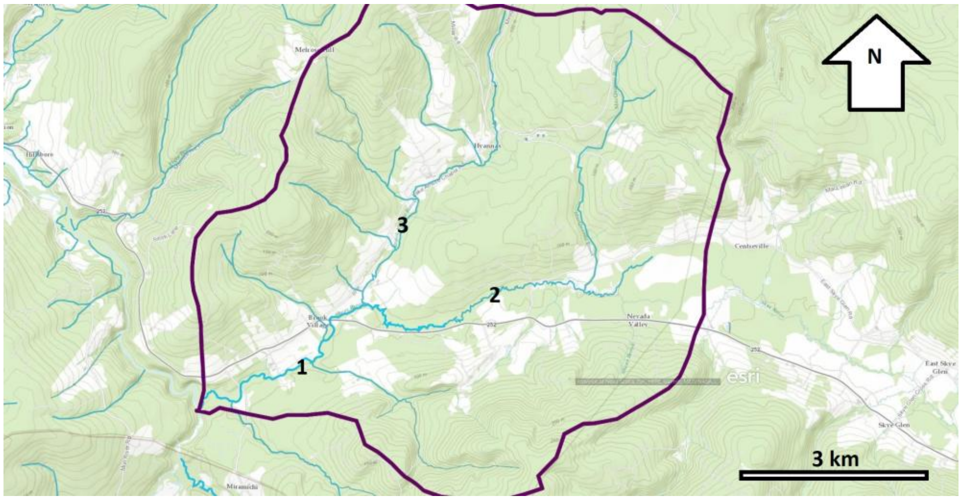

Figure 81: Topographic map of Sheas Brook showing the three restoration sites.

Site Information	Sheas Brook – Site Specific Information		
Site #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
1	9.72 meters	2800 meters	27,216 sq. meters
2	8.4 meters	4000 meters	33,600 sq. meters
3	7.1 meters	1900 meters	13,490 sq. meters
Total Potential	74,306 square meters of potential instream habitat restoration.		

Table 24

Figure 82: Looking downstream on Sheas Brook approximately 1 kilometer from Mull River confluence.

Figure 83: Looking downstream on Sheas Brook approximately 500 meters above Mull River confluence.

Glendyer Brook

Glendyer Brook is well-known locally for supporting an abundant sea trout fishery as well as an abundance of juvenile Atlantic salmon rearing habitat. Glendyer Brook drains a 21.3 square kilometer watershed on the northern side of the Mull River, which it joins at the head of the tidal waters. Glendyer Brook has cold-water seeps throughout much of its headwaters and therefore provides an excellent refuge for trout and salmon during the summer months. Restoration work was completed in the Glendyer Brook in the early 2000s and about 50% of those structures remain in place today.

Site Information	**Glendyer Brook – Site Specific Information**		
Site #	**Avg Calculated Bankfull Width**	**Stream Length**	**Available Habitat for Restoration**
1	8.10 meters	2260 meters	18,306 sq. meters
Total Restoration Potential	18,306 square meters of potential instream habitat restoration.		

