MARSHES, TIDES, AND CROSSINGS

COLCHESTER COUNTY TIDAL BARRIERS AUDIT REPORT 2002

By: Shirley-Ann Dalton
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Coastal Issues Committee Special Publication Number 1

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Part I

Introduction

1.1 Purpose

Marshes, Tides and Crossings: Colchester County Tidal Barriers Audit Report 2002 is a joint publication of the Ecology Action Centre in Halifax and the Municipality of Colchester County. This report discusses the impacts of tidal barriers such as culverts, dykes, aboiteaux and bridges on salt marshes and tidal rivers in the Bay of Fundy. It also provides an overview of some of the consequences for fish, wildlife and the integrity of coastal ecosystems resulting from the loss and degradation of salt marsh habitat.

The core of this report is the results of a summer of field work in coastal Colchester County. During the summer of 2002, field workers conducted a tidal audit to locate and assess tidal crossing throughout Colchester County, Nova Scotia. The study area encompassed the southern portion of Cobequid Bay, the northern portion of Cobequid Bay, and the Minas Basin, as well as the tidal portions of the Shubenacadie and Stewiacke Rivers. These findings are discussed in the Results Section of this report. The Results Section also presents sites in Cochester County that might benefit from restoration activities. The last section of the report, Conclusions and Recommendations, suggests a research and education agenda for salt marsh protection and restoration in Colchester County.

1.2 Project Background

The Ecology Action Centre (EAC) has been a strong advocate for the protection and restoration of salt marshes and coastal habitats throughout Nova Scotia since 1997. We have been active with the Global Program of Action for the Gulf of Maine (GPAC) since 1998. The restoration of lost and degraded salt marsh habitats was a priority activity identified by the GPAC coastal habitat working group. The EAC decided to initiate a pilot restoration project in the Bay of Fundy to raise awareness and interest in broader issues of salt marsh health.

Between October 1999 and October 2002, the EAC received funds under the North American Fund for Environmental Cooperation (NAFEC) for a community-based salt marsh restoration project. Our involvement in this specific project quickly broadened into a range of activities including public education and advocacy. Throughout the 3 year project, the primary project focus has been identifying sites with potential for salt marsh restoration.

Salt marshes cannot develop and thrive without regular tidal flow. Tidal barriers such as causeways and culverts prevent the free exchange of tidal and freshwater and negatively impact salt marshes. These impacts can be reversed through restoration activities such as replacing improperly sized culverts. The EAC has done tidal barriers audits along the Fundy shore to identify tidal barriers and sites with high restoration potential. In November 2001, the EAC published a report titled *Assessment of Tidal Restrictions along Hants County Highway 215: Opportunities and Recommendations for Salt Marsh Restoration* (Bowron and Fitzpatrick 2001). This report identified a number of sites with high potential for restoration in Hants County. Baseline biophysical data is now being collected at one of these sites, Cheverie Creek, to further assess the feasibility of restoration activities at that site.

Marshes, Tides and Crossings – Colchester County Tidal Barriers Audit Report 2002 continues the tidal crossings audit along the coast of the Minas Basin's Colchester County. The Municipality of Colchester partnered with the EAC to produce this report in order to develop a comprehensive assessment of tidal barriers affecting the coastal rivers and marshes in Colchester County. Inventories of tidal crossings and restoration opportunities will be expanded over the coming years to encompass the entire coast and tidal river systems on the Nova Scotia side of the Bay of Fundy. Once completed we will have compiled a complete inventory of the tidal crossings in this region, which will include an assessment of the degree to which these crossings are inhibiting the form and function of salt marshes and tidal rivers. This inventory will be a record of the condition of each crossing and highlight those areas that would benefit most from restoration efforts.

Throughout the salt marsh restoration project, the EAC has played a leading role in public education, awareness building, research and networking for salt marsh restoration in the region. This has developed into a more coherent coastal thrust in our programming and the formation of the Coastal Issues Committee (CIC) in the fall of 2001 to promote coastal conservation and sustainable coastal communities in Nova Scotia. We continue to pursue salt marsh restoration within the context of a larger emphasis on coastal land use planning and coastal access issues.

Section 2: Humble Habitats

2.0 Excited about Estuaries

The coastal areas of the Bay of Fundy are dynamic places shaped by water, wind, and geography. Estuaries are semi-enclosed bodies of waters found where fresh water from rivers mixes with salt ocean waters (Koller, 2001). The mixing of lighter fresh water with nutrient-rich ocean water leads to the high productivity of estuarine areas. Nutrients are trapped and circulated in estuarine areas, and recycled by bottom dwelling organisms to create a self-enriching system whose productivity nourishes the estuary's inhabitants as well as adjacent systems (Koller, 2001).

Estuaries provide many ecological benefits. They generate year-round primary productivity from the production and breakdown of plant materials and the activities of benthic invertebrates (Koller, 2001). Estuaries are also important nursery areas for the larval stages of many marine species. The also provide habitat and food for resident and migratory fish and shellfish species. Many species spend their entire life cycle in estuaries, while others migrate to the fresh water to breed (Harvey *et al*, 1998, Nova Scotia Museum of Natural History, 1996).

Salt marshes and tidal rivers are a key component of estuarine systems in the Bay of Fundy. Salt marshes develop on sheltered coastlines and along the protected edges and floodplains of tidal rivers. Tidal flooding is integral to the development and continued health of salt marshes.

2.1 Salt Marsh: Characteristics and Critters

Salt marshes have a number of recognizable features, including mudflats, low marsh, high marsh, tidal creeks and marsh pannes. It is the interaction between salt marshes' unique landscape elements that make them highly productive ecosystems and an important source of food and habitat for many species.

Salt marshes are built upon **mudflats** that have formed from the deposition of sediments on a low-lying shoreline (Nova Scotia Museum of Natural History, 1996). The mudflats are held together by a thick layer of mud algae that binds the sediment into a firm surface. The mud algae also supports a tremendous numbers of invertebrates such as mud shrimp (C*orophium volator*) that in turn support the huge populations of migratory and resident bird and fish species (Harvey *et al.* 1998). Once a mudflat has become established and stabilized, the upper edges or landward regions may begin to be colonized by plants. The first plant to establish itself is the salt-tolerant cordgrass (*Spartina alterniflora)*, which holds the mud together and begins to spread. In this way, a full salt marsh gradually begins to establish itself (Koller, 2001).

Salt marshes are highly dynamic ecosystems, responding to the interactions between freshwater, saltwater and sediments. They exhibit complex patterns of zonation with respect to plants and animals that reflect the daily and seasonal changes in water depth, salinity and temperature. Salt marshes are typically divided into two distinct zones. The **lower marsh** which spans the tidal range (high tide line to below the mean water mark) experiences flooding twice daily (normal tidal cycle), while the **high marsh**, above the high tide line, experiences flooding only several times a month (spring tides, storms and other extreme tidal events). In the Maritimes, salt marshes represent the climax, or final, community for coastal flood plains.

In Nova Scotia, the hearty salt marsh cord grass dominates the low marsh. Glasswort, Sea-blite, Seaside Sand Spurrey, Orach and atypical algae such as rockweed are common species also found in the low marsh. These plant species are able to withstand high levels of salinity and are adapted to both aquatic and terrestrial environments. The high marsh, which has a higher elevation then the low marsh, is dominated by the slightly less salt tolerant cord grass species known as salt meadow hay (*Spartina patens*). Other plants that often grow in these areas are Sea-lavender, Milkwort, Arrow Grass, Seaside Plantain, as well as various grasses, sedges and rushes (Nova Scotia Museum of Natural History, 1996). It is because the high marsh is flooded less frequently, the high marsh plant community is more diverse than in the low marsh.

The high and low marsh areas of a salt marsh are sometimes flooded and sometimes dry, while the tidal creeks and marsh pannes usually always contain some water. Fresh water **tidal rivers** flow from the land into the sea, but during the rising tide, the incoming water overflows the creek banks and carries salt water upstream and throughout the marsh surface. The vegetation and creatures found in tidal creeks and channels are adapted to a dynamic environment of variable salinity, water depth and temperature.

Salt marsh pannes are shallow ponds on the marsh surface in areas where poor drainage prevents the tidal water from draining off the marsh surface. If pannes are regularly replenished by tidal waters, they will retain water all summer long and create valuable habitat for fish and invertebrates and feeding areas for birds and mammals. Pannes also contain vegetation such as Sea Lettuce, filamentous algae and aquatic angiosperms such as Widgeon Grass. Low marsh pannes may contain Eel Grass, while Ditch-grass and Horned Pondweed are common plants in high marsh pans (Nova Scotia Museum of Natural History, 1996).The inhabitants of a salt marsh are all key players in the survival of the marsh ecosystem and in estuarine food chains. These fauna include, but are not limited to, burrowing animals (Razor Clams, Fingernail Clams, Soft-shell Clams, Quahogs, Blue Mussels, and Ribbed Mussels), several gastropod species (periwinkles, Spire Snails, and the Eastern Mud Snail), insects (grasshoppers, crickets, spiders, flies and mosquitoes), invertebrates (crustaceans), fish (Killifish, Sticklebacks, Silversides, and juveniles of local fish species such as flounder, trout and salmon), waterfowl (ducks, herons, shorebirds, Marsh Hawks, gulls and terns) and mammals (raccoons and mink) (Teal and Teal, 1969; Nova Scotia Museum of Natural History, 1996).

Just like the vegetation, the range and duration of the tide also affect the creatures living in salt marshes. Low marshes are rarely inhabited by terrestrial species; however, high marshes, which are flooded only a few times a year contain a greater diversity of terrestrial fauna (Long and Mason, 1983). Faunal species in the intertidal zone have to adapt quickly to the desiccation and changes in salinity (Long and Mason, 1983). The majority of these species burrow to escape being left high and dry at low tide. Creeks and pannes within a salt marsh can vary in salinity so that one creek supports only freshwater fauna while another may have a higher salinity and more salt-tolerant inhabitants.

Since it is only flooded a few times a year, the high marsh is the preferred habitat for most terrestrial species found in salt marshes (Long and Mason, 1983). In the high marsh, residents and visitors such as raccoon and deer are able to benefit from the vegetation and landscape features of the marsh, but do not need to adapt to the tidal extremes of the low marsh (Nova Scotia Museum of Natural History, 1996).

2.1 Salt Marsh Services

Salt marshes are a valuable part of the coastal ecosystem. They provide protection for coastal shores by stabilizing shorelines and reducing coastal erosion by decreasing wave energy as water flows over the marsh. Salt marshes are highly productive ecosystems producing 23 percent of the world's net productivity, though they only occupy 0.4 percent of the world's area. Studies have shown there is a net export of particulate organic carbon from salt marshes, which when combined with the movement of species into and out of marshes and tidal rivers contributes significantly to the productivity of estuaries and coastal waters. This export fuels the food web, eventually leading to fish and ultimately humans (Long and Mason, 1983).

The net outflow of organic materials to intertidal flats and coastal waters is the main nutritional source for many birds and fish, especially those in the larval stage (Long and Mason, 1983). The invertebrate species (oysters, the common mussel and clams) contained in the outflow provides abundant food for birds. Plant material produced in the summer months is broken down throughout the winter to provide food for marine organisms. (Nova Scotia Museum of Natural History, 1996). Dead salt marsh grass is broken down by bacteria and fungi producing a natural compost which is consumed by a wide range of marine organisms. Detritivores, in turn provide food for small fish, which are consumed by larger fish and birds.

Salt marshes also provide safe roosting sites for flocks and individual bird species, such as the Nelson's Sharp-tailed Sparrow (Long and Mason, 1983). Salt marshes provide spawning areas and migratory routes for local fish species, they also foster areas for the cultivation of shellfish, thus supporting the inshore fisheries (Long and Mason, 1983).

In addition to their important ecological functions, salt marshes provide many social, ecological and economic benefits (Bowron *et al*., 1999). Salt marshes provide edible plants such as Seaside-Plantain and Glasswort (Davis and Browne, 1997), while Sweetgrass and Sea Lavender are harvested for crafts and decoration. Salt marshes also offer the opportunity for tourism and recreation, as well as opportunities for environmental education and scientific research (Bowron *et al*., 1999).

Section 3: A Legacy of Loss

3.0 The Salt Marsh Saga

Despite their importance and value, many of the original Bay of Fundy salt marshes have been lost or seriously degraded. It is estimated that as much as 80% of the original marshes in the upper Bay of Fundy alone have been lost or degraded since the arrival Europeans to this region over 350 years ago. The original coastal landscape of much of this province has been so altered that many people do not realize that many urban and suburban areas sit on former coastal marshes and wetlands.

Humans have long relied on productive marsh systems. The Mi'kmaq and Passamaquoddy people harvested plants, fish, birds and animals in salt marshes and estuaries. The first large scale human impacts on salt marshes came with the arrival of European settlers. Acadians constructed dykes and aboiteaux to in order to 'reclaim' salt marshes and coastal floodplains from the sea. The resulting dykelands were fertile and extensively farmed (Koller, 2001). Maintaining and expanding existing dykelands was continued by British loyalist settlers and has been the responsibility of the Nova Scotia Department of Agriculture in Nova Scotia since the 1950s. Though not used as extensively as in the past, dykeland agriculture remains an important part of Nova Scotia's farming industry, particularly in the upper Bay. In some areas, agricultural infrastructure is no longer maintained and the sea has been allowed return and naturally restore salt marshes. In many such sites, the remains of dykes may still hamper the natural movement of water and species which can prevent the full habitat and food production potential of these areas from being realized.

The conversion of salt marshes to terrestrial lands for agriculture is a well known and visible form of salt marsh alteration, but there are many other development activities that impact salt marsh systems. Much of the damage to salt marshes is cumulative and occurs in small increments that collectively have led to the degradation and disappearance of most salt marsh ecosystem in the Bay of Fundy. Activities such as infilling of wetlands, ditching, flood control infrastructure, coastal development and highway construction all have had a negative impact on salt marshes.

The construction of railways, roads and highways in coastal areas usually involves building crossings through salt marshes and across tidal rivers. These crossings become tidal barriers when they restrict the natural flow of a waterway. These barriers have a negative impact on marsh health, as they reduce or completely eliminate tidal exchange leading to habitat decline and prevent the movement of materials and species, particularly fish. Tidal barriers come in a variety of forms and restrict waterways in a variety of ways. Some common types of tidal restrictions are discussed below.

