Petitcodiac River Causeway project

Stage 2 Follow-up Program
Year 1 Results

Executive Summary

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1.0 INTRODUCTION

1.1 PURPOSE

This document is a summary of the results of Year 1 of the Stage 2 Follow-up Program (S2FUP) for the Petitcodiac Causeway Project (the “Project”). Year 1 results are compared to baseline conditions established during the Stage 1 Follow-up Program (AMEC 2010a) with respect to predictions and conclusions contained in the Environmental Impact Assessment (EIA) and the effectiveness of mitigation measures undertaken in Stage 1. The predictions and conclusions contained in the EIA are generally focused on conditions that will be present following completion of Project Option 4B; therefore it is not possible to verify these during Stage 2 of this three stage Project. This document focuses on how the environmental effects observed during Year 1 of Stage 2 are trending as compared to the EIA predictions and conclusions specific to Stage 3 and beyond. The document focuses on the findings and conclusions relevant to the six Valued Ecosystem Components (VECs). For a comprehensive description of background and methods the reader is encouraged to refer to the main report.

1.2 FOLLOW-UP PROGRAM OBJECTIVES

The S2FUP objectives are to:

- Examine trends in environmental conditions for selected VECs to determine how environmental conditions are trending in regards to the environmental effects predictions in the EIA.
- Verify the effectiveness of measures to protect physical works installed during Stage 1.
- Provide an early indication of any unexpected change in environmental conditions.
- Improve understanding of environmental cause and effect relationships.

1.3 SCOPE

The S2FUP comprises six VECs:

- Physical Characteristics of the Petitcodiac River and Estuary
- Tourism
- Commercial Fisheries
- Archaeology
- Public Health and Safety
- Engineered Environmental Protection Works

1.4 REGULATORY CONTEXT

The EIA required a Follow-up Program that would satisfy the objectives presented above. The S2FUP is a key component of the Environmental Management Plan (EMP) (AMEC 2008a), and is required as per Condition of EIA Approval (4). The Follow-up Program is divided into stages that correspond with the Implementation Plan, as per Condition of EIA Approval (5), and has been and will continue to be
submitted to the New Brunswick Department of Environment (NBENV) for review and approval when required. The Follow-up Program is also required under the Canadian Environmental Assessment Act (CEAA) as a condition of the CEAA Screening undertaken by Fisheries and Oceans Canada (DFO). A Technical Review Committee (TRC), comprised of federal and provincial agency and department representatives, presided over the EIA process. The TRC was co-chaired by NBENV, and DFO acting as the federal lead Responsible Authority. A similar TRC, chaired solely by NBENV with input from DFO, was assembled to preside over the implementation of the Project.

2.0 PHYSICAL CHARACTERISTICS

2.1 OBJECTIVES

The objective of this component is to monitor and measure changes to the Petitcodiac River (hereinafter River), the Petitcodiac Estuary (Estuary), and the Upper Bay of Fundy after gate opening in order to understand effects on width, depth, and other physical characteristics as compared to baseline conditions.

2.2 RESULTS

2.2.1 Sediment Movement

The visible sediment plume, at low tide, emanating from the mouth of the River into the Upper Bay of Fundy in Stage 2 appears to be the same if not smaller than the plume in Stage 1. These observations support the EIA predictions in that accumulated sediment in the River is not likely transported over a larger area in the Upper Bay of Fundy. The visible surface water plume contains the finer fraction of transported sediments which would delineate the maximum possible extent of transported sediment. The heavier and larger fraction of sediment will likely be transported over a shorter distance and closer to the mouth of the River.

2.2.2 Cross-sections

All references to “right” or “left” are taken as looking upstream.