Table 25

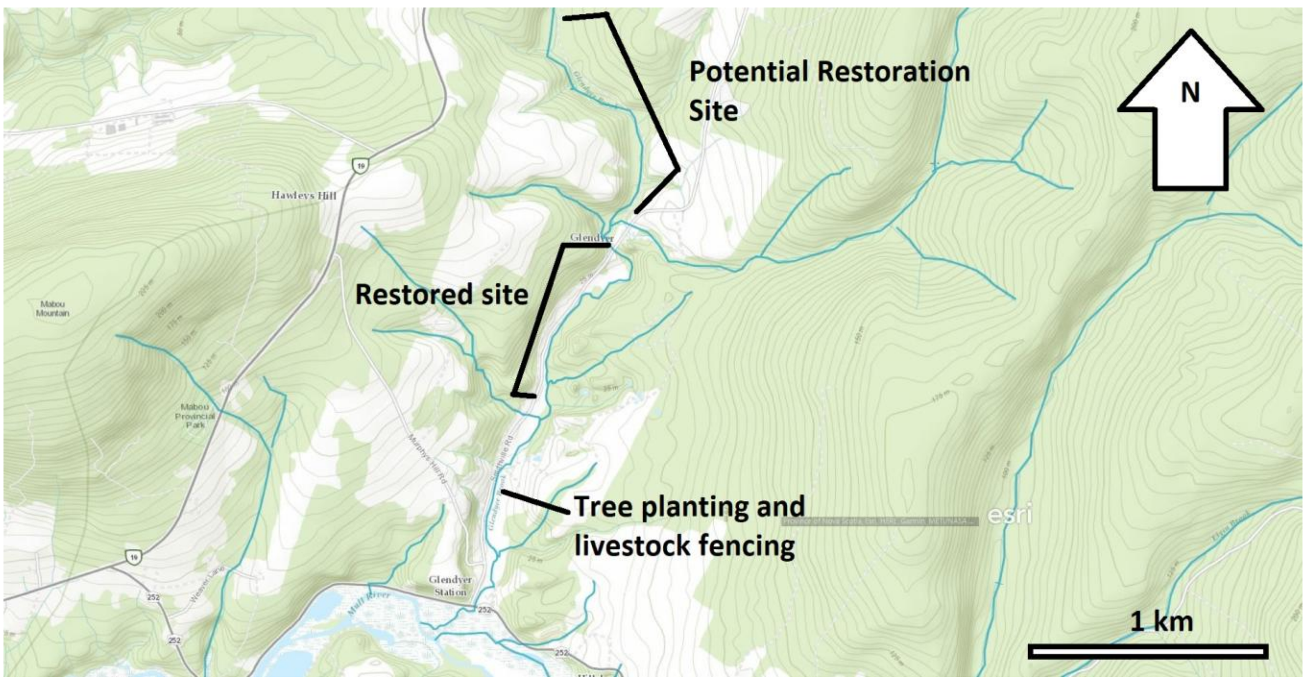

Figure 84: Topographic map of Glendyer Brook showing restoration sites.

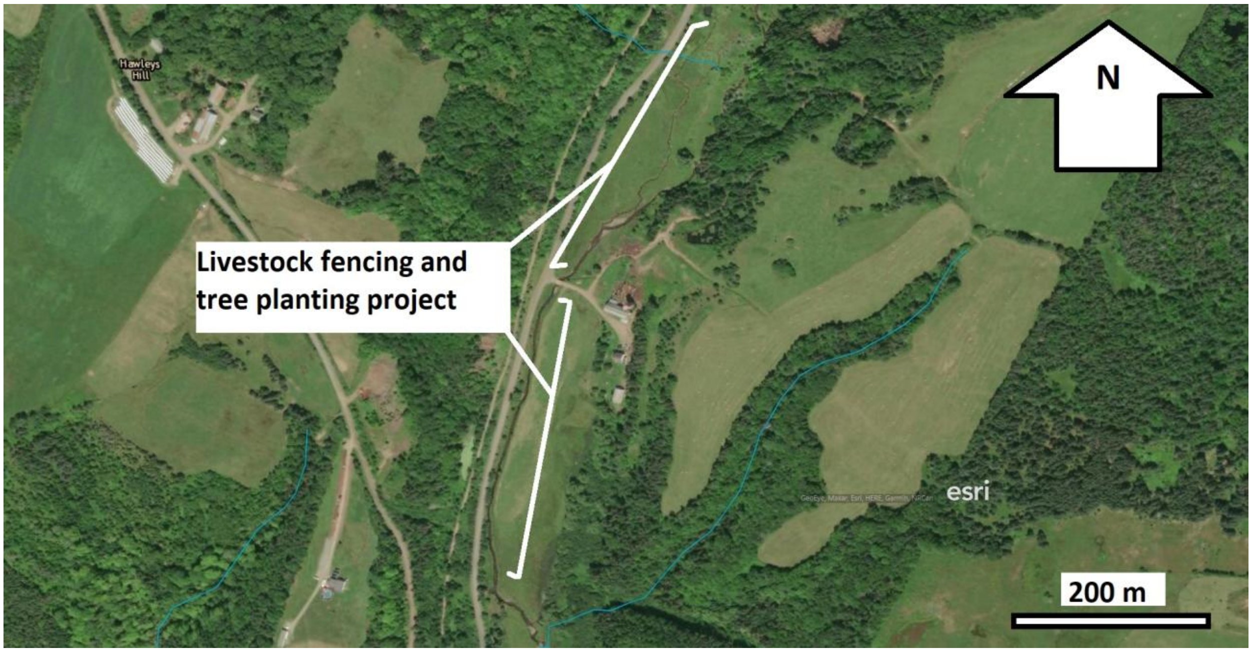

Figure 85: Lower Glendyer Brook - potential for riparian zone project with landowner permission.

Figure 86: Approximate location of digger logs marked in red.