3.1 Dykes

Dykes and aboiteaux are a major part of farming in the Bay of Fundy and there are numerous examples of these structures throughout the Minas Basin. Dykes are constructed embankments along tidal waterways that prevent the tide from flooding the marsh surface above the dyke. Dykes are built with aboiteaux in order to hold back the tide will still allowing for the fresh water to flow out. Of approximately 80,000 acres of salt marsh in Nova Scotia, 43,000 acres is now dyked agricultural land and of that 76.7% is considered Nova Scotia's most valuable farmland (Hatcher *et al*., 1981).

3.2 Aboiteaux

Aboiteaux are very effective tidal barriers since they are specifically designed to prevent tidal flow from travelling upstream. A surprisingly large number of aboiteaux are still in operation along the Bay of Fundy. An aboiteaux consists of a box culvert with at least one hinged tidal door that prevents the tidal flow from passing through the crossing and travelling upstream. During the rising tide, the force created by the in-flow will push the tide doors closed, allowing no salt water flow or fish passage inland from that point.

Figure 1. Photograph of an aboiteau within a dyke system at site SH7A

The presence of aboiteaux can cause significant erosion problems as scour pools are formed above and below the tidal gate when tidal and fresh water accumulates that cannot move either up or downstream. The upstream tidal gates re-open when the upstream water build up overcomes the pressure from the downstream site. The eventual freshwater outflow will dredge an even deeper scour pool downstream causing sediments to be deposited in a different location.

3.3 Culverts

The culvert is the most common type of tidal restriction. Culverts are placed in the ground during road construction to allow for water passage under the roadway. A well-designed culvert lies even with the stream bed up and down stream and is large enough for the water to flow through at any tide. A

Figure 2. Photograph of a culvert situated at site SH2C.

common problem with culverts is that they are too small to allow for a natural volume of water to pass through. Undersized culverts cause water to accumulate at either end of the crossing creating large pools, known as scour pools, as well as very strong and dangerous currents as water is forced through the small open. Another common problem with culverts is location. Often times culverts, even large ones, are misplaced in the roadbed with respect to the natural channel. Misplaced culverts (placed too high, too low or misaligned with the natural watercourse) create abnormal flow conditions, often only allowing water to pass in a single direction and in some cases, not at all. These common culvert problems can lead to the reduction or complete prevention of the movement of water, species and materials through the crossing which can result in the loss of habitats and species.

3.4 Bridges

Bridges are crossings elevated above a waterway by support structures (Koller, 2001). Properly constructed bridges do not restrict the tide's natural flow. In some circumstances, an inappropriate bridge location, oversized support structures, or a design too small for the waterway may create a tidal restriction by causing alterations in the channel direction, sediment build-up, and stream bed burrowing (Koller, 2001). These problems modify the natural flow behavior of the tidal waterway involved. A bridge should always be designed with adequate distance on either side of the waterway during its highest tide.

3.5 Causeways

A causeway is also a structure allowing passage over a body of water but contrary to bridges, a causeway generally causes restrictions (Koller, 2001). Closed causeways are constructed by filling by building a road across a river or stream that completely fills in a section of the waterway. This form of causeway completely restricts the waterway causing salt marshes upstream to disappear.

An open causeway allows tides to cross through an opening (Koller, 2001). The degree of restriction depends on the size of the stream width verses the opening of the causeway, as well as the height from the stream bottom to the bottom of the culvert. If construction of a causeway is necessary, it is recommended to install an open causeway with a large opening placed close to the stream bottom. These steps would reduce the restriction of tides and allow for aquatic species to travel upstream.

3.6 Dams

There were no dams found in Colchester County during the tidal barriers inventory. It is worth noting, however, that dams are major problems for tidal flow and fish passage. Dams are erected to regulate the movement of water, whether to restrain or to reduce flow, and often to utilize water flow for other purposes. As a result, fish passage is often restricted and tidal flow depleted. Restoration can occur only if the dam is removed or replaced with a new structure. This will cause some degree of downstream flooding, but in time if the system has not been permanently altered, the salt marsh will re-establish itself.

Part II

TIDAL BARRIERS AUDIT 2002 - COLCHESTER COUNTY

4.0 Study Area

This tidal audit took place in coastal Colchester County, Nova Scotia. The coastal portion of Colchester County encompasses the southern portion of Cobequid Bay, the northern portion of Cobequid Bay and the Minas Basin, as well as the tidally influenced sections of the Shubenacadie and Stewiacke Rivers. We looked at tidal crossings from the border of with East Hants County (along the tidal portion of the Shubenacadie River up to Greens Creek) to the border of Cumberland County at Five Islands. We examined tidal crossings along the main roads through this area, which included highways 236, 102, and 2 as well as many smaller roads. Colchester County is mainly rural, with towns and villages dispersed throughout the entire area. Truro, the largest population centre, is located at the head of Cobequid Basin, near the head of the Salmon River. The coastal area of Colchester County is a mix of agricultural lands, rural development (Truro), and forested lands. A significant number of the original salt marshes in this area were historically dyked and continue to be used agriculture.

4.1 Methods

The initial step in this project was to identify the location and type of tidal crossings. This was done in June 2002, using topographical maps of Colchester County at scales of 1:50,000 and 1:10,000. We examined the contour lines and topography of areas where the roads crossed coastal waterways to estimate the natural tidal range of the river. We also used aerial photos (1:10000, c.1994) to confirm the presence of tidal barriers such as dykes and abouiteaux, bridges, culverts, and dams. Onsite assessments of identified crossings were conducted during June and July 2002, to determine if the crossing was restrictive to tidal flow and fish passage, as well as to assess the condition of each crossing.

These assessments were completed using a modified version of the Parker River Clean Water Association (PRCWA) methodology (Purinton and Mountain, 1998). The Parker River methodology had been previously modified by members of Bay of Fundy Ecosystem Partnership's (BOFEP) Salt Marsh and Restricted Tidal Systems Working Group (SMaRTS) in order to account for the extreme tidal conditions experienced in the Bay of Fundy. At each site, a Phase I Audit Data Sheet was used to assess the site. This data sheet (included in Appendix A) is a guide to allow the degree of tidal restriction to be assessed visually. In cases where restriction was difficult to assess visually during the initial site visit, a second assessment was done using a Phase II Audit Data Sheet during a subsequent field visit. The Phase II Measurement Data Sheet can be found in Appendix B.

4.2 Phase I Visual Assessments

Every site underwent a Phase I assessment. Key features of the Phase 1 data collected include:

- Weather and tide conditions that may have an impact on tidal height and flow
- Crossing conditions indicating obvious causes of restriction due to the construction or deterioration of the crossing, and/or debris present
- Dominant land use both above and below the crossings to determine if the land use is a contributing factor to restriction, and if future salt marsh restoration for an area is plausible
- Quantitative measurements of tidal crossings and stream dimensions for a comparison of potential and actual tidal flow both above and below the barrier
- Visual assessments of bank/channel erosion, stream flow and vegetation present both above and below the crossings to use as indicators as to the amount of tidal flow reaching these areas

The following table, reproduced from Koller (2001), summarizes the primary types of tidal restrictions and corresponding visual evidence that can be found during the Phase 1 Visual Assessment.

Table 1. Summary of causes of restriction and visual evidence. Note that the relationship between [A] and [B] is site-specific.

Causes of Restriction [A]	Visual Evidence of Tidal Restriction [B]
Misplaced culverts	Difference in water height upstream and downstream
Undersized culverts	Erosion
Damaged culverts, aboiteaux, and piping	Difference in plant type and abundances
Land-use purpose, eg. dyking	Difference in stream widths

4.3 Phase II Measurements

If an initial Phase I assessment did not provide adequate data to make a judgment as to whether a site was restrictive, a Phase II measurement was taken. The Phase II assessment involved measuring the tidal range on each side of the crossing. To get the tidal range, a measurement from a reference point to the water surface was taken using surveying equipment (a tripod, bubble level, and metric measuring rod). Essentially this procedure was done to verify if the heights of the tidal water differed on either side of the crossing.

The tidal measurements were taken during regular intervals over a six-hour period. Measurements began three hours prior to high tide and ended three hours after high tide, or when it was evident that the tide was no longer influencing the movement of water through the crossing. The height of the tripod was also measured from the ground surface to the bottom of the pendulum hook. This data was manipulated using a formula provided by PRCWA, and plotted on graphs to determine if there was any discrepancy between water levels above and below the crossing (Purinton and Mountain, 1998). Tables and graphs of Phase II measurements, along with an example of a spreadsheet including the formula used, are found in Appendices E and F respectively.

Results

5.0 Restrictions

A total of 52 sites in Colchester County were found to be tidally influenced and were assessed to determine the degree of tidal restriction. Out of these 52 sites, 13 were partially restricted, 11 completely restricted, and 28 crossings were unrestricted.

Sites are considered partially restricted when the stream is reduced in size and flow due to the structural characteristics of the crossing, such as the crossing being misplaced in the stream bed, the crossing size or, debris, channel divergence and erosion. Thirteen sites were classified as partially restricted.

Restricted sites are those where no tidal flow passes through the crossing. Restricted crossings completely prevent fish passage and eventually lead to the decline of the original salt marsh on the upstream side of the barrier. Visual signs that a crossing is completely restricted include: erosion, scour pool formation, turbulence, and a noticeable difference between upstream and downstream plant type and abundance, and stream width and height. There were 11 completely restricted crossings found in Colchester County. Of these, 9 were identified through a visual Phase I assessment, while the remaining two sites required a Phase II assessment.

The remaining 28 tidal crossings were not restricted, that is both tidal and fresh water moved through the crossing at a normal rate. However, 5 of these unrestricted sites had downstream blockages such as aboiteaux, dykes, or filled in culverts. Therefore, out of 52 tidal crossings in Colchester County, there were only 23 sites where tidal flow was not affected by a tidal crossing.

Table 2. Partially restricted and completely restricted sites in Colchester County

Location	Partially Restricted Sites	Completely Restricted Sites	Total
Cobequid Bay South Side	3	6	9
Cobequid Bay and Minas Basin North Side	7	2	9
Shubenacadie River Area	1	3	4
Stewiacke River Area	2	0	2
Total	13	11	24

The majority of the completely restricted crossings were identified as aboiteaux, while the partially restricted crossings were mostly culverts. Table 2 shows that largest number of completely restricted tidal crossings were found along the south side of the Cobequid Bay (including Lower Truro, Old Barns, and Clifton areas). Along this area of the Cobequid Bay, culverts were generally located along a coastal dyke running the length of the Bay included in this audit. In contrast, the aboiteaux were located further inland along tidal rivers. The high number of completely restricted crossings was due to dykelands still being actively farmed in this area.

Along the north side of the Cobequid Bay and Minas Basin was the location of many partially restricted crossings. Many of these restrictions were due to culverts placed too high in the stream bank. The only two completely restricted crossings in this area were caused by aboiteaux. Appendices C and D contain a complete description and photographs of all the sites visited during this study.

5.1 Sites with restoration potential

Salt marsh restoration can involve a number of different activities intended to restore a more natural flow regime to a tidally restricted site. This can include replacing a restrictive culvert, such as an improperly sized culvert, with one that allows natural flow in and out of the marsh system. Other examples of restoration activities include removing the remains of dykes, clearing drainage channels on the marsh surface, plugging drainage ditches or installing two-way flow gates on aboiteaux.

Sites considered to have a high restoration potential are those in which both an opportunity exists for significant habitat gain and the required restoration activities are of low cost. Significant habitat gain is possible when a site is in poor condition, mostly due to low flow rates through a tidal crossing, yet the natural hydrology of the system has not been significantly altered. Restoration activities are most cost effective when they can be done in conjunction with other road maintenance activities such as repairing a damaged bridge or culvert, or when they bring other immediate benefits such as reducing shoreline erosion, or roadside flooding. Restoration is also more feasible when the site is easily accessible and when very little property or infrastructure will be affected by improving tidal flow.

There are a number of such potential salt marsh restoration sites in Colchester County. The following table provides a list of some of these sites and the recommended restoration activities.

Table 3. Sites in Colchester County with restoration potential

Site	Location	Restoration Potential	Photograph (Appendix G)
CBSS8C	Cobequid Trail	Replace rusting culvert that is beginning to collapse with new culvert to allow for adequate water flow upstream.	Figure 24
CBSS14A	Black Rock	Replace old wooden aboiteaux with small culvert to restore water flow to this area.	Figure 25
SH1C	Princeport	Lower wooden block culvert to allow for tidal flow upstream.	Figure 26
ST7C	MacKay Siding Road	Lower wooden box culvert and widen opening to increase water flow to the upstream side of the crossing.	Figure 27
CBNS1A	Chiganoise River	Open one to three tide gates, to allow for salt marsh re-establishment	Figure 28

CBNS2B	Debert River	Alter design of original support structures to smaller round supports which allows for less disturbance to channel flow	Figure 29
CBNS5A	Great Village River by Cemetery	Fish ladder placement to allow for passage with minimal flooding.	Figure 30
CBNS13B	Carrs Brook	Deepen the channel under wooden bridge to allow for fish passage.	Figure 31
CBNS14C	Carr Brook Road	Remove debris in front of upstream side of culvert to increase natural water flow in this area.	Figure 32

Recommendations

6.0 Recommendations

The purpose of this audit was to locate and assess all significant tidal barriers in Colchester County, providing a comprehensive inventory of the tidal restrictions. This inventory is only a first step towards a longer-term goal of protection and restoration of salt marshes in the entire Bay of Fundy. The following recommendations summarize the required actions to achieve this goal.

i. Tidal inventory for entire Bay of Fundy

To date, the Conservation Council of New Brunswick (CCNB) has completed a tidal inventory for the New Brunswick coast of the Bay of Fundy. The Ecology Action Centre has conducted a similar inventory for Hants County and Colchester County, through a partnership with the Municipality of Colchester County. The EAC plans to extend this inventory to encompass the entire upper Bay of Fundy in the summer of 2003. In subsequent years, the entire Nova Scotia portion of the Bay of Fundy coast will be completed. Such an inventory is a necessary step in assessing the extent and condition of the remaining salt marshes and in identifying priority areas for restoration activities.

i. Baseline Data Collection

A tidal inventory identifies sites with restricted crossings that might benefit from restoration. The inventory, however, is not sufficiently detailed to determine whether or not restoration is actually possible at the sites in question. The EAC is currently collecting baseline data on the plants, animals and physical condition, including elevation and sediment characteristics, at Cheverie Creek in Hants County. Similar data collection should be undertaken at sites where restoration is a possibility. This biological and physical data is important to collect prior to restoration as it establishes a baseline indicator to compare future conditions. In addition it assists to develop models concerning restoration feasibility and what potential positive and negative impacts on the salt marsh and surrounding areas can be expected by restoring normal tidal flow to the site.

iii. Public Awareness and Community Involvement

In order to bring about a change in the current condition of salt marshes, a positive attitude towards salt marshes and restoration must first be established. This will require an active emphasis on public awareness and environmental education about salt marshes and coastal habitat. It is essential to first contact local landowners who own property along side the restoration site to secure their permission and support for data collection and restoration on site. The wider community including schools and community groups should also be the focus of marsh education and information campaigns. The Ecology Action Centre has an ongoing focus on public education regarding salt marshes, however, new material needs to be developed in order to educate a wider variety of audiences about salt marsh restoration in the Bay of Fundy.

iv. Piloting restoration activities

A demonstration site is a very powerful tool in promoting salt marsh restoration. The Ecology Action Centre is planning for pilot restoration work at Cheverie Creek in Hants County. Cheverie Creek will be a venue for learning and teaching about salt marsh restoration. It will allow scientists and academics to study the re-establishing salt marsh vegetation and contribute to a regional database of restoration activities. Most importantly, the Cheverie site and other pilot restoration projects will be a catalyst showing other community groups and government agencies that restoration is possible.