2.2.2.1 Upstream of the Causeway

- **At km 1.0**, the channel near the left bank changed rapidly after gate opening, where the bed elevation has increased by about 1.5 metres (m) by June 1, 2010. Major deposition has taken place to the right side where about 1 to 2 m of deposition seems to have occurred by September 9, 2010.
- **At km 5.9** (just downstream of the confluence of Turtle Creek), a maximum deposition in the order of 1 to 2 m was measured on September 9, 2010. On November 24, 2010 deposition continued to occur on the left bank, while most of the silts deposited in the main channel had eroded to near pre-gate opening condition. A relatively well defined low flow channel having a width in the order of 100 m has developed on the right bank.
- **At km 14.9 km**, deposition has taken place over the entire section with a maximum deposition of 2 to 3 m recorded on September 9, 2010. On November 24, 2010 approximately one-half of
the sediment deposition observed on September 9 had eroded, resulting in an average bed level 1 to 1.5 m higher than the pre-gate opening level.

### 2.2.2.2 Downstream of the Causeway

- **At km 0.9** (about halfway between the causeway and Gunningsville Bridge), the bed elevation experiences a large seasonal change in this portion of the estuary. Prior to gate opening the thalweg could vary as much as 8 m during a year. Between November 18, 2009 and November 8, 2010, it is estimated that the bed has lowered about 3 m. The channel has widened about 8 m at elevation 2.0 m. All of the widening has taken place on the right bank (looking upstream).
- **At km 5.1** (just downstream of the confluence of Halls Creek), over the period of November 18, 2009 to November 8, 2010, the bed of the channel has eroded about 4 m over much of the width of the channel. The channel has not widened appreciably.
- **At km 7.6** (Chartersville area), the cross-section exhibits some of the greatest changes along the reach to Hopewell Cape. The channel deepened by about 6 m between November 18, 2009 and November 8, 2010. The typical erosion along the channel bed was about 1.5 to 2.0 m. The deepest portion of the channel has moved about 150 metres toward the left side. The left bank of the channel has moved to the left by about 40 m at elevation 2.0 m.
- **At km 21.1** (about 4 km upstream of Stoney Creek), the bed has been eroded about 2 m for much of the width of the cross-section between November 18, 2009 and November 8, 2010. On the September 8, 2010 survey, the erosion of the bed exceeded that of the November 18, 2009 survey by about 2 m. The width of this local scour was about 50 m (12% of the channel width). The channel is moving laterally into the left bank. The change over the period November 18, 2009 to November 8, 2010 at elevation 2.0 m is about 15 m (3.5% of the channel width).
- **At km 37.3** (Hopewell Cape), there is appreciable deposition over November 18, 2009 to November 8, 2010. The annual deposition is about 1 to 2 m over the right half of the section and the annual erosion was about 0.5 to 1 m over the left quarter of the section. A mid-channel bar may be forming at this section. It appears that the transition from dominant erosion to dominant deposition occurs about 5 km upstream.

### 2.2.2.3 Upper Bay of Fundy

- **At km 39.2** (Calhoun Flats), most of the change between November 3, 2009 to December 1, 2010 occurred near the left bank where a deposition of about 1 m occurred over a length of about 350 m.
- **At km 42.8** (Grand Anse), between November 3, 2009 and December 1, 2010, the bed level in the “middle ground” (as referenced on pre-1967 charts) has risen about 0.5 to 1 m over a width of about 2000 m. This is attributed to the erosion of sediment from the estuary upstream of Hopewell Cape.
- **At km 74.9** (Cape Enrage), virtually no change was noted except for the evidence of the movement of large dunes on the New Brunswick side.
- **At km 85.2** (Alma), virtually no change has occurred except for a minor change on the Nova Scotia side. The source of the sediment is most likely not associated with gate opening.

### 2.2.3 Thalweg Profiles

The thalweg profile represents the lowest elevations along the length of the estuary and provides a means of assessing areas where water may pond during periods of low tide and low flow from the land.
**Estuary:** Downstream of the causeway, the thalweg elevation has dropped from about 1 to 3 m in the first 28 km, and has risen about 1 to 2 m from km 32 to 37.3. Between May 21, 2009 and September 8, 2010, the maximum decrease in thalweg elevation was about 1.6 m at km 21. Upstream of the causeway to Salisbury, the maximum increase in thalweg elevation was about 2.6 m at km 12. Very little change in the thalweg elevation has occurred at Hopewell Cape.

