Annapolis Watershed Salt Marsh Evaluation: Surveying Tidal Barriers Along the Annapolis Basin

Denise Sullivan
Clean Annapolis River Project
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Acknowledgements

The Annapolis Watershed Salt Marsh Evaluation Project and the completion of this report was made possible with the financial support from the Bay of Fundy Ecosystem Partnership and the Department of Fisheries and Oceans as well as in-kind support from the Gulf of Maine Council and the Nova Scotia Department of Environment and Labour.

Thank you also to Tony Bowron at the Ecology Action Centre who kindly shared field protocols and reports from previous salt marsh inventories and was always available to answer questions.

A special thank you goes out to the landowners who graciously gave access to their properties during the field evaluations.

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Executive Summary

The Annapolis Watershed Salt Marsh Evaluation Project identified a shortlist of potential salt marsh restoration sites throughout the Annapolis Basin and area. A total of 27 salt marsh sites, including 20 aboiteau and culvert barriers, were evaluated during the summer and autumn of 2005. Additional information was collected on four shortlisted potential sites, from which two were deemed high priorities.

Two of the four potential salt marsh sites were tidally restricted by a dyke and aboiteau barrier. Both were located within Annapolis County, one on French Basin Marsh in Annapolis Royal, the other on part of Allain's River Marsh in Allain's Creek. The remaining two potential sites were restricted by poorly sized and/or improperly placed culverts. The range ratio, or the ratio between the upstream and downstream water levels, was measured at two potential sites. A site at the Little Joggins in Digby County had a range ratio of 0.85, while a site on the Allain's River Marsh in Annapolis Royal recorded a range ratio of 0.71.

Due to a combination of the potential restorable area and the land tenure, the sites on the French Basin Marsh and the Allain's River Marsh in Allain's Creek were deemed top priority. A restoration plan was developed and preliminary water quality monitoring was initiated. The restoration plan involves, as an initial step, a feasibility study to examine if restoration is technically, physically, and biologically possible at a site. If restoration is possible, the site is paired with a reference marsh of comparable characteristics for pre and post-restoration monitoring. Four reference marshes were identified during the inventory: Allain's River Marsh in Annapolis Royal, the east end of Dentabella Marsh in Granville Beach, Stoney Beach Road Marsh in Granville Beach, and the west end of Queen Anne Marsh in Port Royal.

Several physical, chemical, and biological indicators are recommended for pre and post restoration monitoring. These include hydrology, soils and sediments, vegetation, fish, and birds. Different variables are identified for each indicator as well as a general timeline for monitoring.

Preliminary water quality monitoring on French Basin Marsh showed the water pooling behind the dyke to be slightly oxygen depleted due to little or no flushing and the presence of thick algae in and along the creek. The dissolved oxygen saturation ranged on average from 61.4% to 72.4% on the freshwater side of the barrier compared to 87.9% in the basin salt water. A malfunctioning aboiteau is seeping salt water on the high tide and trapping it on the low tide, shown by higher than normal salinity and conductivity values in the freshwater brook. Initial monitoring on Allain's River Marsh in Allain's Creek revealed a low pH level on the lower parts of the brook. A pH of 3.20 was recorded from a small tributary draining from an adjacent field. pH ranged from 3.84 to 4.75 below the tributary and 6.14 to 6.17 above the tributary. Additional monitoring is required at the site to determine if these values are consistent over time.

Introduction
Historically, the shores of the Annapolis Basin were covered by extensive salt marshes. These rich and diverse ecosystems contributed to the overall health of the Annapolis Basin and the adjacent Bay of Fundy in a number of ways. Being one of the most productive habitat types, these salt marshes produced large amounts of vegetation that fuelled complex food chains in the Basin and the Bay. The marshes also provided important protection against erosion and storm surge as well as improved water quality by filtering out toxins and excess nutrients. In addition, the salt marshes provided important habitat for both terrestrial and aquatic species, including migratory birds and important fish species.

Several hundred years of development in the area have resulted in many of the salt marshes along the Annapolis Basin being destroyed or altered. Large portions of marshland were both dyked for agricultural use, and fragmented by numerous roads and railways. The construction of a large causeway at Annapolis Royal also greatly influenced salt marshes on the upper reaches of the estuary. The last remaining salt marsh of any significance in the Annapolis Basin is located on the Allain's River, and covers an area of approximately 83 hectares.

In recent years, the Ecology Action Centre (EAC) has pioneered the evaluation and restoration of salt marshes in Nova Scotia. Using protocols developed in New England and adapted by the EAC and others for use in the Bay of Fundy, the Clean Annapolis River Project undertook the Annapolis Watershed Salt Marsh Evaluation Project. The goal of the project was to identify and evaluate existing tidal barriers to salt marshes in and around Annapolis Basin. A shortlist of potential restoration sites was identified and a restoration plan developed for two priority sites.

Methodology
The initial work involved gathering the relevant background information and materials needed to start the inventory. This included printing and reviewing several salt marsh monitoring protocols and reports from both the Ecology Action Centre as well as New England monitoring groups (ie: Parker River Clean Water Association). This was done in order to both learn the relevant information as well as remain consistent with previous salt marsh monitoring activities. Information on active dykes was obtained from the Nova Scotia Department of Agriculture and Fisheries (NSDAF). These are dykes currently being maintained by the NSDAF to protect agricultural dykelands. Finally, air photos of the Annapolis Basin were obtained from the Service Nova Scotia & Municipal Relations office in Lawrencetown.

Once all the relevant materials were gathered, topographic maps and air photos were reviewed for potential sites to investigate in the field, as well as potential reference marshes in the area. The sites were evaluated using the same protocol and coding system used by the EAC in 2004. Dykes on both shores of the Basin were surveyed to identify structures in poor condition as well as dykelands that are no longer being used for agricultural purposes. Roads along the basin were also surveyed for restrictive crossings, such as culverts and/or bridges. Data sheets were adapted from those used by the Ecology Action Centre, and can be seen in Appendix C.

The numbering system was consistent with that used by the EAC, with slight variation to accommodate sites with dykes and multiple aboiteaux. The format [XX##X(#)] contains the following:

- Two letters for the county (AC – Annapolis County; DC – Digby County)
- A two-digit number for the tidal barriers, starting at 30 in Annapolis County and 20 in Digby County (EAC inventoried barriers AC01-AC29 and DC01-DC19 in 2004)
- A letter indicating type of barrier (A – Aboiteau; C – Culvert; D – Dyke; R – Rail bed; RD – Road)
- If multiple structures on one barrier (ie: multiple aboiteaux on one section of dyke), another number was added at the end of the code, in sequential order for each structure (ie: A1, A2, A3…)

Since dykes and dykelands were not part of previous EAC surveys, a method for allocating a new number to a tidal barrier, or section of dyke, was developed. Three criteria were used in the field to decide if a new site code was required:

1. A clear change or distinction in backshore land use (ie: cow pasture, fallow field, etc)
2. A change in the barrier type (NSDAF dyke, non-NSDAF dyke, rail bed, road)
3. A clear distinction in the area that would be flooded, if the tidal barrier was removed. This distinction could be either due to man-made features (e.g. road, rail bed, dyke) or landscape features (slope).

(Example: A 400m section of NSDAF dyke contains 3 aboiteaux. The land use behind the dyke is cultivated agricultural fields. If any section of the dyke or any single aboiteau were removed, all the agricultural land would flood. The entire dyke would have the site code AC35D. The three aboiteaux would be sequentially numbered AC35A1, AC35A2, and AC35A3.)

Once the initial survey was complete, the sites were rated on their feasibility for future restoration.
The sites were ranked based on a combination of the following criteria:

1. Land Use – Priority was given to sites where the backshore land was currently fallow or restricted salt marsh. This included dykelands that were no longer being used for agricultural purposes and where there were no residential or commercial buildings as well as sections of marshland where the normal flow of the tides are restricted by a tidal barrier (ie: undersized culverts and bridges).
2. Restoration Area – Priority was given to sites with larger restoration areas
3. Restoration Effort – Priority was given to sites which required less restoration effort (ie: sites where no new dyke was needed to protect adjacent land)
4. Landowners – Priority was given to sites that involved a smaller number of landowners and/or landowners that were more likely to participate in a restoration project (ie: land owned by the Town of Annapolis Royal, local non-profit groups, etc.)