6.1 Closing Remarks

Salt marsh restoration is not a purely technical endeavor. Community support is an important consideration in selecting an area for salt marsh restoration. It is essential that the project is supported by the community, and that their questions, concerns, and opinions are respected and integrated into the project (BoFEP, 2000). A community can contribute significantly to a restoration project by their knowledge of local tidal and land use history, equipment use, labour, and future monitoring and care of the salt marsh. An active program of community outreach and dialogue is essential if individuals are to provide financial assistance, voluntary services, or the donation of land for a salt marsh restoration project. (Bowron *et al*., 1999).

Areas which are potential candidates for a restoration project may not be feasible due to the lack of community support (BoFEP, 2000). In the short term, the positive benefits of restoring a salt marsh may not outweigh its negative effects on the community and the residents' way of life. For example, a small community financially dependent on agriculture may perceive that the lost income from flooding agricultural land does not justify the ecological gains. If there is a negative feeling about restoration, that site should not be pursued (Bowron et al.,1999). People may be more willing to support restoration when they see that the values and opinions of their community are being honoured (Koller, 2001).

Restoration is not the only goal of the Ecology Action Centre's salt marsh project. We may have lost 80% of the original salt marshes along the Bay of Fundy, but 20% still remain relatively intact. Protecting and enhancing this valuable existing habitat must be a priority. Research to identify the location and condition of existing marshes remains a focus of the Ecology Action Centre and its partners.

No one group can protect and restore salt marshes in isolation. Partnership is key. One of the greatest achievements of the project to date is the building of a constituency around salt marsh restoration that brings together scientists, academia, landowners, community groups and various levels of government. Restoration requires collaboration.

Marshes, Tides and Crossings: Colchester County Tidal Barriers Audit Report 2002 is an example of collaboration between the Municipality of Colchester County and the Ecology Action Centre. This report presented the impacts of tidal barriers such as culverts, dykes, aboiteaux and bridges on salt marshes in the Bay of Fundy. It also provides an overview of some of the consequences for fish, wildlife and the integrity of coastal ecosystems caused by the loss and degradation of salt marsh habitat. It is hoped that this report will in itself be a catalyst for future research, and eventual protection and restoration of salt marsh habitat in Colchester County and throughout the Bay of Fundy.

For more information regarding salt marshes, tidal barriers and restoration, please contact the Ecology Action Centre. Photographs and Tidal Barrier Audit Data Sheets for all sites assessed during this study are available at the EAC. Along with this publication, there are other EAC publications including *Assessment of Tidal Restrictions Along Hants County's Highway 215: Opportunities and Recommendations for Salt Marsh Restoration*, *Community and Social Considerations in Salt Marsh Restoration Work in Nova Scotia* and *Getting Dirty: The Why and How of Salt Marsh Restoration, Proceedings of the Salt Marsh Restoration Workshop,* also available through the EAC.

Glossary

Aboiteau/Aboiteaux (pl.) - A hinged tidal gate located on the downstream side of the crossing, usually extending as a culvert or square tunnel upstream. Constructed from wood or metal, these structures are often built into dykes allowing for freshwater outflow to drain agricultural land, while restricting saltwater passage upstream (Bowron and Fitzpatrick, 2001).

Bridge - A road crossing elevated above a waterway by support structures to allow for water flow.

Causeway - A rock-filled road crossing over a body of water or a wet place, which generally causes restrictions. Some have openings to allow for water flow (Koller 2001).

Cordgrass (*Spartina alterniflora*)- Abundant salt-resistant vegetation located in the low marsh which acts as a stabilizer to marsh mud, and also provides food and habitat for other plants and animals (Bowron and Fitzpatrick, 2001).

Culvert - A tunnel running underground which is intended to allow water flow in both upstream and downstream directions. They are usually constructed from wood, concrete, or corrugated metal. Culverts constructed in coastal areas have, in the past, often been constructed with tide gates, creating an aboiteau (Bowron and Fitzpatrick, 2001).

Dam - A barrier generally created from wood, rock boulders, and concrete which restrains or reduces water flow to an area, or divert it to another area.

Downstream - The waterway and its surrounding area located on the seaward side of a tidal crossing.

Dyke - An embankment, usually built out of soils and materials from the marsh, which acts as a barrier preventing tidal infusion onto low lying coastal land, typically salt marsh, in order to create agricultural land and protect infrastructure (Koller, 2001).

Euryhaline - Species common in estuarine systems which are able to withstand a wide variation in salt content of surrounding bodies of water.

Fauna – Scientific term used when referring to animals.

Flora – Scientific term used to refer to plants.

Fodder - Dried food, such as hay, for stall-feeding cattle.

Intertidal Zone - The region of salt marsh which extends from the where the spring tide reaches and includes the lower elevation of the salt marsh. Taller smooth grasses such as cordgrass dominate this area (Purinton and Mountain, 1998).

Neap Tide - A tide occurring just after the quarter moons each month when the gravitation pull of the sun is acts at right angles to that of the moon, causing an abnormally low tides.

Pannes - Depressions in the marsh surface which have a decreased abundance of vascular plant vegetation but which are excellent habitat for a range of fish and invertebrates and feeding areas for birds (Long and Mason, 1983).

Salt Marsh - "Low-lying wetlands periodically inundated by tides" (Purinton and Mountain, 1998).

Salt Marsh Hay (*Spartina patens*) – Semi-salt resistant plant usually found in the high marsh (Koller, 2001).

Sand Spit - An extension of land into surrounding waters composed mostly of sand, which provides protection to the shoreline. Unlike sandbars, sand spits are generally visible above the water level.

Scour Pool - A dredged out area commonly located just upstream and downstream of restrictive tidal crossings caused by erosion due to inadequate water flow.

Spring Tide - "A tide occurring just after the new and full moon each month, in which there is the greatest difference between high and low water. Not related to the season, but rather to the phenomenon where the water "springs" higher than normal" (Bowron and Fitzpatrick, 2001).

Tidal Barrier - Any obstruction located across a tidal water body which influences the tidal flow in all or part of the waterway (Koller, 2001).

Tidal Range - "The change in tide level between low tide and high tide measured at a given location" (Bowron and Fitzpatrick, 2001).

Upper Intertidal Zone - The region of salt marsh which extends from the where the neap tide reaches and includes the higher elevation of the salt marsh. Short, coarse grasses such as Salt Marsh Hay dominate this area (Purinton and Mountain, 1998).

Upstream - The waterway and its surrounding area located on the terrestrial side of a crossing furthest away from the direction from which the tide flows in.

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Appendix A

Tidal Crossings Audit Data Sheet: Phase 1 Visual Assessment

Visual assessments are to be done approximately two hours before the high tide. Preferably, they will also be done during the peak tides of the lunar cycle.

Name:_________________________ **Date:**________________ **Time:** _______________

Location:____

GPS Coordinates: _________________________ **Crossing code:** __________________

Weather: [Check Environment Canada web site] ____**Wind velocity and direction**: ____

Rain [circle one]: Heavy Moderate Light. **Fresh water flow conditions** [from station?] _______________ _______________

Tide conditions [height and time as recorded in tide book, adjusted for area]: High tide____________________ Low tide ______________________. Mean high tide for area [in metres]: _____________________

Crossing characteristics [circle one]: Bridge; Culvert B corrugated concrete steel PVC wooden block

Crossing condition [circle one]: Is original design intact? Yes No. Describe condition if in need of repair:
____
____

Width of road [in metres] ____________________ **Length of opening** [in metres]:___________

Describe dominant land use or features: Above the crossing:_____________________________________
____
____

Below the crossing:____
____
____

Restoration potential, if restricted: Area with restoration potential [in hectares] _______________________
____
____

Type of restoration work [circle one]: Culvert repaired Culvert replaced Culvert installed
Bridge installed Bridge widened Other ____
____
____

Photographic record checklist: Crossing upstream ___ Crossing downstream ___ Landscape upstream ___Landscape downstream ___ Dominant plants upstream ___ Dominant plants downstream ___ Water flow at crossing: upstream ___ downstream ___ Erosion evidence: upstream ___ downstream ___

Crossing measurements: Please indicate on diagram where measurements were taken

Measurement	Upstream (cm)	Downstream (cm)
Stream width at opening*		
Opening diameter		
Opening height		
Vertical distance, creek bottom to road surface (estimate if necessary, in metres)		

*May be X distance away from opening as long as you are consistent with upstream and downstream.

Bank / channel erosion assessment:

Evidence of bank/channel erosion	Upstream (Yes No)	Downstream (Yes No)
Bank slumping		
Scour pools		
Current channel appears divergent from original channel		
Other		

Flow restriction assessment:

Evidence of flow restriction	Upstream (Yes No)	Downstream (Yes No)
Smooth flow		
Turbulent flow		
Slack (still) water		
Eddies, swirling water		
Flow direction	**Upstream**	**Downstream**
Choose one: straight; angular; reversed		
Water level variance	**Yes**	**No**
Is there a visible difference in water level on each side of the crossing?		

Vegetation comparison:

Is there a significant difference between downstream and upstream vegetation [circle] : Yes No

Obvious plants	Upstream Yes No	Downstream Yes No
Cordgrass: *Spartina alterniflora*		
Salt marsh hay: *Spartina patens*		
Cattails		
Phragmites		
Other?????		

Appendix B

Tidal Barriers Audit Data Sheet: Phase 2 Measurement

The primary tool for determining whether a crossing is restrictive is the Visual Assessment (Phase 1). Measurements of tidal crossings will be made where it is uncertain whether there is a restriction, or where there is a need for more information about the degree of restriction (Phase 2). Measurements will be made over approximate 6-hour period, from three hours flood tide to three hours ebb tide. Ideally, measurements will be made during the highest tides of the month (spring tide). This should capture a "worst case" normal -- as opposed to abnormal scenario - which would most likely demonstrate restricted flow if there is any. It is important to determine whether the restriction is ongoing or periodic. If possible, the site should be visited twice under different tidal conditions to make this assessment.

Name:________________________________**GPS Coordinates:**______________________ **Crossing code:** ___________________

Crossing characteristics [circle one]: Bridge Culvert B corrugated concrete steel PVC wooden block

Visit #1. **Date:** __________________

Weather: [Check Environment Canada web site]:____

Wind velocity and direction: ____________________

Rain [circle one]: Heavy Moderate Light. **Fresh water flow conditions** [from station?] ____________

Tide conditions [height and time as recorded in tide book, adjusted for area]:

High tide ____________ Low tide ____________

Tidal Range Measurements: [from a reference point on each side of the crossing to the water surface Refer to Tidal Audit Handbook, either Parker River or CCNB version, for a full explanation of the methodology].

Tide Time (high tide = 0)	Actual time	Upstream (in cm)	Actual time	Downstream (in cm)
0 - 3				
0 - 2				
0 - 1.5				
0 - 1				
0 - .5				
0				
0 + .5				
0 + 1				
0 + 1.5				
0 + 2				
0 + 3				

Tidal Barriers Audit Data Sheet: Dykes

The priority for assessment is dykes no longer maintained by the Department of Agriculture. Assessment of dykes should be carried out from high tide plus or minus two hours [????]

Name:__________________________**Date:**__________________**Time:** _______________

Weather: [Check Environment Canada web site]
Wind velocity and direction: ______________________

Rain [circle one]: Heavy Moderate Light. **Fresh water flow conditions** [from station?]
____

Tide conditions [height and time as recorded in tide book, adjusted for area]: **High tide** _______________ **Low tide** ______________________ **Mean high tide for area** [in metres]: ___________________

Dyke name/location: ____

GPS coordinates: ___________________________ **Dyke code**: _________________**Elevation:** ________________

Aboiteau_____________________________ **name/location:** ____________________________

GPS coordinates:___________________________________ Aboiteau code:____________

Length [in metres]: __________________**Width at base** [in metres]: _________________

Original purpose of dyke: ____
____

Current use: On top of dyke: ____
Landward:____
Seaward: ____

Degree of restriction: Dyke - Total _______ Partial _______ Aboiteau - Total _____ Partial _____

Comments: ____
____
____

Breaches, weak points: GPS coordinates _______________________________________

Tidal channels blocked by dyke: Name ___________________________ GPS coordinates ______________
____

Name____________________________________GPS coordinates _____________________

Name____________________________________GPS coordinates ____________________________
Name _____________________________________ GPS coordinates ___________________

Land ownership [number of properties in each category]: Private _______ Crown _________ Non-profit
____

Land area behind dyke [in hectares]: _________________

Vegetation comparison:
Is there a significant difference in vegetation landward and seaward of the dyke? [circle] : **Yes** **No**

Obvious plants	**Landward Yes No**	**Seaward Yes No**
Cordgrass: *Spartina alterniflora*		
Salt marsh hay: *Spartina patens*		
Cattails		
Phragmites		
Other?????		