**“Mud Plug”:** The “mud plug” was formed during periods when the gates were temporarily opened in the past (1988) and when there was upstream flow through the fishway and the gates. Between gate opening and June 1, 2010 the thalweg along the primary flow path through the “mud plug” decreased by up to 2.8 m. On June 1, 2010 a high point in the channel elevation (a “knick point”) was evident at a location about 750 m upstream of the control structure.

**Scour Hole:** Since the control structure was designed for flow in the downstream direction only, no extended apron was placed on the upstream side. A short concrete slab extends 8.7 m upstream of the location of the bridge deck. Rough estimates of maximum scour hole depth ranged from 5.4 m to 11.5 m with an average of 8.7 m. The maximum depth of the scour hole was 5.4 m on December 22, 2010. Any additional scour in the future at this site should be relatively small.

2.2.4 **Bottom Sediment Samples**

Generally bottom samples collected in Stage 2 were consistent in nature with those obtained during Stage 1. The material recovered was predominately silt and/or sand with varying amounts of clay and gravel sized particles present.

2.2.5 **Suspended Sediment Sampling and Current Profiling at the Gunningsville Bridge in the Petitcodiac River Estuary**

**Sub-surface Current Velocities:** Sub-surface current velocities for both spring and late summer events that occurred between May 7, 2009 and April 29, 2010, and September 21, 2009 and September 10, 2010 were compared. The current velocities in the upstream direction have similar magnitudes suggesting that they are mainly controlled by the tide; however, a small increase in upstream water velocities was measured after gate opening. In the downstream direction, current velocities increased significantly after gate opening, especially during the ebbing tide. In general, velocities in both upstream and downstream directions were sustained for longer periods of time after gate opening, confirming EIA predictions of more dynamic conditions.

**Total Suspended Solid (TSS) Measurements:** TSS concentrations normally increased during the arrival of the tidal bore and during ebbing tide for all events, which is a direct consequence of an increase in current velocities. TSS concentrations were also higher during Stage 1 when compared to Stage 2 and presented smaller peaks and lower magnitudes during the tidal cycles; likely due to an increase in water volumes after gate opening. TSS concentrations to date in Stage 2 have decreased when compared to Stage 1 and earlier. In addition, maximum TSS concentrations have decreased when compared to Stage 1.

**Suspended Sediment Transport:** A comparison of suspended sediment loads for periods May 7, 2009; April 29, 2010; September 21, 2009; and September 10, 2010 show that suspended sediment...
movement is larger in Stage 2. This is in agreement with the increase in current velocities in the channel. The suspended sediment loads for all available events were calculated and sediment transport estimates indicate that during Stage 1 the net sediment flux was negative (in the upstream direction) with a depositional effect in the upstream regions of the Gunningsville Bridge. However, for the first year of Stage 2 the sediment flux was positive (in the downstream direction). These observations are in agreement with the EIA predictions.

**Suspended Sediment Samples in the Upper Bay of Fundy:** TSS concentrations in the Upper Bay of Fundy during Stage 2 appear consistent with those observed during Stage 1, and are likely most influenced by tide, wind and wave conditions.

### 2.2.6 Ground-level Observations

No discernable changes in the shoreline at the lower portions of the estuary were noted. Flow from the land in the small creeks flowing into the River appear unaffected by gate opening, and the silt build up in the mouth of Halls Creek and Jonathan Creek was less than was observed seasonally, due to the deepening of the River bottom in these areas. No appreciable silt build up was observed on the Hopewell Cape beach. Widening of the River immediately downstream of the causeway in the Moncton and Dieppe area occurred quite rapidly in the weeks and months following gate opening. While widening of the River is ongoing as evidenced by the sloughing vegetation along the riverbanks, it appears that the rate of widening had decreased by the fall of 2010.

Upstream of the causeway rapid mud deposition has occurred, most evident by the increase in elevation of the mudflats from an average 3.5 m (prior to gate opening) to about 6 meters by the spring of 2011. As a result lower tides no longer cover the mudflats. By the fall of 2010 a well-defined channel was present through the lower portion of the mud plug. Mud deposition was also observed in the estuary at the near head of tide at the former railway bridge in Salisbury in September 2010; however most of this mud was eroded by December 2010 in response to high flows from the land.