Six sites were shortlisted from the initial survey list. Some of the sites were completely restricted by aboiteaux while others were only partially restricted by other tidal barriers such as undersized culverts. Where some tidal flushing was occurring through culverts and/or bridges, a tidal range analysis was conducted to determine the degree of restriction. Using a tripod, autolevel and metric measuring rod, water levels were measured on both the upstream and downstream sides of the barrier. Measurements were taken 3 hours before and after a high tide event, at regular time intervals, every 30 minutes. The data was entered into an Excel spreadsheet, which computed the peak-to-peak water level change, or tidal range. Using the Parker River Methodology (Purinton and Mountain, 1998), the data was manipulated so it could be visualized in a graph showing water level changes on both the upstream and downstream sides of the barrier plotted against the time of day. The water level change was calculated by subtracting the mean distance to the water surface on both sides of the barrier from data points on each side of the barrier (see Appendix D for the spreadsheet template). The curves of non-restrictive sites should lay directly on top of each other throughout the tidal cycle, with natural variation no more than 10 centimetres. Sites where the upstream and downstream level changes differed by more than 10 centimetres were deemed restrictive. Tidal range was not measured at sites with dykes and aboiteaux because no tidal flushing was occurring at these sites.

Shortlist of Potential Restoration Sites

A total of 27 sites were surveyed on the dykes and roads around the Annapolis Basin, including 20 aboiteau and culvert barriers. A summary of sites visited is shown below in Table 1. A map of the Annapolis Basin with the location of all tidal barriers surveyed is available in Appendix A. For specific locations of aboiteaux and culverts, see Appendix B.

Table 1: Summary of Sites Evaluated for Tidal Restriction

Site Code	Location	Current Land Use on Landward Side of Barrier	Number of Culverts or Aboiteaux	Approximate Restorable Area (ha)	Number of Landowners*	NSDAF Dyke (Y/N)
AC30D	Allain's River Marsh	Fallow	1	4	4	Y
AC31D	Allain's River Marsh	Agriculture	0	4	NA	Y
AC32D	Allain's River Marsh	Agriculture	0	3	NA	N
AC33R	Allain's River Marsh	Fallow	1	5	1	Y
AC34R	Allain's River Marsh	Fallow	1	9	1	Y
AC35D	Upper Clements	Fallow	0	1.5	1	N
AC36D	Upper Clements	Agriculture	2	30	NA	Y
AC37D	Upper Clements	Salt Marsh	0	3	1	N
AC38D	Upper Clements	Agriculture	1	9	NA	Y
AC39RD	Allain's River Marsh	Salt Marsh	1	2	1	N
AC40D	Allain's River Marsh	Dyke demonstration area	1	4	1	N
AC41D	Dentabella Marsh	Fallow	1	2	1	Y
AC42D	Dentabella Marsh	Agriculture	3	67	NA	Y
AC43D	Queen Anne Marsh	Fallow	2	18	11	Y
AC44D	Queen Anne Marsh	Agriculture	0	24	NA	Y
AC45D	Queen Anne Marsh	Fallow	1	18	5	Y
AC46D	Queen Anne Marsh	Fallow	2	20	12	Y
AC47D	Allain's River Marsh	Salt Marsh	0	18	18	N
AC48D	Allain's River Marsh	Salt Marsh	0	NA	NA	N
AC49D	Allain's River Marsh	Salt Marsh	0	NA	NA	N
AC50D	French Basin Marsh	Fallow	0	1	1	N
AC51D	French Basin Marsh	Freshwater Marsh	0	15	NA	N
AC52D	Annapolis Royal	Commercial, Salt Marsh	0	1	2	N
AC53D	Annapolis Royal	Fallow	1	12	1	N
AC54D	Annapolis Royal	Residential, Fallow	0	4	NA	N
DC20R	Digby	Fallow	1	< 1	NA	N
DC21R	Conway	Salt Marsh	1	6	7	N

* Landowner information was only collected from properties that were not currently being used for agriculture or any other reason that would eliminate the option of restoration.

Six potential restoration sites were shortlisted from the complete list based on the above-mentioned criteria. These sites, shown in Figure 1, were identified as restrictive and/or potentially restrictive during the preliminary visual assessment.

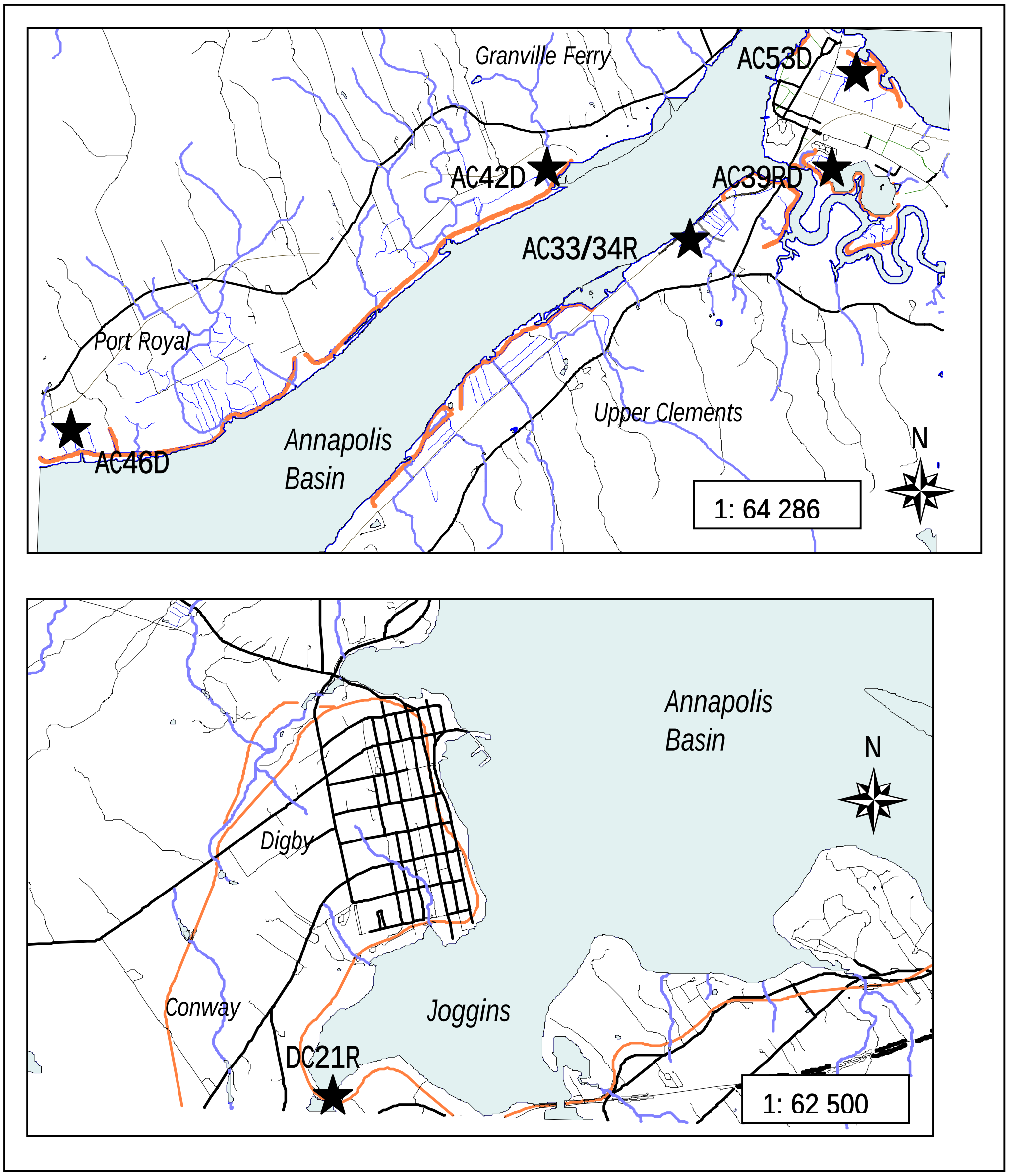

Figure 1: Approximate location of six short-listed salt marsh restoration sites, Annapolis Basin

From the shortlist, four potential sites were revisited for further analysis. The four sites were AC39RD at Allain's River, DC21C at Little Joggins, AC53D at French Basin Marsh, and AC33/34R at Highway 1, Allain's Creek. The two remaining potential sites were to be re-examined if any of the four sites proved unsuitable for a restoration project. The discussion below contains detailed descriptions of the four potential sites and tidal range analyses, as well as recommendations on restoration options.