Summary of Mull River Restoration Plan

Freshwater fish habitat in the Mull River continues to adjust from the pre-war settlement era (1860-1935) when much of the watercourse was impacted by agricultural expansion and timber clearing. In most reaches the effects of these past activities is confirmed by measuring the bankfull width of the stream bed. In almost all sites throughout the river, the bankfull width was 20-40% wider than the hydrological data would suggest. The over-widened channels have led to a simplification of the instream habitat as displayed by long-stretches of straightened channel and the absence of debris jams and other unique features.

Despite the challenges that exist within the watershed, the Mull River contains reaches of high quality and productive fish habitat and continues to see a strong fall run of Atlantic salmon and sea trout. Evidence of instream habitat recovery was observed throughout the watershed, however recovery potential is limited by the absence of important biological inputs such as large woody debris, particularly the recruitment of large mature trees that would have been part of the instream ecosystem during the early 1800s. Addressing these particular issues is the most pertinent step for instream restoration and can be achieved by using well-established river restoration techniques outlined in this report. In total this report concludes that the restoration potential for the Mull River is 405,325 square meters of habitat.

The first step for implementing this restoration plan will include landowner consultations and public engagement. Without access to the river, restoration work will not be completed therefore it is important to develop relationships with private property owners within the watershed. Typically landowners view a static stream as a healthy stream, however science on stream restoration has found the opposite – change is important and necessary to move towards a more complex ecosystem. The goal of this restoration plan is to introduce complexity to the instream environment so that each stage of the Atlantic salmon’s life cycle has the required habitat niches it needs to survive and eventually return to spawn. By installing digger logs, deflectors and the other structures described in this report, ISAA can replicate the natural complexity that was once found throughout the Mull River. These structures will help induce channel meandering, pool scouring as well as providing instream cover for fish.

Habitat fragmentation issues were observed throughout the headwater section of the Mull River, with three barrier culverts identified on MacKinnon Road. The owners (Department of Transportation) of these structures should be notified immediately that issues of fish passage exist and that remediation work will begin next year by surveying each culvert to determine remediation options. Desktop surveys of logging roads indicates that privately owned culverts may also be causing barriers to upstream migration of fish. These potential issues will require surveys in 2021. Overall the ISAA has both the experience and the reputation within the community required to implement this large-scale restoration project. Funding for this project will likely include government grants, habitat offsetting credits and private donations.

References

Armstrong, J. D., Kemp, P. S., Kennedy, G. J. A., Ladle, M., & Milner, N. J. (2003). Habitat requirements of Atlantic salmon and brown trout in rivers and streams. *Fisheries Research, 62*(2), 143-170.

Bennett, S., Simon, A., Castro, J., Atkinson, J., Bronner, C., Blersch, S., et al. (2011). The evolving science of stream restoration. In S. Bennett, A. Simon & and Janine Castro (Eds.), *Stream restoration in dynamic fluivial systems* (pp. 1-9). Washington, D.C: American Geophysical Union.

Department of Fisheries and Oceans Canada. (2012). *Stock status of Atlantic salmon (salmo salar) in DFO gulf region (salmon fishing areas 15 to 18)*Government of Canada.

Ellen Wohl. (2013). Landscape-scale carbon storage associated with beaver dams. *Geophysical Research Letters, 40*, 3631-3636.

Fryirs, K. A., & Brierley, G. J. (2013). *Geomorphic analysis of river systems: An approach to reading the landscape.* (1st ed.). Sussex, UK: Wiley-Blackwell.

Kozlowski, T. T. (2002). Physiological-ecological impacts of flooding on riparian forest ecosystems. *Wetlands, 22*(3), 550.

Opperman, J., Moyle, P. J., Larsen, E. W., Florsheim, J. L., & and Manfree, A. D. (2017). *Floodplains: Processes and management for ecosystem services*. Oakland, California: University of California Press.

Palmer, M. A., & Bernhardt, E. S. (2006). Hydroecology and river restoration: Ripe for research and synthesis. *Water Resources Research, 42*(3), n/a-n/a.

Rosgen, D. (1994). *Applied river morphology* (Second ed.). United States: Wildland Hydrology.

Wohl, E. (2017). The significance of small streams. *Frontiers of Earth Science, 11*(3), 447-456.

Wohl, E. E. (2004). *Disconnected rivers linking rivers to landscapes*. New Haven: New Haven : Yale University Press.

Wohl, E., Angermeier, P. L., Bledsoe, B., Kondolf, G. M., Macdonnell, L., Merritt, D. M., et al. (2005). River restoration. *Water Resources Research, 41*(10), n/a-n/a.