During the winter and spring months, particular attention was paid to the build-up of both shorefast ice and sheet ice which has the potential to damage the causeway gates or jam the opening in the control structure. Shorefast ice did build up to levels comparable to past years in both the River and its tributaries, but the typical number of large ice cakes either on the adjacent marshes or more importantly in the River were not observed.

### 2.2.7 Water Levels

**Associated with the Gate Opening:** The tidal influence became dominant on the first tidal cycle after gate opening. Tidal influence extends all the way to Salisbury. The low water elevation at Turtle Creek evened off at about 3.5 m after the first tidal cycle. The water level during low tide just upstream of the causeway was about 1.0 m. This difference in low tide water elevation is associated with the “mud plug” and to some extent by the deposition of sediment in Turtle Creek between the gauge and the confluence with the River.

**Associated with High Flow from the Land:** During a major rainfall event over the period of November 5 to November 8, 2010 the runoff intensity was greatest from the north flowing sub-basins.
The peak elevation of the River at Salisbury on November 8, 2010 was about 1.0 m higher than the peak water elevation at Turtle Creek. The high flows from the land are also evident at the Gunningsville Bridge where the low water elevation is about 2 m higher than the low water elevation during periods of low flow from the land. The rough estimate of the peak flow at the railway bridge (Salisbury) is 550 m$^3$/s for an estimated drainage area of 968 km$^2$. The approximate average return period for this event is in the order of 1:10 to 1:20 years. Just before the rainfall event, the high tide water elevation at Gunningsville Bridge was about equal to that at the Turtle Creek gauge for a high tide of 5.0 m and about 0.5 m higher than that at Turtle Creek for a high tide of 6.5 m. During the rainfall event the high tide elevation at Gunningsville Bridge was in the order of 0.2 m lower than that at Turtle Creek.

**At Turtle Creek:** The low water elevation at Turtle Creek tended to increase during periods of low flow from the land in the summer in response to sedimentation associated with the sediment laden tidal water in the River and in the 1.35 km reach along Turtle Creek between the gauge and the River. Following periods of high flows from the land, (November 2010), the levels declined slightly indicating that some erosion had taken place downstream of the gauge.

**Difference Between Gunningsville Bridge and Turtle Creek:** As more sediment became deposited in the former headpond the storage available for tidal water decreased during each tidal cycle. The difference in high-tide elevations has decreased by about 0.45 m for any high-tide elevation at the Gunningsville Bridge.

2.2.8 *Sediment Deposition, Erosion and Net Accumulation*

The following estimates are provided for changes in volume during the monitoring period:

- **Upstream of the Causeway** - Between May 21, 2009 and September 8, 2010 a total of 4.8 million m$^3$ was deposited after gate opening. Approximately 1.4 million m$^3$ eroded out by November 24, 2010 in response to high flows from the land, resulting in a net infilling of approximately 3.4 million m$^3$.

- **Causeway to Hopewell Cape** - Between November 18, 2009 and November 8, 2010 a net erosion of approximately 19.3 million m$^3$ has occurred in this reach. The most active widening of the River seems to be from Dieppe to Saint Anselme.

- **Shepody Bay** – Prior to gate opening substantial seasonal changes were occurring in the area between Hopewell Cape and Daniels Flats, with deposition occurring on the Calhoun Flats and the northern portion of the Daniels Flats, as well as in the area offshore known as the middle ground. Virtually no changes are seen below Daniels Flats either before or after gate opening. Between May 13, 2009 and November 5, 2009, before gate opening, a net deposition of 49 million m$^3$ occurred as opposed to a net deposition of 51 million m$^3$ between May 27-28, 2010 and October 24-25, 2010, after gate opening. Between October 24-25, 2010 and December 1–2, 2010 a net erosion of 38 million m$^3$ had occurred resulting in a net deposition of approximately 13 million m$^3$ between May 27-28, 2010 and December 1-2, 2010.