Allain's River

Site Description

The site is a small area (2 ha) of salt marsh on Allain's River Marsh, behind Charlie's Restaurant in Annapolis Royal. A road with a small PVC culvert placed high in the streambed is partially restricting tidal flow. The road is made of large cobble and gravel and is used as an access route onto an adjacent dyke. During very high tides, the road is overtopped, flooding the upstream marsh. High velocity flows displace rocks and debris, which are visibly moved from the road onto the marsh surface. Small patches of marsh directly above the road are therefore covered in rocks, preventing *Spartina spp.* growth. The property is bordered by Highway 1 to the North and a demonstration area of an Acadian dyke and aboiteau maintained by the Annapolis Royal Historic Gardens to the South. There are several evident signs of tidal restriction at the site, including bank slumping, scour pools, turbulent flow and a large stand of the invasive *Phragmites australis* on the upstream side of the culvert. The land is owned by a local non-profit organization, the Annapolis Royal Historic Gardens Society.

Figure 2: Landward view of site showing commercial building to the East and Highway 1 to the North (left); and photo showing the barrier being overtopped during a high tide event (right)

Tidal Analysis

On August 22, 2005, one day after a monthly spring tide, CARP staff conducted a tidal range analysis at the Allain's River site. Measurements were taken approximately every half hour, according to the Parker River methodology (Purinton and Mountain, 1998). The data in Table 2 show that the change in water level on both sides of the culvert differed at most times by more than 10 centimetres and was therefore considered tidally restricted. The high gradient between the two sides was evident due to very turbulent flow, the formation of considerable foam downstream and the creation of a large whirlpool on the upstream side. The culvert was completely submerged for four and a half of the six hours of measurements.

Table 2: Tidal Data Collected During High Tide, Allain's River, August 22, 2005

Upstream			Downstream		
Time (24hr)	Raw Data (m)	Change (m)	Time (24hr)	Raw Data (m)	Change (m)
11:15	4.3	-0.81	11:12	5.51	-1.82
12:14	4.12	-0.63	12:12	3.97	-0.28
12:43	3.35	0.14	12:42	2.96	0.73
13:13	2.74	0.75	13:10	2.14	1.55
13:45	1.55	1.94	13:45	1.55	2.14
14:15	1.27	2.22	14:15	1.27	2.42
14:45	1.42	2.07	14:45	1.42	2.27
15:15	1.87	1.62	15:15	1.87	1.82
15:45	2.24	1.25	15:45	2.45	1.24
16:15	2.42	1.07	16:15	3.08	0.61
17:15	3.2	0.29	17:13	4.52	-0.83
Tidal Range	3.03			4.24	
Range Ratio	0.71				

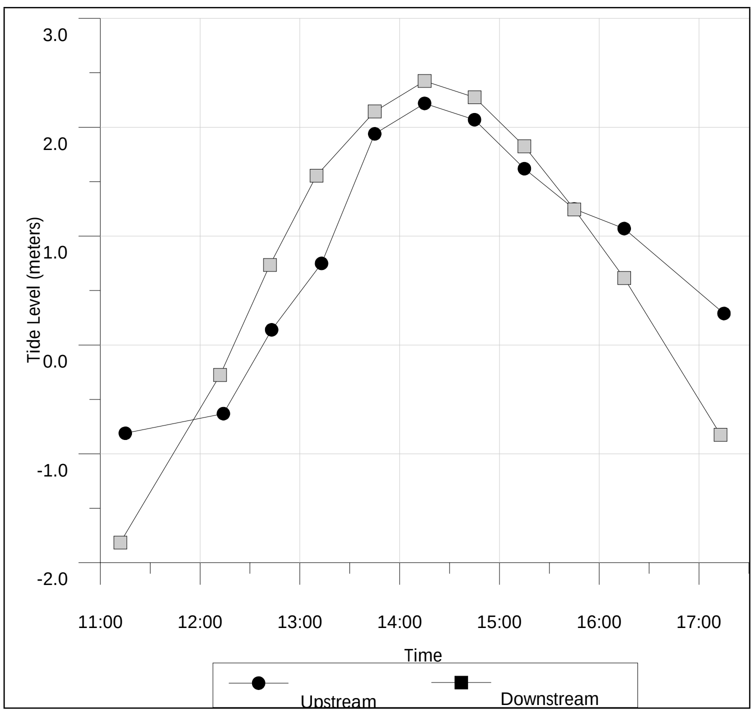

Figure 3: Change in tide levels upstream and downstream of culvert at Allain's River, Annapolis County

Figure 3 provides evidence of a tidal restriction at the Allain's River culvert. This occurs because the culvert is both too small and located too high on the channel bed. As seen on the graph, upon arrival at the site, water was pooling on the upstream side behind the culvert. The change in water level on the upstream side was much slower in the beginning, seen by a gentler slope on the curve, and then increased suddenly (13:15) when the road barrier was overtopped. The change between the two sides was then equal, until the tide dropped below the height of the road. At this point, the undersized culvert once again began holding back water, shown by a decreasing slope on the graph.

Flooding of the road only occurs during very high and spring tides. During neap high tides for example, the road does not flood causing the height differential to exist throughout the entire tidal cylce. The effect of the restriction may therefore actually be greater than that observed at the spring tide, when the water levels on the up and downstream sides equalize for over an hour.

Recommendations

Although the site receives some flooding with every tide, it is clearly restricted. The installation of a larger and better-positioned culvert would allow non-restricted flushing of the upstream marsh. This would reduce the erosion and bank slumping observed on the downstream side and would diminish the spread of the invasive *Phragmites australis* stand on the upstream side. Seeing that the road is currently overtopped during very high tides, flooding of any upstream properties should not be a big concern. When contacted prior to measuring tidal range, landowners expressed no objections with monitoring on their property.

Little Joggins

Site Description

The barrier is a triple concrete culvert beneath the former Dominion Atlantic Railway (DAR) railbed crossing over the Little Joggins in Conway, near Digby. New culverts were installed in the summer of 2004, however their small size restricts tidal flow, as evidenced by two large scour pools and turbulent flow on either side of the barrier. Local citizens use the railbed regularly as a walking trail and an ATV trail to travel to and from either side of the Little Joggins. The upstream side consists of restricted salt marsh (~6ha) that may involve several different landowners and potentially two small tidal creeks further upstream. The downstream side consists of mudflat and poorly developed salt marsh.

Figure 4: The landward view showing large scour pool directly above culverts (left), and a view of the culverts looking downstream (right)

Tidal Analysis

On August 23, 2005, two days after a monthly spring tide, CARP staff conducted a tidal range analysis of the site at Little Joggins. Table 3 shows that the tidal range on the downstream side (4.43m) was higher than the upstream side (3.78m), giving a range ratio of 0.85 for the site. In addition, a difference in water level change greater than 10 centimetres at any given time indicates that the barrier is restrictive. The greatest difference in water level change occurred at the last measurement and showed a difference of over 1m.