Photographic record checklist: Aerial photo of area ______ Breaches/weak points _________ Aboiteau ____

Landscape seaward ________ Landscape landward _________ **Potential for restoration:** _______________

____

____

Comment____

____

____

Contacts made with respect to this dyke/aboiteau:

____

____

Other:

Appendix C – Locations of Tidal Barriers

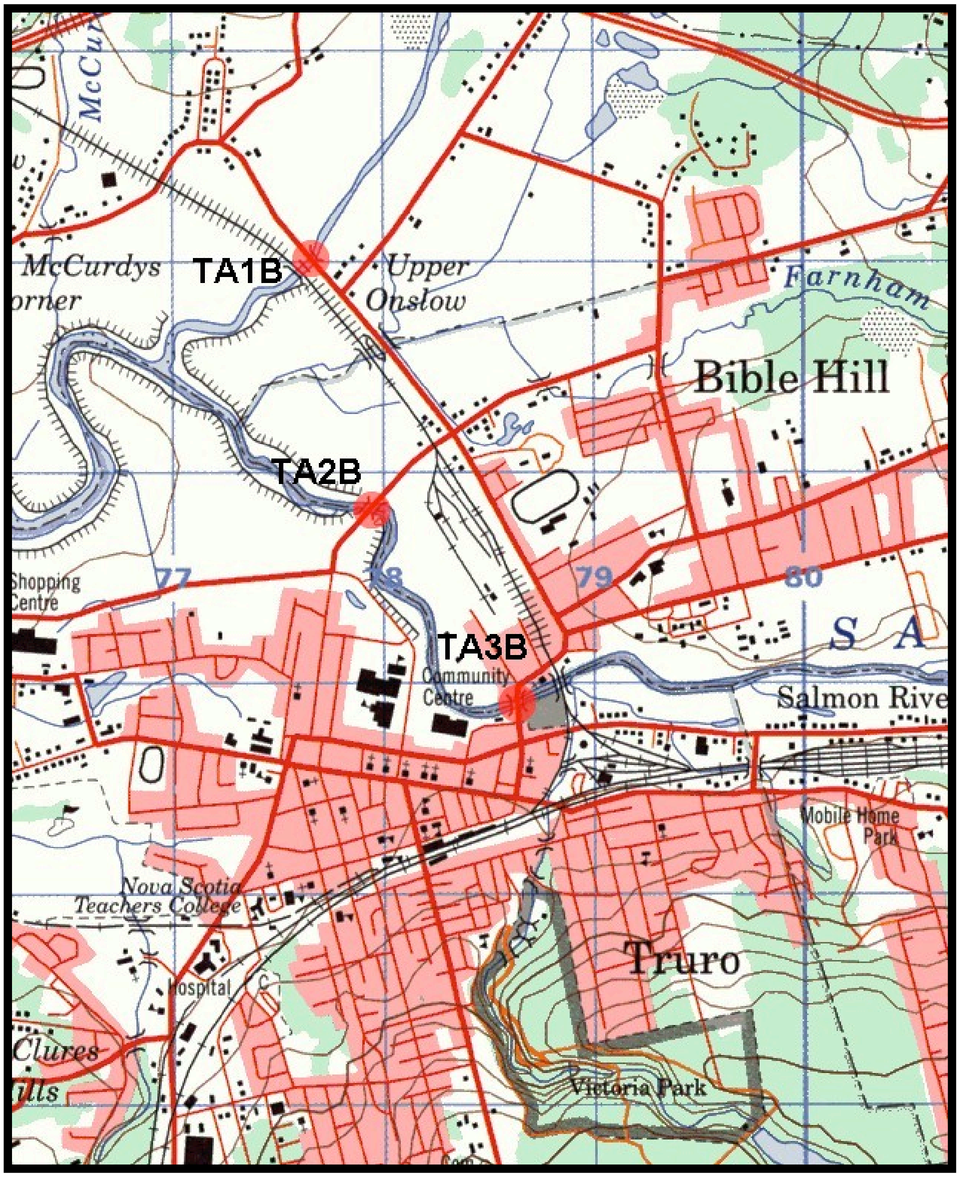


Figure 4. Truro – Bible Hill Area

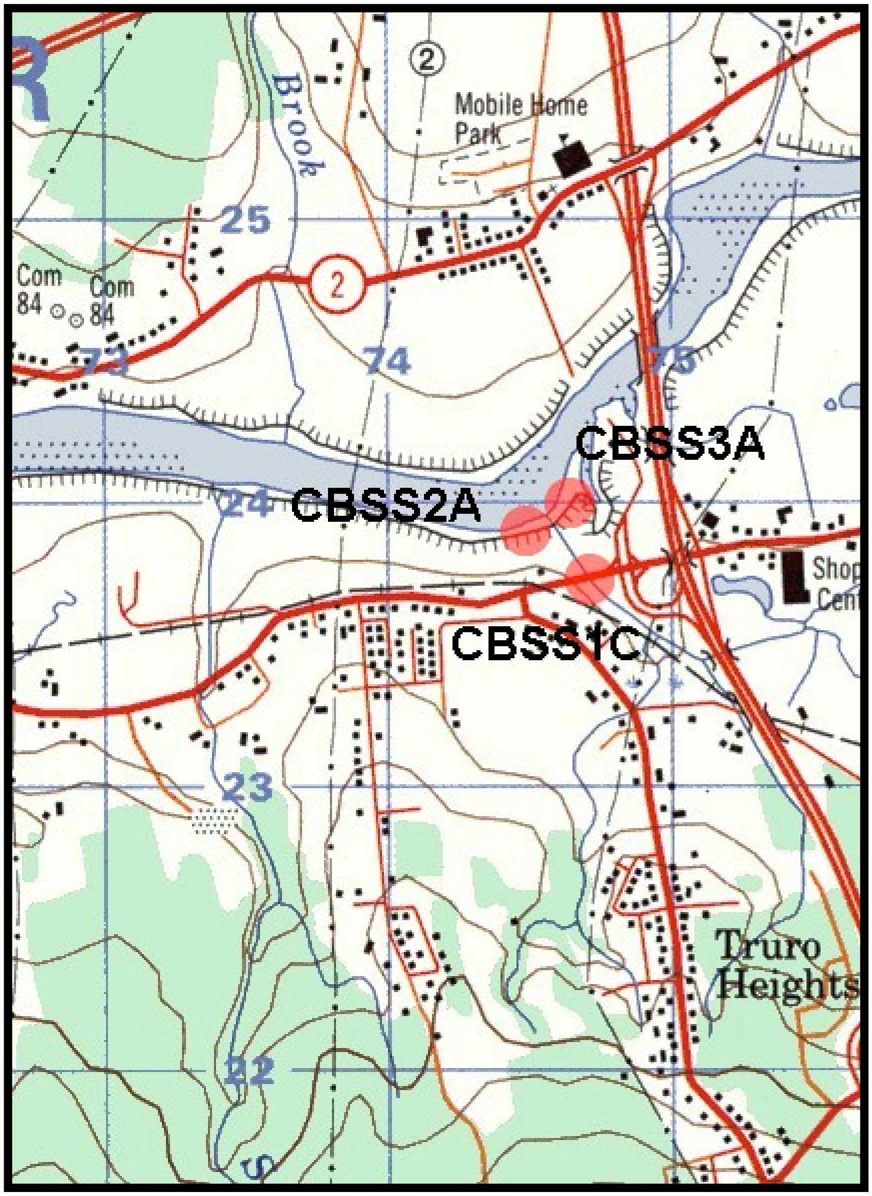


Figure 5. Exit 14, Highway 102, Lower Truro

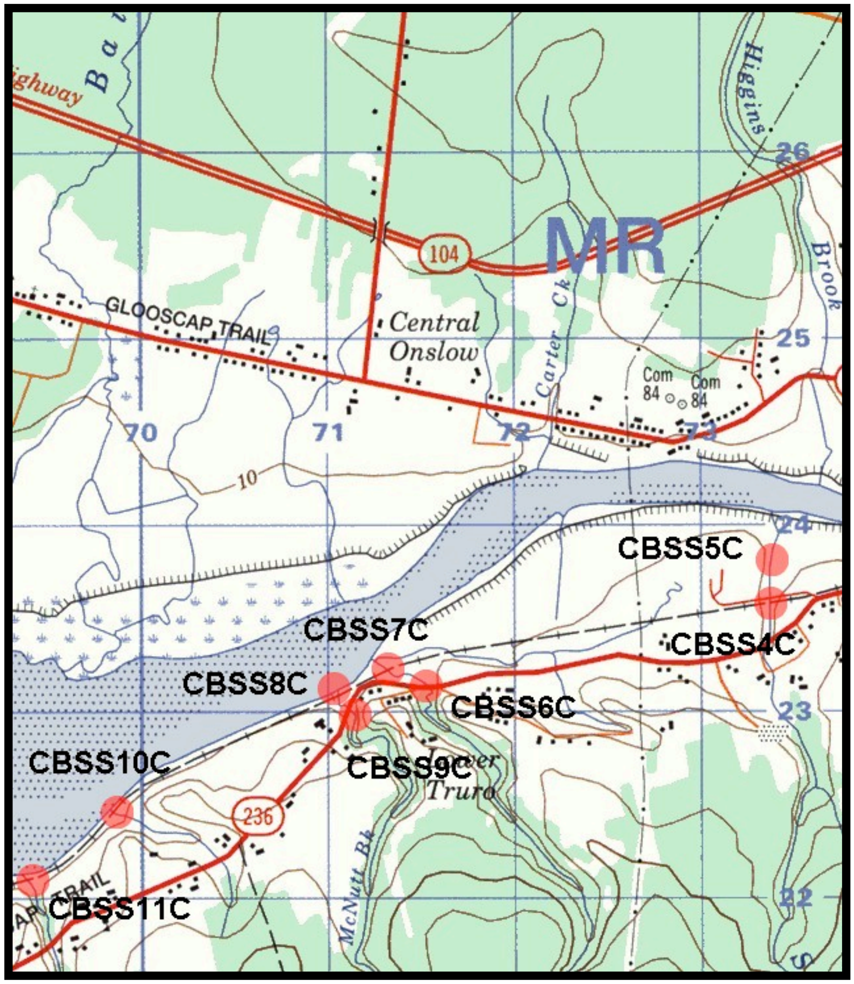


Figure 6. Lower Truro

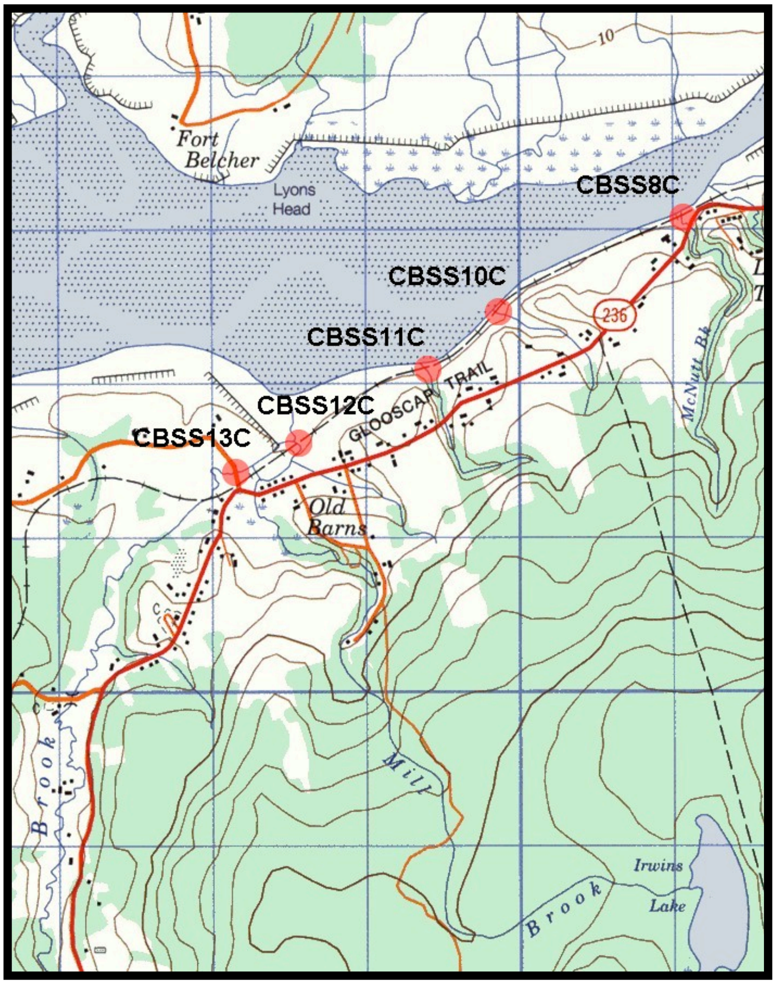


Figure 7. Old Barns

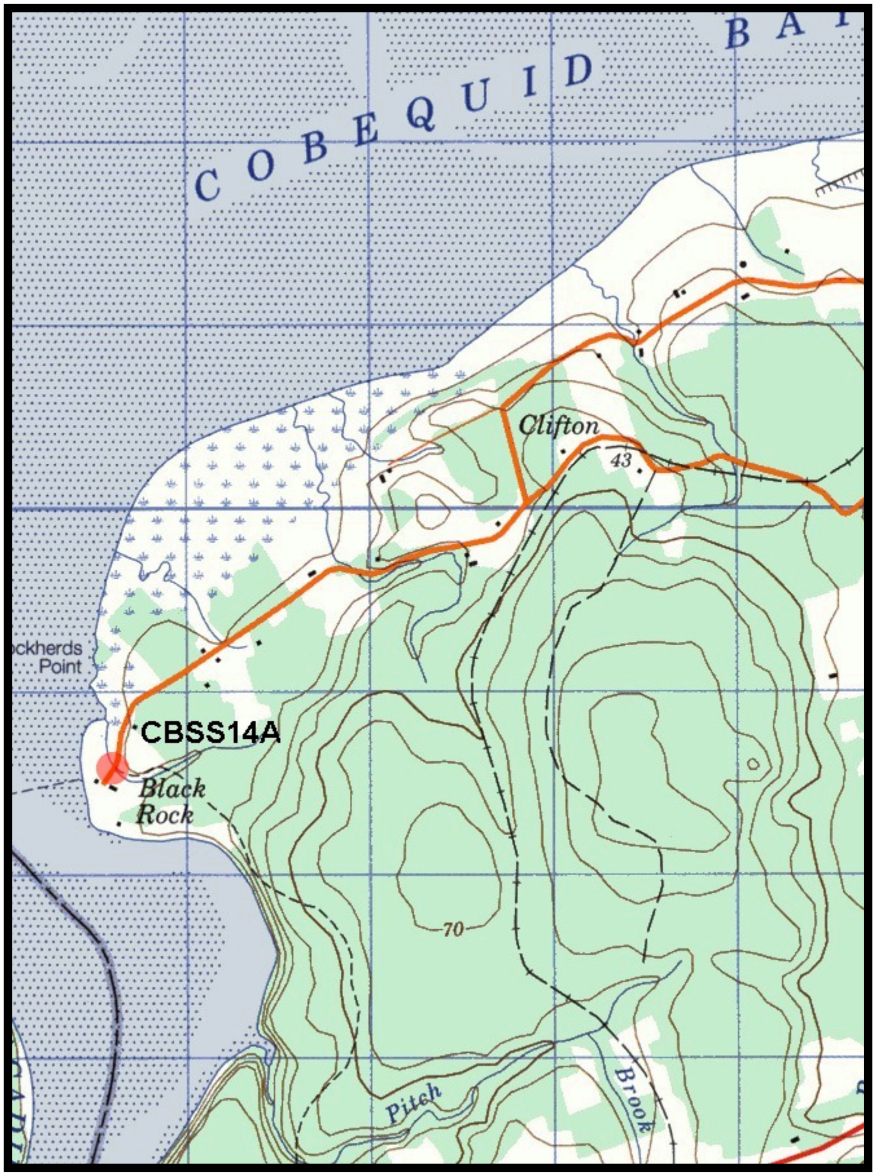


Figure 8. Clifton – Black Rock Area

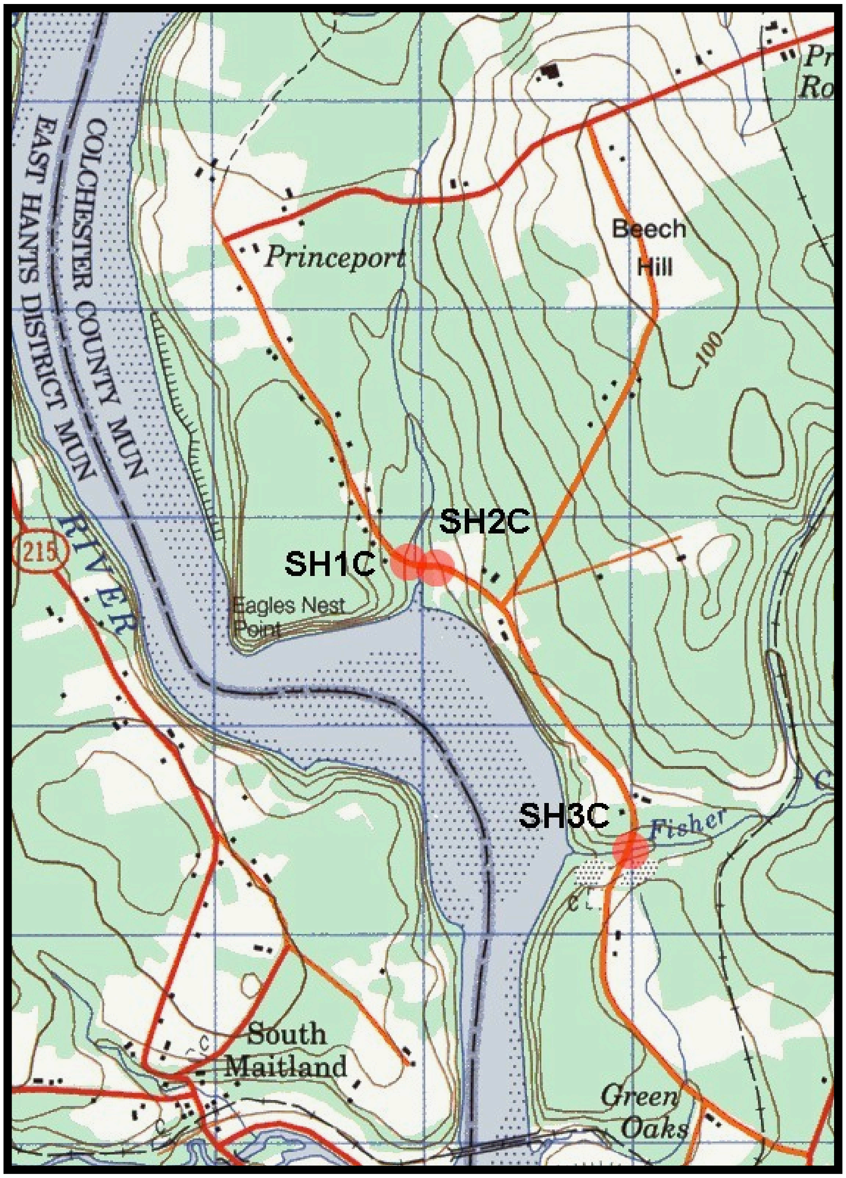


Figure 9. Princeport – Green Oaks

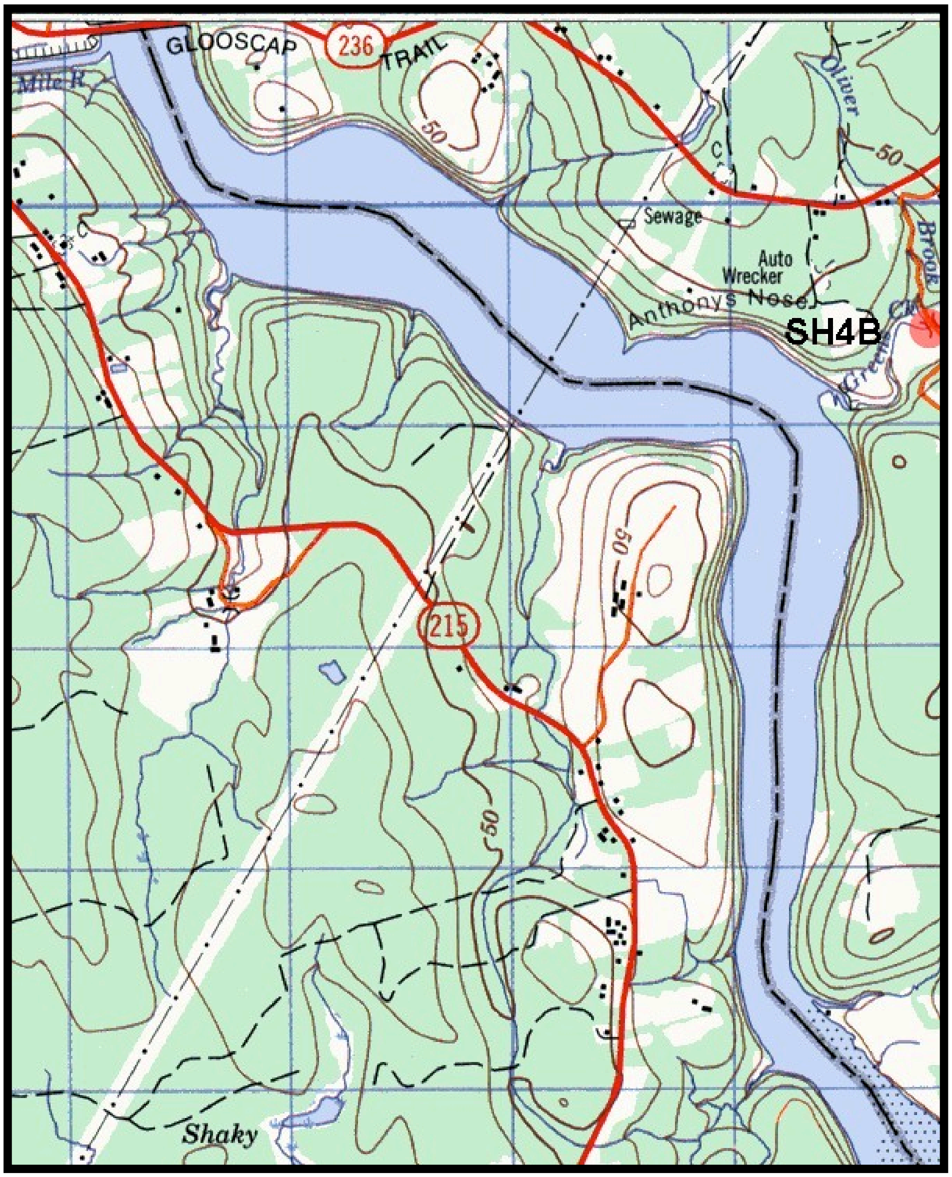


Figure 10. Greens Creek off the Shubenacadie River

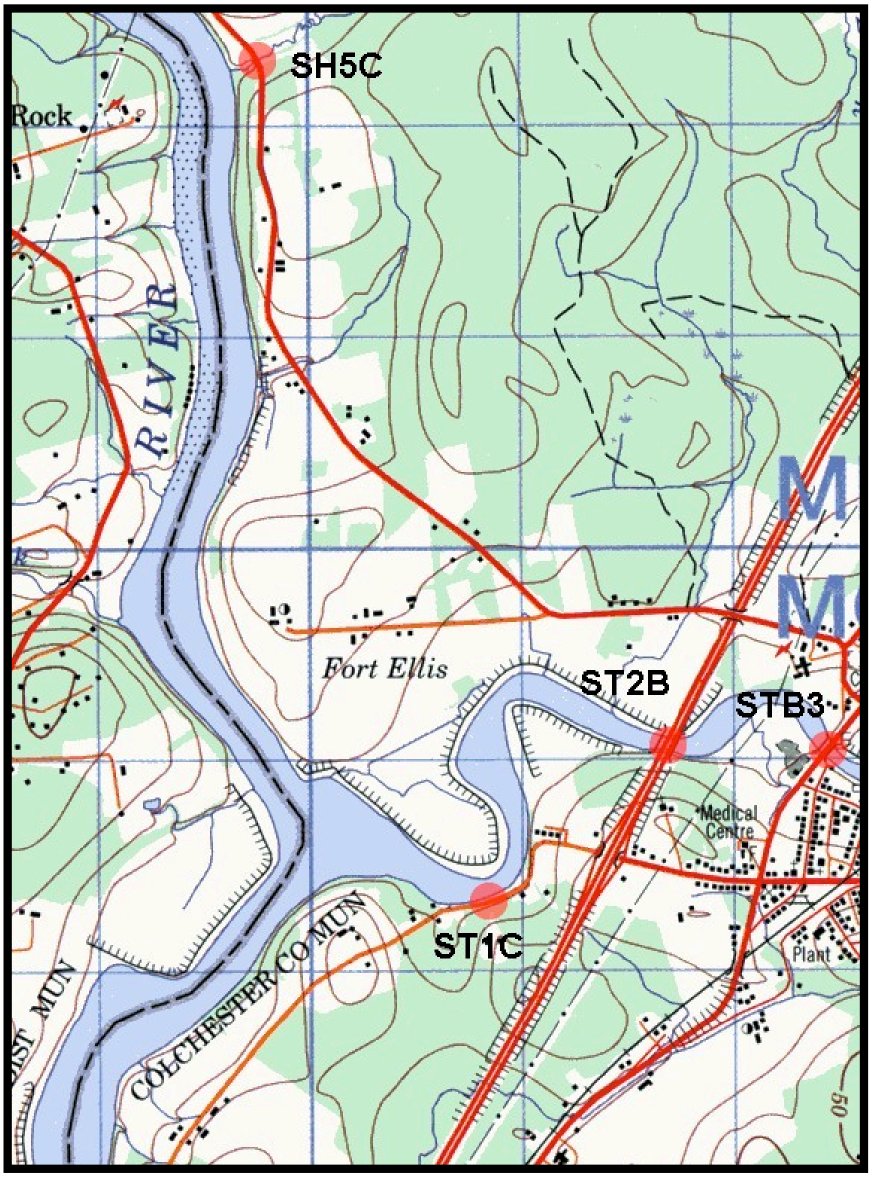


Figure 11. Fort Ellis

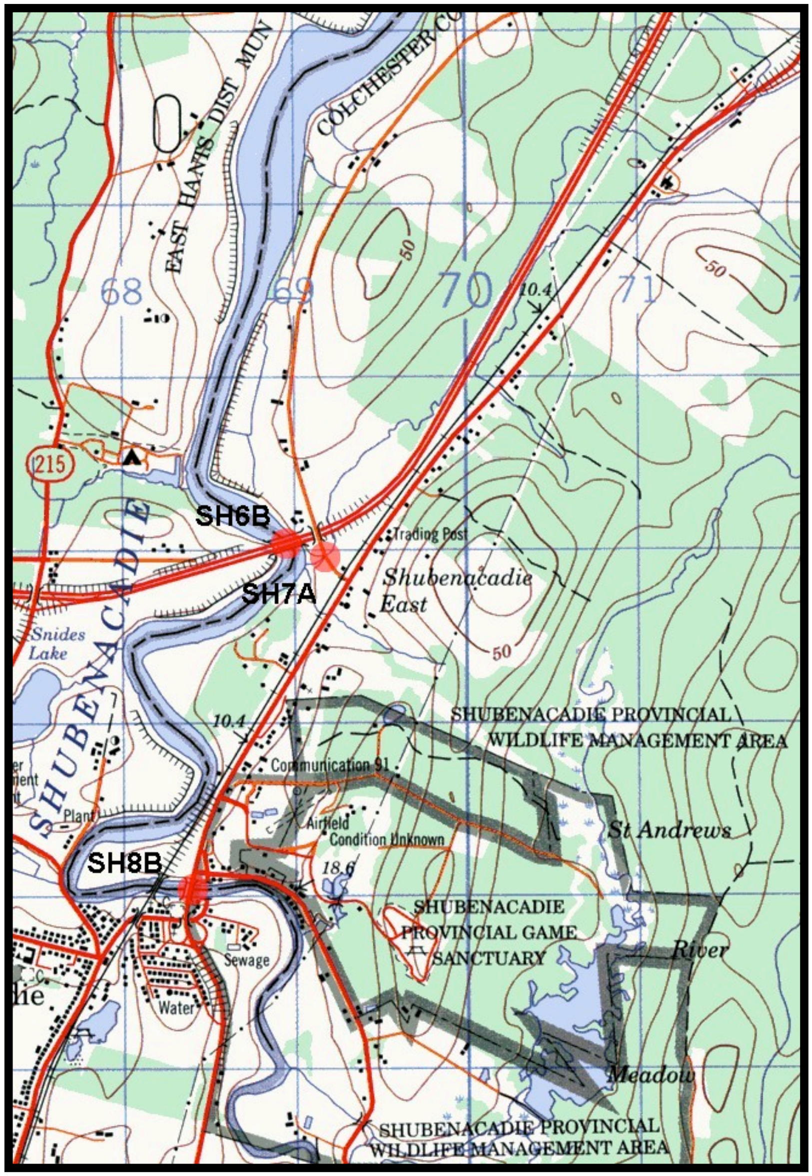


Figure 12. Shubenacadie

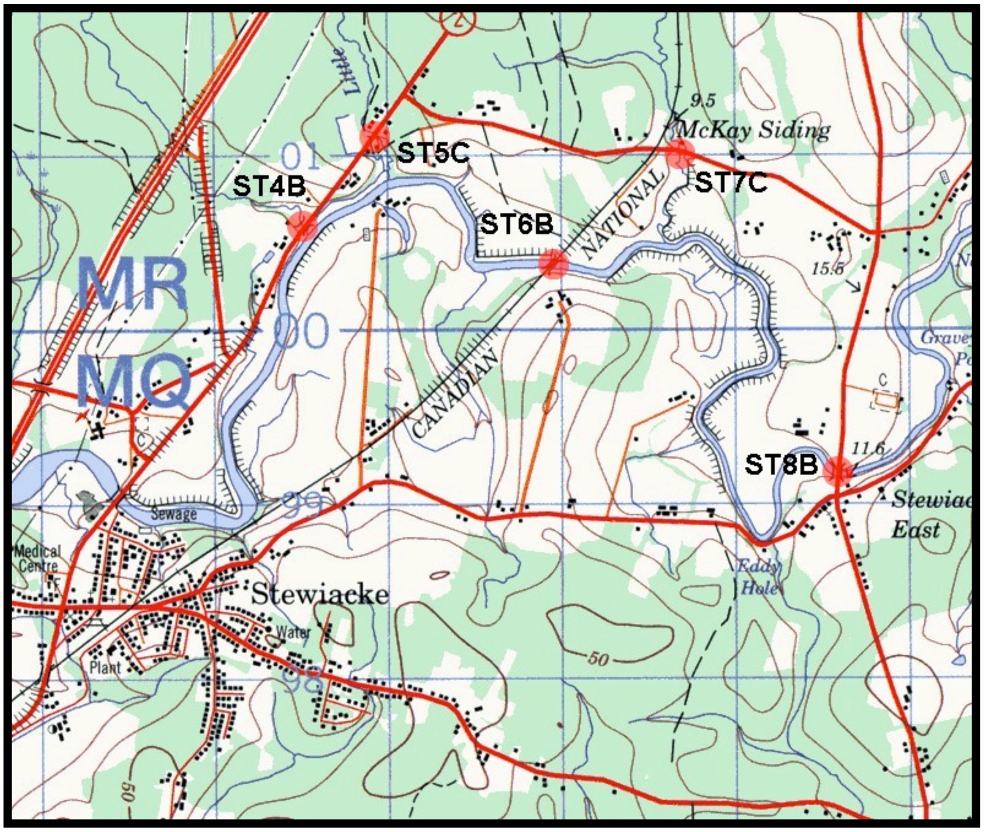


Figure 13. Stewiacke River

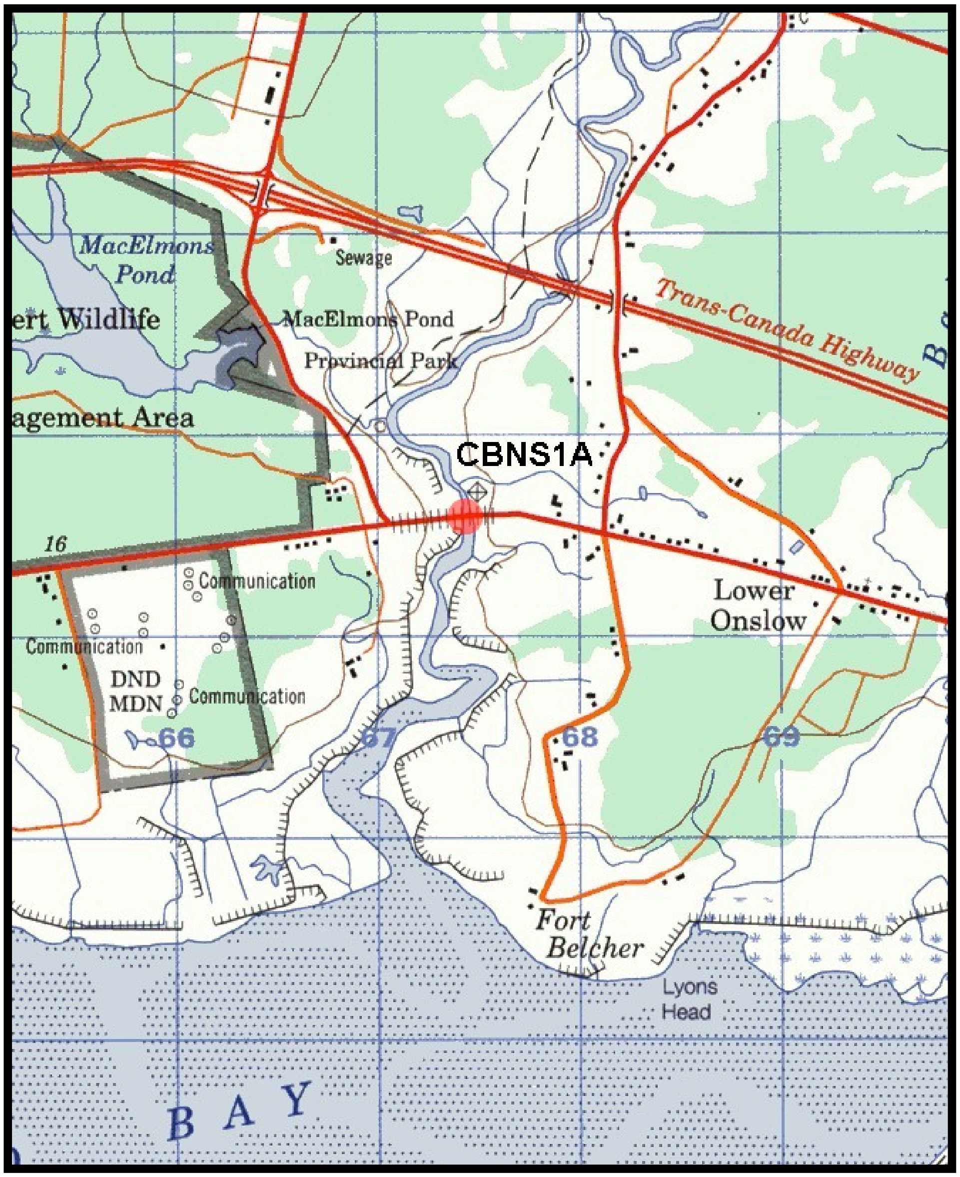


Figure 14. Lower Onslow

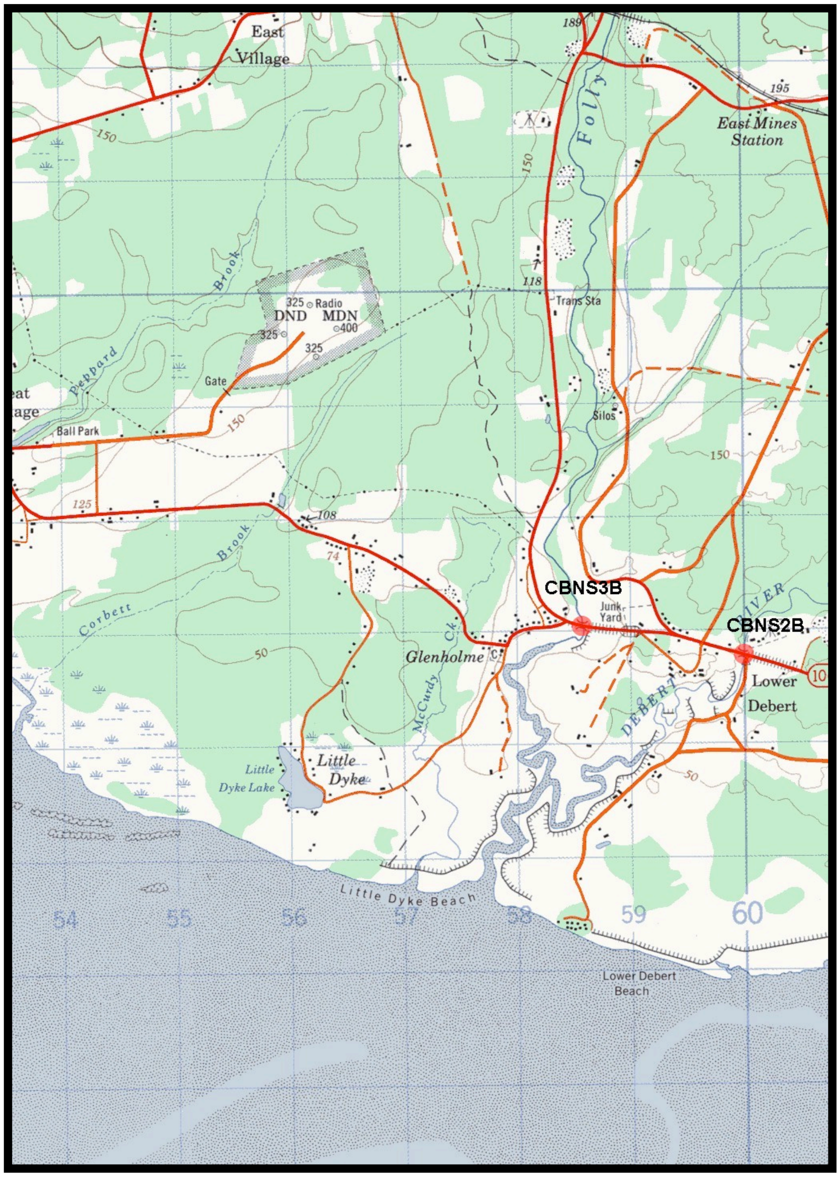


Figure 15. Glenholme

Figure 16. Great Village

Figure 17. Bass River

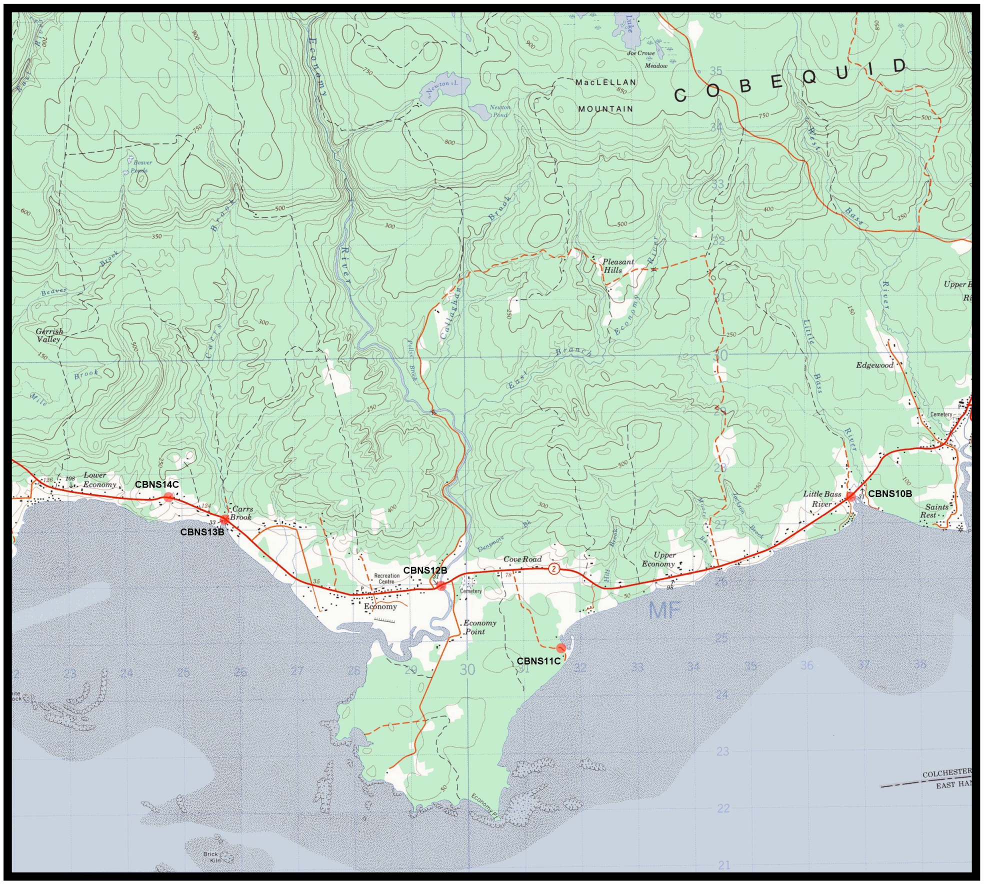


Figure 18 Economy

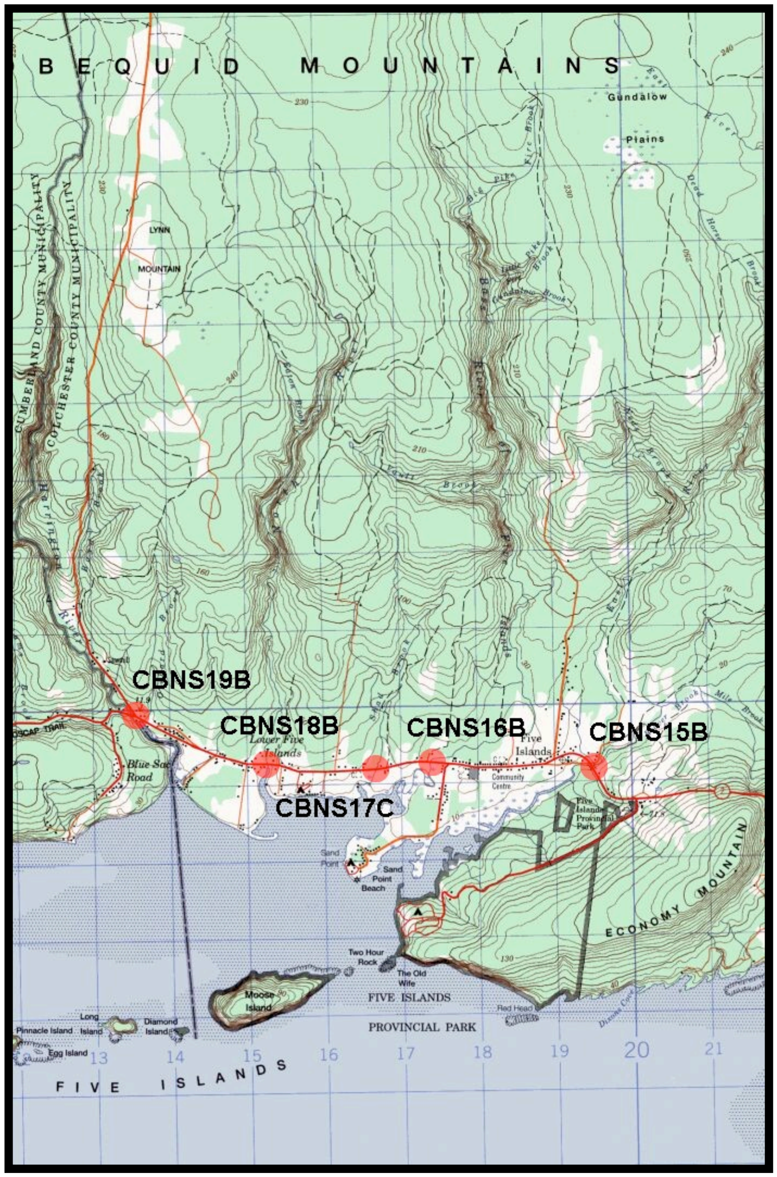


Figure 19. Five Islands

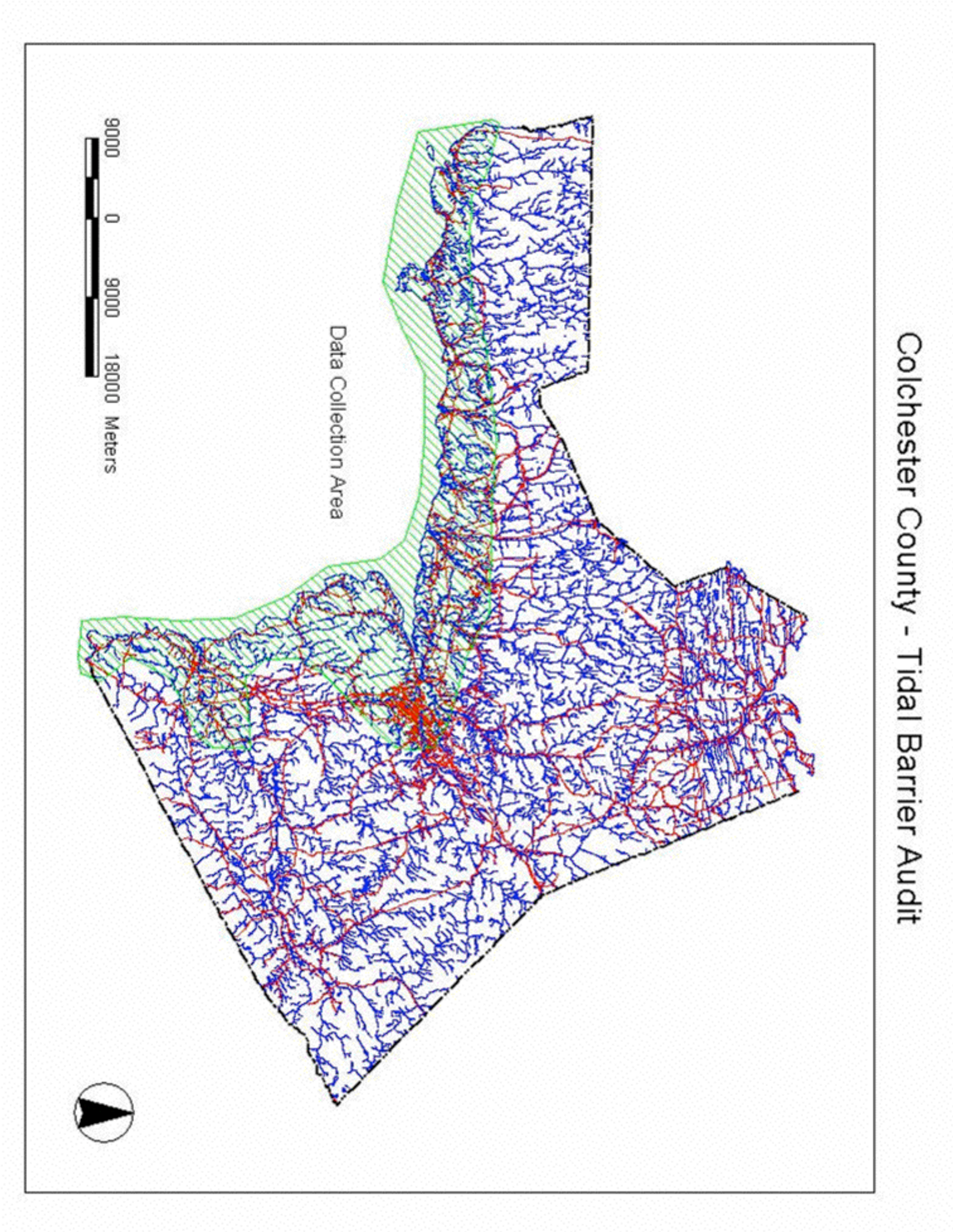


Figure 20. Tidal Barrier Audit – Data Collection Area.

Appendix D – Summary of Tidal Barriers Audit

Table 4. Summary of Tidal Barriers Audit 2002

Crossing Code and Map Figures	Locations & GPS Coordinates	Crossing Category	Crossing Material	Degree of Restriction	Fish Passage	Site Adjustment (refer to codes)
TA1B Figure 4	Route2/North River N45°23'25.9 E63°17'77.5	Bridge	Steel	No	Yes	NR
TA2B Figure 4	Park Street/Salmon River N45°22'24.8 E63°17'77.9	Bridge	Steel	No	Yes	NR
TA3B Figure 4	Main Street/Salmon River N45°22'24.0 E63°16'78.8	Bridge	Steel	No	Yes	NR
CBSS1C Figure 5	Route 2/Lower Truro N45°22'23.7 E63°19'74.7	Culvert	Cement	No *(upstream of aboiteau)*	No	OA FP