2.2.9 *Estuary Volume and Tidal Prism*

Upon gate opening the tidal prism or volume of water coinciding with the elevation of the vegetated mudflats and the low tide elevation, was increased immediately by about 20.4 million m$^3$ or about an 8% increase from the 2002 value. This has decreased over 2011 to about 17.6 million m$^3$ due to
channel narrowing and mudflat build-up upstream of the causeway. At the same time the tidal prism downstream of the causeway has increased by an estimated 11.8 million m³ and the total volume by 19.8 million m³.

Thus the increase on the total tidal prism in the estuary since 2002 is about 29.4 million m³ or 11.5% greater than in 2002. The rate of erosion is in the order of 3.5 to 6 times that was predicted in the EIA, but the total increase in tidal prism is still well below what was predicted to eventually occur.

3.0 TOURISM

3.1 OBJECTIVES

The objective of this component is to estimate the environmental effects of the Project on tourism.

3.2 RESULTS

The following observations summarize the overall results of the year 1 S2FUP survey:

- an average of 37 people visited Boreview Park each day;
- the average visitor group size was 2.7 persons per group;
- most visitors (74%) to Boreview Park were from outside of the Province;
- most visitors (80%) in 2010 of Stage 2 were at Boreview Park to view the tidal bore;
- most visitors (82%) in 2010 of Stage 2 indicated that they would return to Boreview Park to view the tidal bore; and
- most visitors (96%) said that they would recommend visiting Boreview Park to view the tidal bore to others.

The preliminary results indicate that visitation to Boreview Park to view the tidal bore has increased. The tidal bore has become more of a tourism attraction to visitors from outside of the Province, as well as within the GMA, which would appear to be largely the result of the enhanced interest generated by the gate opening, and the possibility that the tidal bore is increasing in size. These results are consistent with the EIA predictions.

4.0 COMMERCIAL FISHERIES

4.1 OBJECTIVES

The objective of this component is to determine how the Project affects commercial fisheries landings; specifically lobster and scallop in the Upper Bay of Fundy, and American eel within the River and Estuary.
4.2 RESULTS

4.2.1 Total Suspended Solids

The TSS data for Stage 2 show a similar trend to Stage 1 with respect to flooding tides appearing to have higher TSS concentrations compared to ebbing tides. In addition, no discernible differences can be noted in the TSS concentration between Stage 1 and Stage 2 for any of the three zones.

TSS concentration is generally higher in many areas of the Upper Bay of Fundy during the flooding tide compared to an ebbing tide. In addition, the TSS in the Exposure Zone 1 that would receive the plume from the River does not appear to have higher TSS values in Stage 2 when compared to Stage 1.

4.2.2 Sediment in Lobster Traps

Of the 20,794 traps examined during the 2010 commercial and out of season monitoring program, 25 traps contained sediment deposits substantial enough to be visually identified.

4.2.3 Sediment Plume Delineation

The satellite images processed for Stage 2 and delineation of the areas for the various relative classes of suspended sediment concentrations were compared graphically and arithmetically to the satellite data obtained during Stage 1. Multiple processed MERIS satellite images were obtained from DFO’s OPTICs project at the Bedford Institute of Oceanography (G. Bugden, pers. comm. 2010). These images illustrate the sediment plume delineation over an area encompassing the current Project’s area of interest as well as further out into the Bay of Fundy. Using a European Space Agency geophysical product specific to the quantification of total suspended matter (TSM), the DFO-supplied MERIS images illustrated a quantitative sediment plume delineation technique that was applied to images throughout the tidal cycle and not only at low tide.

From the SPOT and Landsat image classifications, comparisons were made between the spring images for Stage 1 and Stage 2. The high tide image of 1984 compared to the low tide images generally resulted in a greater area in the moderate to higher suspended sediment range at high tide, with a decrease in the mudflat area which is anticipated because the majority of the mudflats would be covered by the tide. There is no appreciable difference between the average low tide suspended sediment summaries for Stage 1 and Stage 2.