Table 3: Tidal Data Collected During High Tide, Little Joggins, August 23, 2005

Upstream			Downstream		
Time (24hr)	Raw Data (m)	Change (m)	Time (24hr)	Raw Data (m)	Change (m)
11:53	7.82	-1.65	11:58	8.08	-2.07
13:00	6.52	-0.35	12:56	6.15	-0.14
13:29	5.88	0.29	13:32	5.06	0.95
14:00	5.28	0.89	13:57	4.42	1.59
14:27	4.81	1.36	14:31	3.79	2.22
15:00	4.32	1.85	14:58	3.65	2.36
15:28	4.04	2.13	15:30	3.79	2.22
16:00	4.04	2.13	15:57	4.11	1.90
16:28	4.29	1.88	16:30	4.7	1.31
17:02	4.74	1.43	16:58	5.32	0.69
17:26	5.16	1.01	17:30	6.09	-0.08
Tidal Range	3.78			4.43	
Range Ratio	0.85				

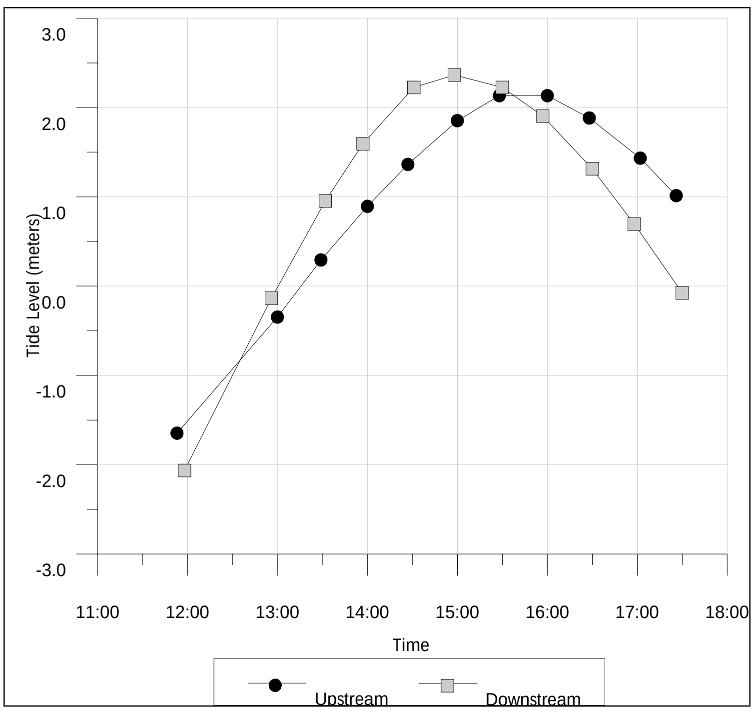

Figure 5: Change in tide levels upstream and downstream of culverts at Little Joggins, Digby County

Figure 5 indicates that the culverts, although allowing some degree of tidal flushing, are insufficient in size for the volume of water at the site. The graph shows that there is a lag of almost 1 hour between the upstream and downstream peak water levels. The difference in tide levels on both sides also confirms that the barrier is restrictive. The culverts were submerged for an hour and a half prior to high tide, after which the upstream water level continued to rise while the downstream water level fell. During the falling tide, multiple large whirlpools could be observed on the upstream side and turbulent flow on the downstream side.

Recommendations

Although the culverts are placed on the bottom of the stream bed, they are of insufficient size to allow unrestricted tidal flushing. The installation of larger culverts or a small bridge would eliminate the time lag between the upstream and downstream peak water levels and restore proper flushing to the upstream marsh. Although the culverts were recently installed, increasing their size would eliminate the strong currents and whirlpools in an area frequented by pedestrians and ATV users.

French Basin Marsh

Site Description

The site (~12ha) is located between the Annapolis Royal Marsh and Highway #1 in Annapolis Royal. The land is currently owned by the Town of Annapolis Royal, and is fallow; however the Town is seeking to sell the property as soon as possible. Directly downstream of the dyke is the Lloyd M. Bourinot Sail Centre, used seasonally as a training centre for sea cadets. The site is located upstream of the Annapolis Royal causeway and Nova Scotia Power's Annapolis Tidal Generating Station. The water levels in the French Basin are controlled by opening and closing sluice gates for power generation and therefore fluctuate less than normal tidal levels downstream of the barrage. Restoration of this site would test the feasibility of salt marsh remediation upstream of the power plant. The drainage structure located at the site is an old aboiteau; however the aboiteau opening is restricted or possibly plugged, resulting in large volumes of water pooling on the upstream side, as seen in Figure 6.

Figure 6: Landward side of dyke showing water pooling behind dyke (left) and photo of drainage structure on downstream side of dyke (right)

Recommendations

Replacing the small drainage structure with a larger culvert or small bridge would restore tidal flushing to the area. A forced sewer main, which runs underneath the dyke, would require additional caution if the site was restored. The freshwater wetland directly to the South of the property is bordered by a walking trail that is very popular among local citizens. Restoring the area to salt marsh would allow both the fresh and salt water marshes to be observed from the trail and would create a unique learning opportunity for local residents and students.

Highway 1, Allain's Creek

Site Description

The site is a large area (~14ha) of fallow land along Highway #1 across from Dugway Road. There is evidence of an old cow pasture, however the area is presently fallow with several trees and shrubs present. The former DAR railbed is completely restricting flooding and an aboiteau is blocking a small tidal creek that runs through the property. The aboiteau has been breached on a number of occasions in the past with several repairs being needed (P.L. Reardon, personal communication, September 22, 2005). The aboiteau structure has been causing significant erosion on the downstream side, where a narrow stripe of salt marsh exists. An old deteriorating dyke separates the two sites (AC33R and AC34R), however it is not currently being maintained. A gradual increase in slope on the landward side of the site would likely protect land behind the property, including homes and a section of the Annapolis Royal Golf Course; however some new dyke may be needed to protect an adjacent hay field. The area is owned by C.H.R. Holdings Ltd, which consists of several members of a local family. Tidal range was not measured at this site, as the aboiteau is completely restricting tidal flow to the upstream side.

Figure 7: Landward view of restorable area (left) and downstream view of aboiteau (right)

Recommendations

Replacing the aboiteau with a large culvert or bridge would allow tidal flow into the creek and restore this large area to salt marsh. The installation of a small bridge at the site would reduce erosion on the upstream and downstream sides and would eliminate the need for frequent and costly repairs to the aboiteau. The land is not currently being used for agricultural purposes nor is there plans to cultivate it in the coming years. If the old dyke that presently separates the two sites (AC33/34R) was reinforced and maintained, no new flood protection structure would be needed to protect the adjacent hay fields. Alternatively, the old dyke could be removed and a new section built on the property boundary, flooding a larger area while still protecting adjacent land.

Restoration Plan of Two Priority Sites

Of the four shortlisted sites described above, two sites were chosen as having priority in future restoration efforts: Highway #1 Allain's Creek and French Basin Marsh. A restoration plan for these priority sites is detailed in the text below, including an initial feasibility study as well as key indicators and reference sites to be monitored and a general timeline for monitoring. The results of preliminary water quality monitoring at the two priority sites are also discussed.

Priority Sites

Mainly due to its large restorable area and potential landowner participation, the site on Highway #1 at Allain's Creek (AC33/34R) was deemed top priority for restoration. Seeing that the land is not currently salt marsh, the ecological benefit of restoring the property may be greater than increasing flushing to a restricted salt marsh. Unfortunately very late in the project, a landowner who had shown previous interest in participating in a future restoration project was forced to withdraw due to conflicting opinions among other co-owners of the property. It was felt however, that this site should still be listed as top priority due to the important benefit restoration could bring and the potential for landowners to change their minds in the future. The site on French Basin Marsh (AC53D), also currently fallow dykeland, was chosen as the second priority site for restoration. This site would test the feasibility of salt marsh restoration above the causeway and tidal generating station at Annapolis Royal, potentially opening the door for restoration to several other areas of fallow dykeland and restricted salt marsh.

Feasibility Study

The initial step in a restoration project would consist of a feasibility study to examine if restoration is technically, physically and biologically possible at the site. A feasibility study would include the following:

1. Digital Elevation Model – In conjunction with the College of Geographic Sciences, prepare a digital elevation model to determine the area to be covered at high tide (spring and neap) as well as at low tide. The model would also determine the volume of water that will flood the restored area.
2. Engineering Study – Measure the surrounding dyke elevations, research drainage from surrounding developed areas and examine what, if any, flood control structures are needed at the site. The engineering study could also determine the size of the opening needed to allow sufficient tidal flow, as well as predict velocity and erosion control measures needed.
3. Biological Assessment – Seek the input from expert biologists to assess if the site will revert back to a functioning salt marsh, as well as estimate the biological value of the restored marsh.
4. Environmental Education Study – Investigate options for environmental education both during and after the restoration, including interpretive signage, guided tours, etc.
5. Landowner/Stakeholder Consultation – Discuss restoration options with all concerned stakeholders, including landowners, relevant municipal, provincial and federal government agencies, as well as other adjacent landowners and local residents of the community.
6. Identification of all municipal, provincial and federal permits and licenses required to carry out restoration activities.
7. Costings – Obtain an estimate of the costings for all restoration work to take place during the implementation phase, including removal of current barrier, installation of new structure, pre- and post-restoration monitoring, etc.
8. Land Ownership – Explore landownership options for properties undergoing restoration, including the transfer of lands to non-profit organizations and conservation easements with conservations organizations such as the Nova Scotia Nature Trust.