CBSS2A Figure 5	Cobequid Trail N45°22'23.9 E63°19'74.6	Aboiteau	Cement	Complete	No	OA FP
CBSS3A Figure 5	Cobequid Trail N45°22'23.9 E63°19'74.6	Aboiteau	Cement	Complete	No	OA FP
CBSS4C Figure 5	Cobequid Tail N45°21'23.6 E63°20'73.4	Culvert	Steel	No *(upstream of aboiteau)*	Yes	OA FP
CBSS5C Figure 6	Off Cobequid Trail N45°21'23.7 E63°21'73.4	Culvert	Steel	No *(upstream of aboiteau)*	Yes	OA FP
CBSS6C Figure 6	Route 2/Lower Truro N 45°21'23.3 E63°21'71.1	Culvert	Cement	No *(upstream of partial)*	Yes	SC FP EO
CBSS7C Figure 6	Cobequid Trail N45°21'23.7 E63°22'71.2	Culvert	Cement	Partial	Yes	LC

Crossing Code and Map Figures	Locations & GPS Coordinates	Crossing Category	Crossing Material	Degree of Restriction	Fish Passage	Site Adjustment (refer to codes)
CBSS8C Figure 6 & 7	Cobequid Trail N45°21'23.3 E63°22'71.2	Culvert	Steel	Partial	Yes	RS
CBSS9C Figure 6 & 7	On the Waste Treatement Road N45°21'23.1 E63°22'71.1	Culvert	Steel	Complete *(upstream of partial)*	Yes	LC
CBSS10C Figure 6 & 7	Cobequid Trail N45°21'23.0 E63°22'70.8	Culvert	Steel	Complete	Yes	SC
CBSS11C Figure 6 & 7	Cobequid Trail N45°21'22.7 E63°22'70.4	Culvert	Steel	Complete	Yes	LC
CBSS12C Figure 7	Cobequid Trail N45°21'22.6 E63°22'70.2	Culvert	Steel	Partial	Yes	LC RS
CBSS13C Figure 7	Old Barns N45°20'21.4 E63°23'68.2	Culvert	Wooden Block	No *(upstream of partial)*	Yes	NR
CBSS14A Figure 8	Black Rock N45°19'18.6 E63°28'62.6	Aboiteau	Wooden Block	Complete	No	OA FP
SH1C Figure 9	Princeport N45°16'13.8 E63°27'64.0	Culvert	Wooden Block	Complete *(upstream of partial)*	yes	LC
SH2C Figure 9	Princeport N45°16'13.8 E63°27'64.2	Culvert	Corrugated Steel	Complete	No	LC
SH3C Figure 9	Fisher Creek N45°15'12.4 E63°26'64.9	Culvert	Corrugated Steel	Partial	yes	EO
SH4B Figure 10	Green Creek N45°14'09.6 E63°24'67.8	Bridge	Steel	No	Yes	NR
SH5C Figure 11	Between Fort Ellis and Riverside N45°10'02.3 E63°23'69.7	Culvert	Steel	No	Yes	NR

Crossing Code and Map Figures	Locations & GPS Coordinates	Crossing Category	Crossing Material	Degree of Restriction	Fish Passage	Site Adjustment (refer to codes)