A comparison of low tide Stage 1 and Stage 2 image classifications reveals slightly elevated suspended sediment concentrations for Stage 2. The average area for each of the four major mudflats in Shepody Bay have not changed considerably between the Stage 1 and Stage 2 monitoring periods.

4.2.3.1 Comparison to Stage 1 Baseline Conditions

A summary comparison of Stage 2 sedimentation results with Stage 1 baseline conditions, and on the basis of total suspended sediment, location and presence of sediment in lobster traps, and plume delineation from satellite data, sedimentation in the Upper Bay of Fundy does not appear to be greater in Stage 2 and after gate opening. Sedimentation appears to be similar with respect to the spatial
extent of the River sediment plume and location of sediment in lobster traps, and even maybe less in Stage 2 when compared to Stage 1 for the concentration of total suspended sediment in the surface water. These observations on sedimentation support the EIA predictions in that accumulated sediment in the River is not likely transported over a larger area in the Upper Bay of Fundy.

4.2.4 Lobster

4.2.4.1 Existing Conditions in 2010-2011

The lobster monitoring program for Stage 2 (conducted in 2010 and continuing in 2011) is considered important due to the potential number of affected parties and the financial value of the fishery. An extensive commercial, out-of-season and juvenile lobster trapping program was conducted during Stage 2 in 2010. During the commercial season, data were collected from 13,924 commercial trap-hauls, and from 4,256 juvenile trap-hauls. During the out-of-season program in 2010, 1,758 commercial and 856 juvenile trap-hauls were monitored.

4.2.4.2 Comparison to Stage 1 for Lobster Existing Conditions

Landings in Lobster Fishing Area 35 of the Bay of Fundy have been increasing since the mid-1990s, with an even sharper increase in the last three years. The results of the 2010 Stage 2 monitoring program (Year 1) do not identify a negative effect of the Project on the lobster fishery.

4.2.4.3 In-season Data

The in-season data are valuable because they are a direct measure of the catch per unit effort (CPUE) of the lobster fishery. In the spring of 2010, the CPUE of legal lobsters was higher than that in spring of 2009 in all of the exposure areas as well as the control areas. Overall, the average weight of legal lobsters per trap haul (TH) in 2010 increased by 50% in the exposure area and by 36% in the control area when compared to 2009. In the fall of 2010, the average weight of legal lobsters per TH in 2010 increased by 37% in the exposure area and by 58% in the control area when compared to the mean of the previous two seasons.

4.2.4.4 Out-of-season Data

Out-of-season data were analyzed separately because the sampling was completed independently from the commercial fishery. The out-of-season data are valuable because they allow CPUE information to be collected within a similar time frame and location each year, as well as allowing the researchers to select the target number of soak days.

Sampling trips within each of the out-of-season areas in 2009 were paired with 2010, as the dates agreed closely across years. For each area and sampling date the mean kg of legal lobster per TH was calculated. In 7 of the 10 areas the mean kg legal lobster per TH was higher in 2010 when compared to 2009. The differential change in CPUE of legal lobsters in area 1 (the area closest to the causeway) was positive, and similar to most other areas.
4.2.5 Scallop

4.2.5.1 Existing Conditions in 2010

For 2010, the results of the scallop fishing monitoring suggest that the meat weight at shell height was similar in the control and exposure areas in 2010. A comparison of random effects at the tow level did not indicate a tendency for scallops to have different meat weights relative to size in SFA 28C compared to 28D in 2010.

4.2.5.2 Comparison to Stage 1 Baseline Conditions

In a few tows in 2007, small scallops in the exposure zone had greater meat yield than the smaller scallops in the control zone. The scallop meat weight at shell height was similar in the control and exposure areas before gate opening as well as after. The results of the 2010 Stage 2 monitoring program (Year 1) do not identify a negative effect of the Project on the scallop fishery.

5.0 ARCHAEOLOGICAL AND HERITAGE RESOURCES

5.1 OBJECTIVES

The objectives of this component are to ensure all areas of potential archaeological interest are identified, and to monitor and, where necessary, mitigate risk to archaeological and heritage resources as a result of changes in flow patterns and erosion.