Reference Marshes

Once a feasibility study suggests a site is a good candidate for restoration and funding is secured to carry out the work, the pre-restoration monitoring can begin. A comprehensive monitoring program pairs restoration sites with reference marshes, which are both monitored before and after the restoration work. Reference marshes are relatively undisturbed sites, which are similar to the restoration marsh in terms of their physical setting and other variables such as temperature, tidal range, elevation, geomorphology, adjacent land use and water quality (Neckles and Dionne, 1999). The tidal restriction should be the only variable of any significance that differs between the restoration and reference sites. The location and approximate size of reference marshes were recorded during the inventory, including reference salt marsh for the two priority sites. Sites chosen as references were typically of considerable size rather than narrow strips along the coastline. In addition, the sites either had no tidal restrictions or consisted of a section of marsh downstream of a barrier. Finally, the reference sites had no evident point source of pollution that may negatively impact the reference condition.

The four reference sites identified around Annapolis Basin are the following:

1. Allain's River Marsh, Annapolis Royal – This salt marsh is the last remaining salt marsh of any considerable size in the Annapolis Basin. Large areas of the marsh were previously dyked and used for agricultural purposes; however large areas also remain relatively untouched. The entire marsh is approximately 83 hectares and is in close proximity to both priority sites. In fact, the site at Highway 1 Allain's Creek was historically part of the Allain's River marsh system. Years of development, road and railroad building have fragmented the marsh, however, both areas would still be subject to similar physical, chemical, and biological variables.

Figure 8: Reference marsh at Allain's River, Annapolis Royal

2. Dentabella Marsh (eastern end), Granville Beach – Most of Dentabella Marsh is presently agricultural dykeland, however there is a 4-5 hectare section of marsh on the far eastern side, which is below the dyke and is currently unrestricted salt marsh. This portion of marsh could serve as a reference to other sites on Dentabella Marsh, such as AC42D, chosen as one of six potential restoration sites.

Figure 9: Reference marsh on the eastern end of Dentabella Marsh, Granville Beach

3. Stoney Beach Road – The site is approximately 5-6 hectares of unrestricted salt marsh at the end of Stoney Beach Road, in Granville Beach. It lies directly between the two large dyked marshes, Queen Anne Marsh and Dentabella Marsh. The site could serve as a reference in future restoration projects on the eastern tip of Queen Anne Marsh (ie: AC34D) and/or on the western tip of Dentabella Marsh (ie: AC41D).

Figure 10: Reference marsh at Stoney Beach Road, showing remnants of an old dyke in forefront

4. Queen Anne Marsh (western end), Port Royal – Approximately 4-5 hectares on the western tip of Queen Anne Marsh remains unrestricted below a dyke. The site is relatively undisturbed and would be subject to many of the same variables as the site at AC46D, another of the six potential restoration sites.

Figure 11: Reference marsh on the western end of Queen Anne Marsh, Port Royal

Indicators to be Monitored

The monitoring protocols recommended in this report are taken from the Global Programme of Action Coalition for the Gulf of Maine Workshop Report (Neckles and Dionne, 1999) and from the Volunteer's Handbook for Monitoring New England Salt Marshes (Carlisle et al., 2002). Table 4 highlights the ecosystem indicators as well as their respective variables that are recommended for pre- and post- restoration monitoring at the above priority and reference sites.

Table 4: Summary of Recommended Indicators for Salt Marsh Monitoring Plan

Indicator	Variables / Metrics	Monitoring Timeline
Hydrology	Tidal range, tidal signal, surface elevation, surface water quality and salinity	Spring tide event; pre- and post-restoration and every 5 years after restoration
Soils /sediments	Pore Water Salinity	Six measurements from early to mid growing season (April to August); yearly
Soils /sediments	Sediment accretion	Yearly
Vegetation	Abundance, species richness, height and stem density of species of concern	Time of maximum standing biomass (mid-July through August); pre-restoration, year 1 and 2 post-restoration, then every 3-5 years
Fish	Species richness, density, length, biomass	Spring tide event during Spring migrations and in August; pre-restoration and years 1,3 and 5 post-restoration
Birds	Abundance, species richness, feeding/breeding behaviour	20-minute morning observation from specific vantage points at low and high tide; 2 times during breeding season, once per week during migration of waterfowl and shorebirds

The above indicators are considered core variables to be monitored in salt marsh restoration projects in the Gulf of Maine (Neckles and Dionne, 1999). They are the minimum deemed necessary to measure change and track responses to tidal restoration. Additional variables, such as invertebrates, can be added to a monitoring program when sufficient resources and expertise are available. The sampling rational for each indicator is discussed in more detail below.

Hydrology

Both the frequency and duration of salt water flooding greatly influences the functioning of salt marshes. In fact, changes to the hydrology of salt marshes due to dykes, roads, and railroads are among the most common impacts to salt marshes. The duration and frequency of flooding, or hydroperiod, in impacted salt marshes is often reduced leading to changes in natural salinity regimes. Reductions in salinity can cause salt marsh plants to die, allowing opportunistic brackish species, such as *Phragmites australis*, to thrive. A reduced hydroperiod can also lead to a reduction in nutrient transfer between the impacted and reference marsh and may result in the accumulation of nutrients and toxins in the restricted portion of the marsh. By measuring changes in hydrology, monitoring practionners can determine if the restoration site is becoming more similar to reference conditions for the particular area.

Soils and Sediment

Soil salinity is another determining factor which impacts the plant community on a marsh. In order to re-establish salt marshes, salinity regimes in soils must often increase thereby allowing native salt marsh plants to thrive again. Closely monitoring changes in soil salinity provides an important indicator of environmental change as well as the success of the restoration effort.

One of the important natural functions a salt marsh provides is its ability to offset sea-level rise through soil accretion. However, when tidal restrictions reduce the volume of water flooding a marsh, less material is deposited on the surface, thereby reducing the rate of soil accretion. Measuring yearly soil accretion rates offers insight in the marsh's ability to keep pace with sea level rise, which is increasing in some areas due to climate change.

Vegetation

Monitoring vegetation can track the change in both the abundance and composition of salt marsh plants over time. Restoration projects often include the elimination non-native invasive plants and the re-establishment of native species. By also monitoring the plant community at a reference marsh, plant surveys can provide input as to how the restoration area is returning to a more natural or pre-restriction condition.

Fish

As tidal flow is restored to a restricted marsh, the types of fish found in its tidal creeks may change over time. The abundance and diversity of fish can serve as indicators of salt marsh health, and track the changes of the restored area over time. Many types of commercially important fish can be found utilizing salt marshes for food and habitat. Tracking the fish populations can therefore help define the impact of restoration on local and near shore fisheries.

Birds

Monitoring the use of restored salt marshes by birds is a common measure of success in any restoration effort. Oftentimes, knowledgeable volunteers who can readily identify marsh birds are available to participate, which can also increase community participation in the project. Abundance and diversity measures provide direct information on the value of the area to the birds that use it. In addition, birds are highly visible and the monitoring can be done in a relatively short period of time.

Pre-Restoration Baseline Monitoring Results

Pre-restoration baseline monitoring in hydrology was initiated at the two priority sites. In addition to conducting the tidal range analysis at two restricted salt marsh sites, weekly surface water measurements were taken at pre-determined locations on both the Allain's Creek and French Basin Marsh sites during October and November 2005. Due to the late change of opinion of the Allain's Creek property owners, only initial monitoring was possible at that site. The data is included below.

Water quality parameters were measured using CARP's Hydrolab Quanta multi-probe water meter. Sampling was done directly above and below the tidal barrier and then at approximately equidistant points along the tidal creek to determine if a gradient in water quality exists. The parameters monitored included water temperature, specific conductivity, dissolved oxygen, pH, salinity, and dissolved oxygen saturation. Standing from the bank of the tidal creek, the meter was thrown into the water and allowed to fall to the bottom. The meter was allowed to stabilize, approximately 2-3 minutes, before the results were recorded. Measurements were taken at both high and low tide levels. Table 5 shows the UTM coordinates for each sampling location at both sites.