SH6C Figure 12	Highway 102 /Shubenacadie River N45°06'95.1 E63°23'69.0	Bridge	Steel	No	Yes	NR
SH7A Figure 12	Shubenacadie East Crossing the TCH N45°06'95.0 E63°23'69.2	Aboiteau	Wooden Block	Complete	No	OA EO FP
SH8B Figure 12	Route 2 /Shubenacadie River N45°05'93.1 E63°24'68.4	Bridge	Steel	No	Yes	NR
ST1C Figure 11	Stewiacke N45°08'98.2 E63°22'70.8	Culvert	Corrugated Steel	No	Yes	NR
ST2B Figure 11	Highway 102 /Stewiacke River N45°08'99.1 E63°21'71.8	Bridge	Steel	No	Yes	NR
ST3B Figure 11	Route 2 /Stewiacke River N45°08'99.1 E63°20'72.4	Bridge	Steel	No	Yes	NR
ST4B Figure 13	Big Meadow Brook N45°09'00.7 E63°20'73.5	Bridge	Steel	No	Yes	NR
ST5C Figure 13	Little Hurd Brook N45°09'01.2 E63°19'74.0	Culvert	Cement	No	Yes	NR
ST6B Figure 13	CNR /Stewiake River N45°09'00.4 E63°19'75.0	Bridge	Steel	No	Yes	NR

Crossing Code and Map Figures	Locations & GPS Coordinates	Crossing Category	Crossing Material	Degree of Restriction	Fish Passage	Site Adjustment (refer to codes)
ST7C Figure 13	Mackay Siding Road/ Stewiacke River Tributary N45°09'01.0 E63°18'75.7	Culvert	Wooden Block	Partial	Yes	LC EO
ST8B Figure 13	Route 277 /Stewiacke River N45°08'99.2 E63°17'76.6	Bridge	Steel	No	Yes	NR
CBNS1A Figure 14	Route 2 /Chiganoise River N45°22'25.6 E63°24'67.5	Aboiteau	Steel	Complete	No	OA FP
CBNS2B Figure 15	Route 2 /Debert River N45°23'26.8 E63°30'60.0	Bridge	Steel	No	Yes	NR
CBNS3B Figure 15	Route 2 /Folly River N45°23'27.1 E63°31'58.6	Bridge	Steel	No	Yes	NR
CBNS4B Figure 16	Route 2 / Great Village River N45°24'29.0 E63°35'53.1	Bridge	Steel	No	Yes	NR
CBNS5A Figure 15	Great Village River by Cemetary N45°23'27.2 E63°36'52.5	Aboiteau	Steel	Complete	No	OA FP
CBNS6B Figure 17	Route 2 /Portapique River N45°24'28.1 E63°42'44.2	Bridge	Steel	No	Yes	NR
CBNS7C Figure 17	Route 2 /Beaver Meadows Brook N45°24'28.7 E63°46'39.1	Culvert	Wooden Block	Partial	Yes	EO

Crossing Code and Map Figures	Locations & GPS Coordinates	Crossing Category	Crossing Material	Degree of Restriction	Fish Passage	Site Adjustment (refer to codes)
CBNS8B Figure 17	Route 2 /Bass River N45°24'29.0 E63°46'39.0	Bridge	Steel	No	Yes	RS
CBNS9B Figure 17	Route 2 /West Bass River N45°24'28.6 E63°47'38.7	Bridge	Steel	No	Yes	RS
CBNS10B Figure 18	Route 2 /Little Bass River N45°23'27.5 E63°48'36.8	Bridge	Steel	No	Yes	NR
CBNS11C Figure 18	Cove Road @ point N45°22'24.8 E63°52'31.7	Culvert	Steel	Partial	Yes (restricted/shallow)	LC EO
CBNS12B Figure 18	Route 2 /Economy River N45°23'26.0 E63°53'29.6	Bridge	Steel	No	Yes	NR
CBNS13B Figure 18	Route 2 / Carrs Brook N45°23'27.2 E63°56'25.8	Bridge	Wooden	Partial	Yes (restricted/shallow)	FP
CBNS14C Figure 18	Route 2 @ Carr Brook Road N45°23'27.5 E63°57'24.8	Culvert	Cement	Partial	Yes	SC GR
CBNS15B Figure 19	Route 2 /Beaver Brook (Five Islands) N45°24'29.2 E64°02'19.5	Bridge	Steel	Partial (bridge location alters channel path)	Yes	RS
CBNS16B Figure 19	Route 2 /BassRiver (Five Islands) N45°24'29.2 E64°03'17.3	Bridge	Steel	No	Yes	NR
CBNS17C Figure 19	Shad Brook N45°24'29.3 E64°03'16.7	Culvert	Wooden Block	Partial *(upstream of dyke)*	Yes (restricted/shallow)	FP RS

Crossing Code and Map Figures	Locations & GPS Coordinates	Crossing Category	Crossing Material	Degree of Restriction	Fish Passage	Site Adjustment (refer to codes)
CBNS18B Figure 19	Route 2 /North River (Five Islands) N45°24'29.3 E64°04'15.2	Bridge	Steel	No	Yes	NR
CBNS19B Figure 19	Route 2 /Harrington River N45°25'29.9 E64°06'13.4	Bridge	Steel	Partial *(support structure alter channel)*	Yes	SC

Site Adjustment Codes:
NR- Not Restrictive GR-Good Repair
OA- Open Aboiteau SC- Site Clean-up
LC-Lower Culvert EO-Enlarge Opening
RS-Repair Structure FP- Fish Passage

Crossing Codes:
TA-Truro Area
CBSS-Cobequid Bay South Side
SH- Shubenacadie River
ST- Stewiacke River
CBNS- Cobequid Bay and Minas Basin North Side

Crossing Categories:
A- Aboiteau
B- Bridge
C- Culvert

Crossing Code Breakdown:
Example: TA1B
TA- Truro Area (Location)
1- Site Number
B- Bridge (Type of crossing)

Appendix E – Phase II Assessment Results

Table 5. Data collected over a six hour period from phase II measurements at site CBSS9C. The collection of raw data includes measurements of the height of the water surface to the sight line of the tripod, as well as the height of the tripod.