Table 5: Sampling coordinates of two priority sites (UTM Zone 20, WGS84)

Site	Easting	Northing
French Basin Marsh		
AC53-00	301280	4958013
AC53-01	301280	4958013
AC53-02	301218	4957954
AC53-03	301189	4957895
AC53-04	301177	4957825
Highway #1, Allain's Creek		
AC34-00	299782	4956484
AC34-01	299782	4956484
AC34-02	299799	4956412
AC34-03	299902	4956465
AC34-04	299977	4956375
AC34-05	299808	4956342
AC34-06	300031	4956208

French Basin Marsh

The site at French Basin Marsh was visited five times from October 21 to November 21, 2005 for collection of preliminary water quality data. The sites were visited four times during high tide levels from October to November and once at a low tide level in November. The five sampling locations are shown in Figure 12. The site receives little flushing or drainage due to a malfunctioning aboiteau beneath the dyke. The water pools behind the dyke, and the bottom sediment is a black, foul smelling, anoxic mud. Large amounts of thick algae cover the banks of the brook as well as the aboiteau structure. A muskrat was seen swimming in the brook on several occasions. The preliminary water quality data at high and low tide is presented in Tables 6 and 7, respectively.

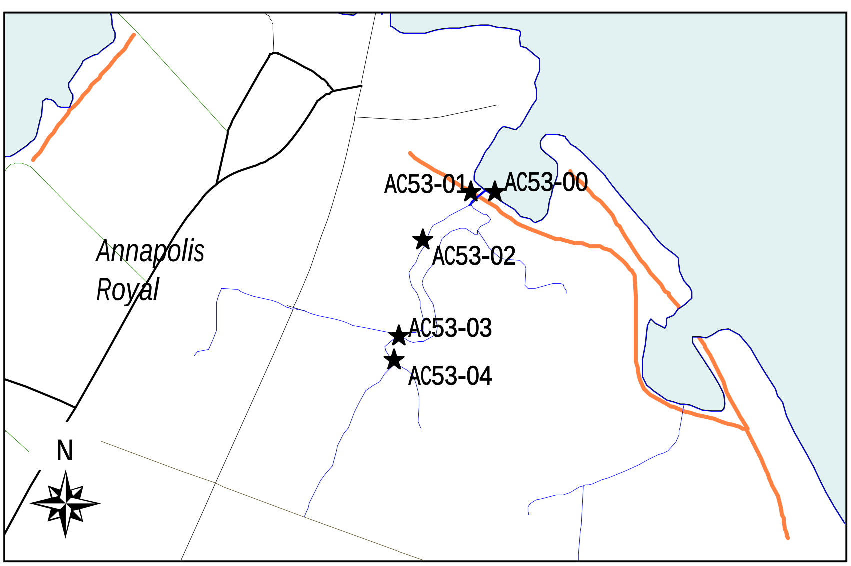

Figure 12: Sampling locations along creek at French Basin Marsh (Scale 1: 8 621)

Table 6: Preliminary water quality data measured during high tide at French Basin Marsh (mean values)

Site	Date	Temperature (C)	Conductivity (mS/cm)	DO (mg/L)	pH	Salinity (PSS)	DOSAT %
AC53-00	October/November	9.43	24.25	8.99	7.06	14.45	87.9
AC53-01	October/November	9.43	5.767	7.93	6.48	3.275	72.4
AC53-02	October/November	8.93	1.108	8.46	6.46	0.543	74.3
AC53-03	October/November	8.79	1.099	8.09	6.41	0.543	70.9
AC53-04	October/November	8.49	0.745	7.02	6.19	0.358	61.4

Table 7: Preliminary water quality data measured during low tide at French Basin Marsh

Site	Date	Temperature (C)	Conductivity (mS/cm)	DO (mg/L)	pH	Salinity (PSS)	DOSAT %
AC53-00	November 21	5.31	7.50	9.92	6.63	4.05	80.7
AC53-01	November 21	6.88	22.7	7.35	6.80	13.34	66.2
AC53-02	November 21	6.41	18.6	7.85	6.76	10.74	68.6
AC53-03	November 21	6.27	16.6	6.81	6.62	9.50	58.9
AC53-04	November 21	4.43	0.773	6.46	5.76	0.37	50.1

The salinity and conductivity data show that there is seepage of salt water on the upstream side of the dyke at high tide. When the site was visited at low tide, the salinity and conductivity were even higher, indicating that the salt water was being trapped on the upstream side of the dyke behind the malfunctioning aboiteau. Dissolved oxygen was generally low at the site, ranging from approximately 61% saturation at the furthest site upstream to 72% directly above the dyke. Sites further upstream had slightly lower pH values as well as lower water temperature.

<u>Highway #1, Allain's Creek</u>

The site at Highway#1, Allain's Creek was visited during high tide on October 21, 2005 for collection of preliminary water quality data. When the landowner withdrew late in project, monitoring at the site was stopped. The six sites that were visited are shown in Figure 13. The data collected is shown in Table 8.

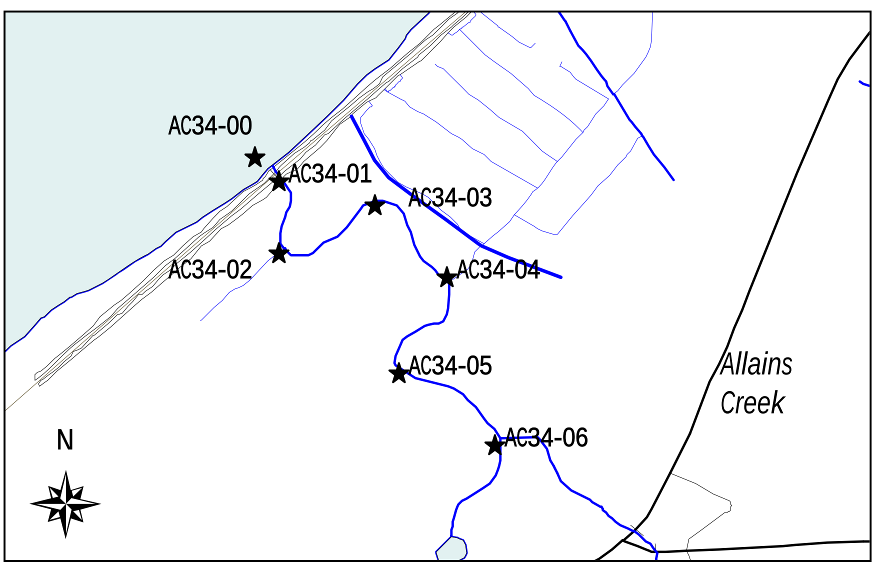

Figure 13: Sampling locations along creek at Highway #1, Allain's Creek (Scale 1: 8 209)

Table 8: Preliminary water quality data measured during high tide at Highway #1, Allain's Creek

Site	Date	Temperature (C)	Conductivity (mS/cm)	DO (mg/L)	pH	Salinity (PSS)	DOSAT %
AC34-00	October 21	10.78	29.50	9.07	7.57	17.86	92.1
AC34-01	October 21	10.53	6.070	8.26	4.75	3.25	75.9
AC34-02	October 21	9.910	0.765	8.21	4.09	0.37	72.8
AC34-03	October 21	10.11	0.717	9.05	4.09	0.34	80.6
AC34-04	October 21	10.06	0.874	8.54	3.84	0.42	76.0
AC34-05	October 21	9.960	0.188	9.88	6.14	0.09	87.5
AC34-06	October 21	10.10	0.153	9.53	6.17	0.07	84.7

Salinity and conductivity values suggest that some salt water is seeping on the upstream side of the dyke. A slight gradient exists along the length of the brook, with upstream sites having increasingly lower salinity concentrations. A pH value of 3.20 was recorded from the small brook draining from an adjacent field. The input of acidic water is lowering pH values from sites AC34-01 to AC34-04. The two sites on the upstream side of the small tributary recorded higher pH values. The dissolved oxygen content varies along the brook, ranging from approximately 73% saturation on the downstream end to 87.5% on the upstream end. Additional monitoring is required at the site to determine if these values are consistent over time.

Conclusions

The combined effects of the many salt marsh tidal barriers have a considerable influence on the health of the Annapolis Basin and greater Bay of Fundy. Centuries of dyking and road building have fragmented previously extensive salt marshes, affecting their ability to cleanse water, support a wide variety of flora and fauna and protect our shorelines from erosion and storm surge.

The Annapolis Watershed Salt Marsh Evaluation Project identified several potential salt marsh restoration sites. Many areas, such as the section on Allain's River Marsh in Annapolis Royal and the Little Joggins near Digby, are tidally restricted by poorly sized and/or improperly placed culverts. Fortunately, many restoration options such as the removal of the culvert and placement of a larger culvert or small bridge can restore proper tidal flushing and therefore important biological functions to the area. Sites such as French Basin Marsh and the section of Allain's River Marsh in Allain's Creek require the removal of dyke or aboiteau to restore tidal flushing.

A detailed restoration plan was developed for two shortlisted priority sites at French Basin Marsh and Allain's River Marsh. The plan includes the steps required for conducting a feasibility study as well as the physical, biological, and chemical indicators and variables that should be monitored both before and after restoration. Relatively unimpacted reference sites for the monitoring plan were also identified in the inventory. Preliminary water quality monitoring was initiated at the two priority sites. Parameters monitored included water temperature, conductivity, pH, dissolved oxygen, salinity, and dissolved oxygen saturation. All the information collected will serve as a baseline for future salt marsh restoration efforts.

References

Bay of Fundy Ecosystem Partnership (BoFEP). 2000. Salt Marsh Saga: Conserving Fundy's Marine Meadows. In: *Fundy Issues*. #16, Cornwallis, Nova Scotia.

Bowron, T.M. and A. Fitzpatrick. 2001. Assessment of Tidal Restrictions Along Hants County's Highway 215: Opportunities and Recommendations for Salt Marsh Restoration. Ecology Action Centre Marine Issues Committee, Halifax, Nova Scotia.

Bowron, T.M., J. Graham, and M. Butler. 1999. Community Considerations in Salt Marsh Restoration Work in Nova Scotia. Ecology Action Centre Marine Issues Committee, Halifax, Nova Scotia.

Carlisle, B.K., A.M. Donovan, A.L. Hicks, V.S. Kooken, J.P. Smith, and A.R. Wilbur. 2002. A Volunteer's Handbook for Monitoring New England Salt Marshes. Massachusetts Office of Coastal Zone Management, Boston, Massachusetts.

Hatcher, A., D.G. Patriquin, Y.F. Fern, A.J. Hanson, and J. Reade. 1981. Salt Marshes in Nova Scotia. A Status Report of the Salt Marsh Working Group. Institute for Resource and Environmental Studies and Department of Biology, Dalhousie University, Halifax, Nova Scotia.

Neckles, H. and M. Dionne. 1999. Regional Standards to Identify and Evaluate Tidal Wetland Restoration in the Gulf of Maine. A Global Programme of Action Coalition for the Gulf of Maine Workshop Report. The Wells National Estuarine Research Reserve, Wells, Maine.

Purinton, T.A. and D.C. Mountain. 1998. Tidal Crossing Handbook: A Volunteer Guide to Assessing Tidal Restrictions. Parker River Clean Water Association, Byfield, Massachusetts.

Appendices

Appendix A – Approximate Locations of Tidal Barriers (Culverts and Aboiteaux) in Annapolis Basin

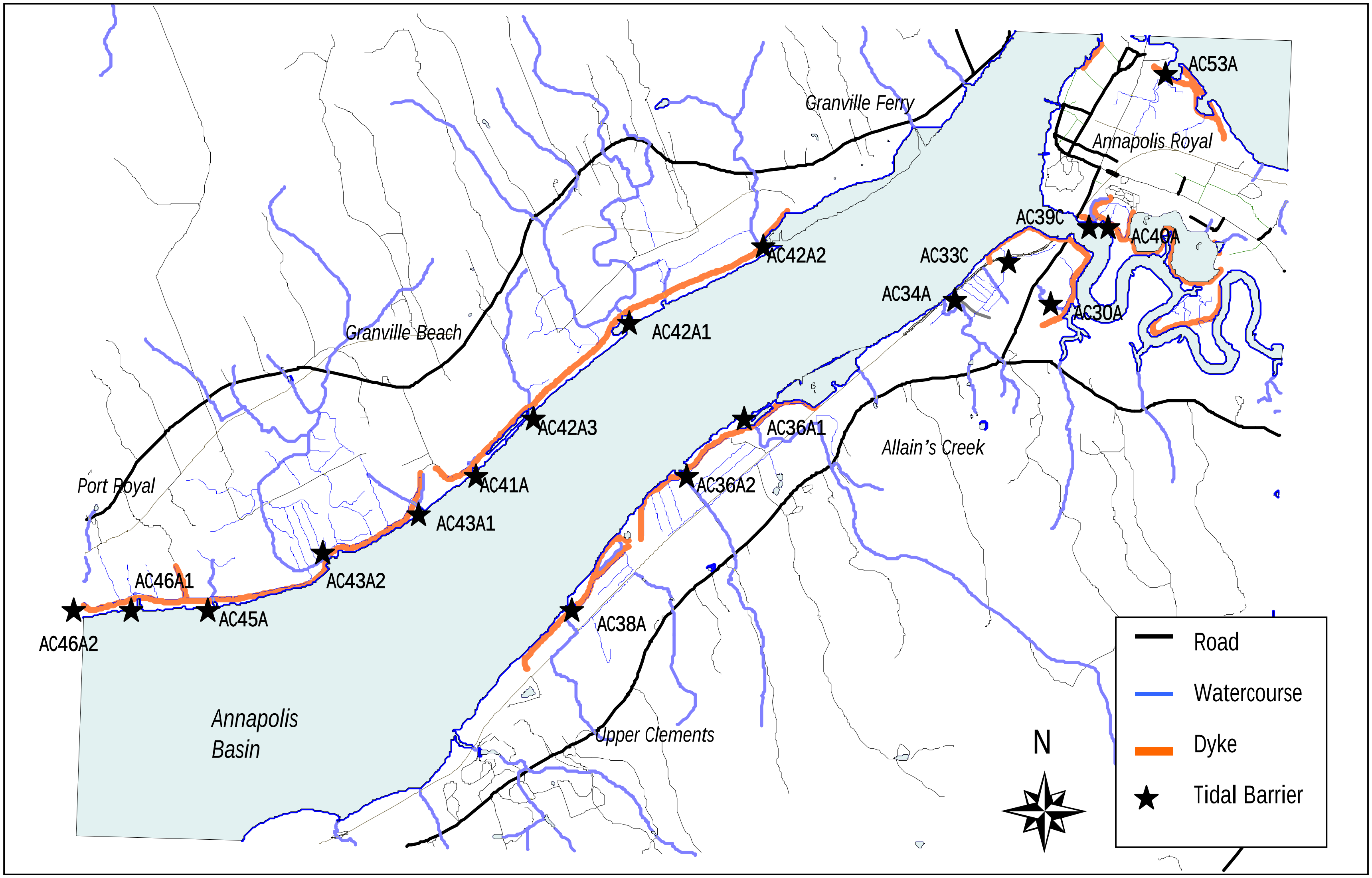

Figure A1: Approximate locations of tidal barriers in Annapolis County (Scale 1: 39 286)