Cobequid Bay South Side site 9 Culvert : Phase II Measurements							
Upstream				Downstream			
Time	Height from Water Surface (m)	Tripod Height (m)	Change in Water Height (m)	Time	Height from Water Surface (m)	Tripod Height (m)	Change in Water Height (m)
11:42 am	2.22	1.15	1.1867	11:34 am	2.64	0.99	1.1850
12:42 pm	2.26	1.18	1.1767	12:34 pm	2.86	1.24	1.2150
1:12 pm	2.23	1.16	1.1867	1:04 pm	2.87	1.22	1.1850
1:42 pm	2.22	1.17	1.2067	1:34 pm	2.92	1.27	1.1850
2:12 pm	2.31	1.23	1.1767	2:04 pm	2.99	1.27	1.1150
2:42 pm	2.23	1.16	1.1867	2:34 pm	2.83	1.19	1.1950
3:12 pm	2.26	1.18	1.1767	3:04 pm	2.75	1.15	1.2350
3:42 pm	2.24	1.15	1.1667	3:34 pm	2.80	1.16	1.1950
4:12 pm	2.29	1.22	1.1867	4:04 pm	2.85	1.20	1.1850
4:42 pm	2.26	1.18	1.1767	4:34 pm	2.84	1.19	1.1850
5:12 pm	2.25	1.20	1.2067	5:04 pm	2.85	1.22	1.2050
5:42 pm	2.31	1.24	1.1867	5:34 pm	2.82	1.20	1.2150

Figure 21. Six hour tidal observing cycle at site CBSS9C. This demonstrates a culvert located too high above the streambed, illustrating a change in height from the water surface downstream, while little change was noted upstream. Small changes recorded downstream suggests a possible downstream restriction at site CBSS8C. High tide, as recorded at Burntcoat Head, was at 2:34 pm.

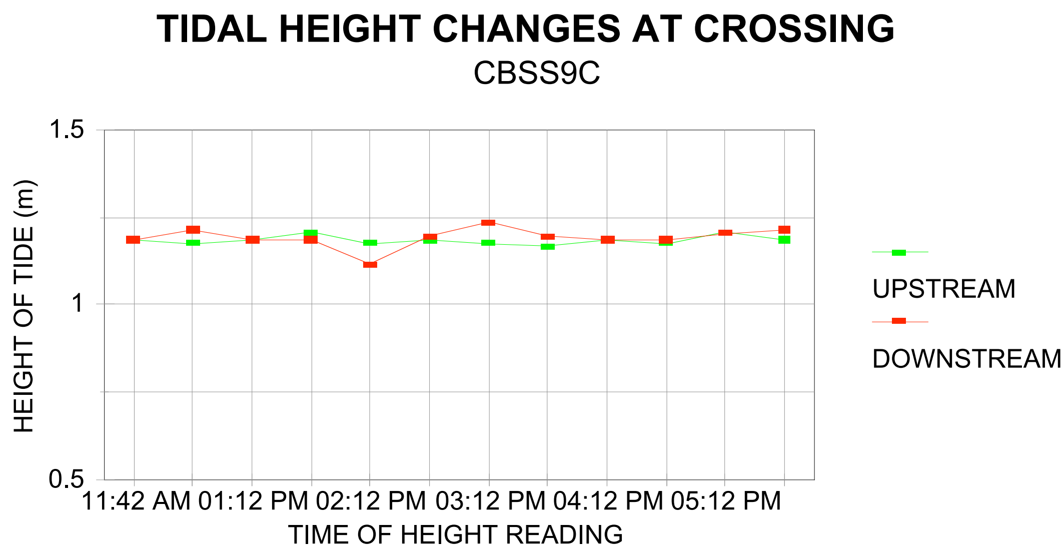


Table 6. Data collected over a four hour period from phase II measurements at site SH2C. The collection of raw data includes measurements of the height of the water surface to the sight line of the tripod, as well as the height of the tripod.

Shubenacadie River site 2 Culvert : Phase II Measurements							
Upstream				Downstream			
Time	Height from Water Surface (m)	Tripod Height (m)	Change in Water Height (m)	Time	Height from Water Surface (m)	Tripod Height (m)	Change in Water Height (m)
9:38 am	3.42	1.16	1.1363	9:12 am	3.12	1.04	1.0712
10:25 am	3.30	1.03	1.1239	10:12 am	3.21	1.02	0.9916
10:54 am	3.30	1.00	1.1003	10:42 am	3.21	1.07	1.0116
11:24 am	3.40	1.06	1.0579	11:09 am	3.20	1.02	0.9744
11:54 am	3.32	1.00	1.0811	11:39 am	3.17	1.06	1.0400
12:24 pm	3.40	1.08	1.0715	12:09 pm	3.16	1.02	1.0128
12:54 pm	3.39	1.05	1.0543	12:39 pm	2.97	1.02	1.2048
1:24 am	3.64	1.02	0.7747	1:09 pm	3.18	1.06	1.0336

Figure22. Four hour tidal observing cycle at site SH2C. The culvert being placed too high prevented changes in height caused by tidal flow to the upstream side. Since high tide did not pass through the culvert, measurements ceased an hour after this recording. High tide, as recorded at Burntcoat Head, was at 12:04 pm.

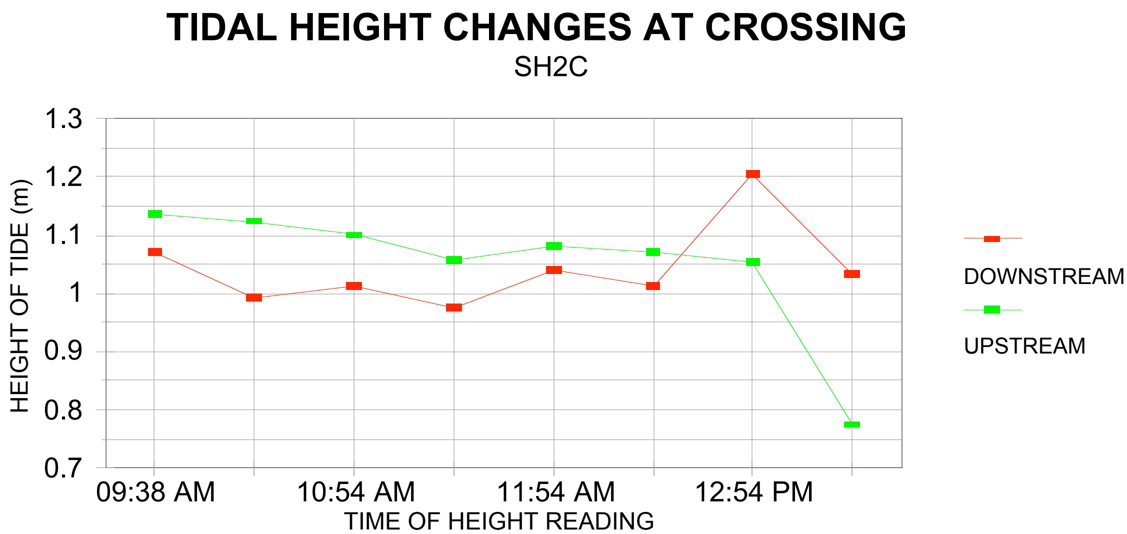
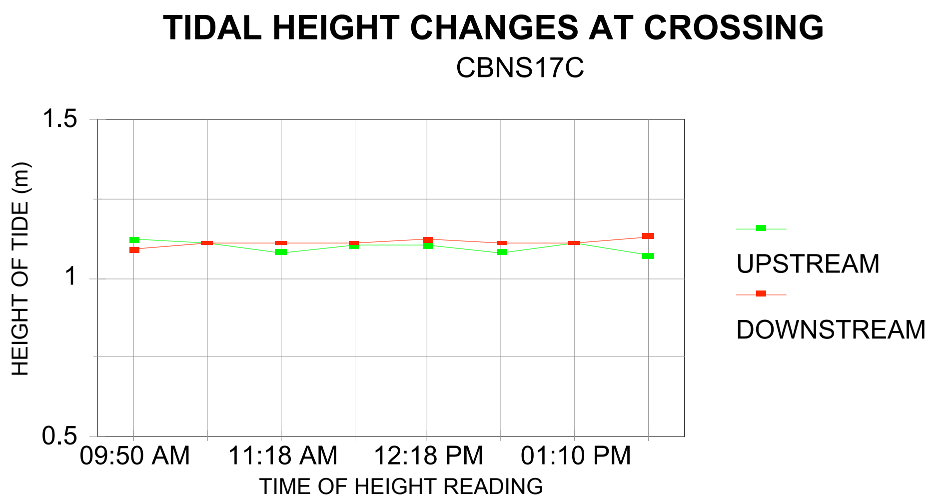


Table 7. Data collected over a four hour period from phase II measurements at site CBNS17C. The collection of raw data includes measurements of the height of the water surface to the sight line of the tripod, as well as the height of the tripod.

Cobequid Bay North Side site 17 Culvert : Phase II Measurements							
Upstream				Downstream			
Time	Height from Water Surface (m)	Tripod Height (m)	Change in Water Height (m)	Time	Height from Water Surface (m)	Tripod Height (m)	Change in Water Height (m)
9:50 am	2.52	1.06	1.1213	9:40 am	2.04	1.09	1.0913
10:48 am	2.55	1.08	1.1113	10:40 am	1.98	1.05	1.1113
11:18 am	2.65	1.15	1.0813	11:10 am	2.05	1.12	1.1113
11:48 am	2.62	1.14	1.1013	11:40 am	2.06	1.13	1.1113
12:18 pm	2.57	1.09	1.1013	12:10 pm	2.09	1.17	1.1213
12:48 pm	2.59	1.09	1.0813	12:40 pm	2.08	1.15	1.1113
1:18 pm	2.58	1.11	1.1113	1:10 pm	2.04	1.11	1.1113
1:48 pm	2.57	1.06	1.0713	1:40 pm	1.99	1.08	1.1313

Figure23. Over a four hour period, a change in tide was not observed on both upstream and downstream sides possibly due to a decreased tidal force resulting from natural landscape features (numerous pools and bends) of the inlet. High tide, as recorded at Burntcoat Head, was 12:50 pm.



Appendix F – Spreadsheet Used for Phase II Data Analysis

Table 8. Spreadsheet (including formulae) used for data analysis of Phase II Measurements

	A	B	C	D	E	F	G	H
	Upstream				Downstream			
	Time	Height from Water Surface (m)	Tripod Height (m)	Change in Water Height (m)	Ti me	Height from Water Surface (m)	Tripod Height (m)	Change in Water Height (m)
1				-(B1-C1)+avg(B1..B12)				-(F1-G1)+avg(F1..F12)
2				-(B2-C2)+avg(B1..B12)				-(F2-G2)+avg(F1..F12)
3				-(B3-C3)+avg(B1..B12)				-(F3-G3)+avg(F1..F12)
4				-(B4-C4)+avg(B1..B12)				-(F4-G4)+avg(F1..F12)
5				-(B5-C5)+avg(B1..B12)				-(F5-G5)+avg(F1..F12)
6				-(B6-C6)+avg(B1..B12)				-(F6-G6)+avg(F1..F12)
7				-(B7-C7)+avg(B1..B12)				-(F7-G7)+avg(F1..F12)
8				-(B8-C8)+avg(B1..B12)				-(F8-G8)+avg(F1..F12)
9				-(B9-C9)+avg(B1..B12)				-(F9-G9)+avg(F1..F12)
10				-(B10-C10)+avg(B1..B12)				-(F10-G0)+avg(F1..F12)
11				-(B11-C11)+avg(B1..B12)				-(F11-G11)+avg(F1..F12)
12				-(B12-C12)+avg(B1..B12)				-(F12-G12)+avg(F1..F12)

Appendix G – Photos of Sites with Restoration Potential

Figure 24. Downstream view of a corrugated steel culvert at site CBSS8C (Cobequid Trail).

Figure 25. Downstream view of an old wooden aboiteau at site CBSS14A (Black Rock).

Figure 26. Downstream view of a wooden box culvert at site SHIC (Princeport).

Figure 27. Downstream view of a wooden box culvert at site ST7C (MacKay Siding Road).

Figure 28. Downstream view of an aboiteau system with three tide gates at site CBNS1A (Chiganois River).

Figure 29. Upstream view of debris built up at site CBNS2B (Debert River).

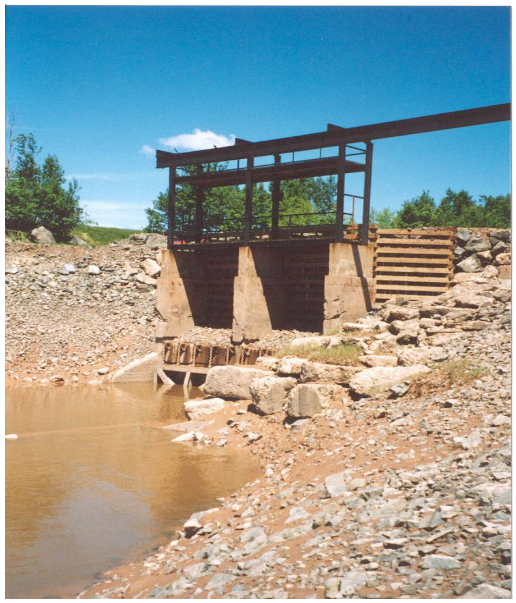


Figure 30. Downstream view of a large aboiteau at site CBNS5A (Great Village River).

Figure 31. Downstream view of a bridge at site CBNS13B (Carrs Brook).

Figure 32. Upstream view of debris built up at site CBNS14C (Carrs Brook Road).