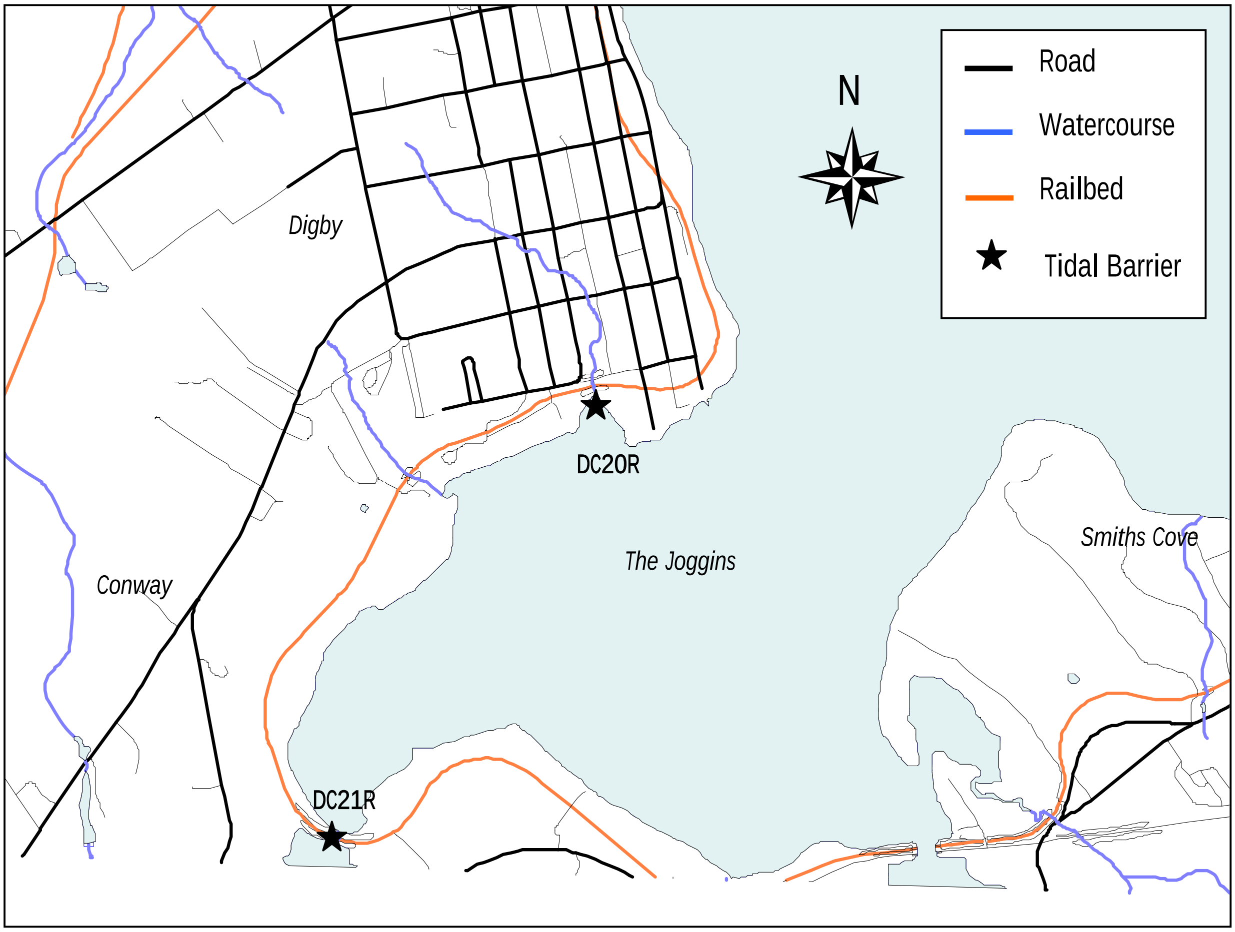

Figure A2: Approximate location of tidal barriers in Digby County (Scale 1: 23 611)

Appendix B — Summary of Aboiteau and Culvert Structures

Barrier Code	Classification	Total/Partial Restriction	Condition of Barrier*	Coordinates (UTM Zone 20, WGS84)
AC30A	Aboiteau	Total	Good	4956409N 300587E
AC33C	Culvert	Partial	Poor	4956762N 300191E
AC34A	Aboiteau	Total	Excellent	4956454N 299764E
AC36A1	Aboiteau	Total	Excellent	4955650N 298505E
AC36A2	Aboiteau	Total	Excellent	4955301N 298035E
AC38A	Aboiteau	Total	Excellent	4954428N 297326E
AC39C	Culvert	Partial	Fair	4957042N 300787E
AC40A	Aboiteau	Total	Excellent	4957045N 300829E
AC41A	Aboiteau	Total	Good	4955374N 296644E
AC42A1	Aboiteau	Total	Excellent	4956349N 297602E
AC42A2	Aboiteau	Total	Excellent	4956875N 298580E
AC42A3	Aboiteau	Total	Good	4955776N 297031E
AC43A1	Aboiteau	Total	Excellent	4955116N 296261E
AC43A2	Aboiteau	Total	Good	4954730N 295654E
AC45A	Aboiteau	Total	Good	4954526N 294907E
AC46A1	Aboiteau	Total	Good	4954527N 294389E
AC46A2	Aboiteau	Total	Fair	4954471N 294022E
AC53A	Aboiteau	Total	Good	4957674N 301073E
DC20C	Culvert	Partial	Good	4943684N 281288E
DC21C	Culvert	Partial	Excellent	4942318N 280509E

*Condition of barrier: Excellent, Good, Fair, Poor, Need of Immediate Repair

Appendix C – Data Sheet Templates

Tidal Barriers Audit Data Sheet: Dykes

The priority for assessment is for dykes no longer maintained by the Deapartment of Agriculture and Fisheries.

Name: ______________________Date:____________________Time:__________

Weather: [Check Environment Canada Website]:______________________________
Wind Velocity and Direction:______________________________
Rain [circle one]: Heavy Moderate Light None

Tide Conditions [height and time as recorded in tide table, adjusted for area]:
High Tide [m]:____________________ Low Tide [m]:____________________
Mean High Tide for Area [m]:____________________

Dyke Code/Location:______________________________ NSDAF Dyke [circle]: Yes / No

Elevation[m]:__________Length[m]:__________Width at base[m]:__________

Original purpose of dyke: ______________________________
____

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

Adjacent land use [circle]: Commercial; Agricultural; Residential; Other______________

Breaches, weak points [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		
Phramites		
Other		

Photographic record checklist:
Aerial photo of area________
Breaches/weak points________
Barrier________
Landward________
Seaward________

Potential for restoration:____
____
____

Contacts with respect to this dyke:____

Tidal channels blocked by dyke:

Name______________________________________ Aboiteau Code:______________________
GPS Coordinates:_________________________ ___________________________
Photos: Land upstream_____ Downstream_____Aboiteau Upstream_____Downstream____Other________

Degree of restriction: Total______ Partial______

Condition of aboiteau [circle one]: Excellent; Good; Fair; Poor; Need of Immediate Repair
Comments:____

Name______________________________________ Aboiteau Code:______________________
GPS Coordinates:_________________________ ___________________________
Photos: Land upstream_____ Downstream_____Aboiteau Upstream_____Downstream____Other________

Degree of restriction: Total______ Partial______

Condition of aboiteau [circle one]: Excellent; Good; Fair; Poor; Need of Immediate Repair
Comments:____

Name______________________________________ Aboiteau Code:______________________
GPS Coordinates:_________________________ ___________________________
Photos: Land upstream_____ downstream_____Aboiteau upstream_____downstream____Other________

Degree of restriction: Total______ Partial______

Condition of aboiteau [circle one]: Excellent; Good; Fair; Poor; Need of Immediate Repair
Comments:____

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		

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

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				

Appendix D — Spreadsheet Template

	A	B	C	D	E	F
1	Upstream			Downstream		
2	Time (24hr)	Raw Data (m)	Change (m)	Time (24hr)	Raw Data (m)	Change (m)
3			-(B3-B18) + AVERAGE(B3:B13)			-(E3-B18) + AVERAGE(E3:E13)
4			-(B4-B18) + AVERAGE(B3:B13)			-(E4-B18) + AVERAGE(E3:E13)
5			-(B5-B18) + AVERAGE(B3:B13)			-(E5-B18) + AVERAGE(E3:E13)
6			-(B6-B18) + AVERAGE(B3:B13)			-(E6-B18) + AVERAGE(E3:E13)
7			-(B7-B18) + AVERAGE(B3:B13)			-(E7-B18) + AVERAGE(E3:E13)
8			-(B8-B18) + AVERAGE(B3:B13)			-(E8-B18) + AVERAGE(E3:E13)
9			-(B9-B18) + AVERAGE(B3:B13)			-(E9-B18) + AVERAGE(E3:E13)
10			-(B10-B18) + AVERAGE(B3:B13)			-(E10-B18) + AVERAGE(E3:E13)
11			-(B11-B18) + AVERAGE(B3:B13)			-(E11-B18) + AVERAGE(E3:E13)
12			-(B12-B18) + AVERAGE(B3:B13)			-(E12-B18) + AVERAGE(E3:E13)
13			-(B13-B18) + AVERAGE(B3:B13)			-(E13-B18) + AVERAGE(E3:E13)
14	Tidal Range	MAX(B3:B13)-MIN(B3:B13)			MAX(E3:E13)-MIN(E3:E13)	
15	Range Ratio	+ B14/E14				
16						
17						
18	Tripod Height:	(m)				