5.2 RESULTS

One new archaeological site was identified during the construction monitoring for the Project between June and December 2010. This historic site (CaDf-31), in addition to the historic sites identified during the previous year’s activities, brings the total number of discovered historic sites to 27 (comprised of 43 associated features). These sites consist of a number of possible Acadian features, including an in situ Acadian aboiteau, as well as other pre-20th century features.

As a result of the Stage 2 Follow-up Program visual survey conducted in November of 2010, five archaeological features associated with five sites (CaDf-16, CaDf-17, CaDf-26, CaDf-29, and CaDf-31) appeared to be at risk of being negatively impacted by River erosional forces. In addition, eight features associated with six sites (CaDf-13, CaDf-14, CaDf-15, CaDf-18, CaDf-21, and CaDf-27) appeared likely to be negatively impacted by erosional forces in the near future. While none of the other known heritage resources or potential high erosion areas surveyed appeared to be negatively impacted by recent erosional forces, they may yet be affected over the coming years.

6.0 SURFACE WATER QUALITY

6.1 OBJECTIVES

The objective of this component was to obtain interim surface water quality data following gate opening, to give an indication of how the environment is trending towards EIA predictions.
6.2 BACKGROUND

The River in the vicinity of Moncton receives effluent from a variety of point and non-point sources including wastewater treatment systems (municipal and private) upstream and downstream of Moncton (Village of Salisbury and Greater Moncton Sewerage Commission (GMSC)) and numerous upstream agricultural sources. None of these sources had or currently have disinfection. The construction of the causeway in 1969 divided the River into two separate ecological systems; a sediment rich tidal saltwater estuary below the causeway, and relatively shallow freshwater impoundment (headpond) above the causeway. Each of these systems had distinct physical characteristics, which influenced water quality including concentrations of bacteria in different ways.

Construction of the Greater Moncton Sewerage Commission treatment plant discharges substantial concentrations of sewage (municipal wastewater from Dieppe, Moncton and Riverview) at Outhouse Point. The GMSC collection infrastructure extends approximately 4 km upstream from the causeway on both sides of the River. Domestic wastes from these areas are treated at the GMSC treatment plant below the causeway.

Water quality in the former headpond upstream of the causeway reflected rural agricultural land use, with some urban and rural influences including contributions from sewerage collection and treatment systems that discharged into and upstream of the headpond. Suspended sediments and concentrations of coliform bacteria were high depending on season and location, and adversely affected by shallow water, wind, minimal input and discharge, and warm temperature. Concentrations of *E. coli* bacteria were recorded in support of the EIA (faecal coliform bacteria measurements) and again in 2008/2009 (*E. coli* measurements) at levels that exceed water quality criteria for frequent direct contact recreation such as swimming and windsurfing. (CCME Recreational Water Quality Guidelines and Aesthetics 1998).

Downstream of the causeway water quality reflected an Inner Bay of Fundy estuarine environment with a range of salinity, and extremely high, suspended sediment levels. Prior to gate opening, the volume of water below the causeway would decrease seasonally by approximately 17,000,000 m$^3$ due to seasonal build-up of sediments on the bottom of the estuary. High coliform bacteria levels would increase markedly from spring (relatively low) through summer (extremely high due to sedimentation and temperature). The causeway created an environment below the causeway that promoted high levels of coliform bacteria (AMEC 2005) in the centre of the Tri-community area.

As predicted in the EIA, the gate opening is resulting in substantive changes to the physical environment both upstream and downstream of the causeway which subsequently influence water quality.

6.3 RESULTS

6.3.1 Environmental conditions

In order to more accurately interpret the sampling data, it is important to know and understand the environmental conditions (e.g., weather, and tide) present on the day of sampling and prior to sampling. Environmental conditions during the Stage 1 and Stage 2 sampling events were similar with the
The sampling event on Sept. 29, 2009 was conducted with smaller tides and a tidal range of only 6 m. For Stage 2, Sept. 12, 2010, the tidal range was 13.3 m, more than double that for Stage 1. This difference was noted leading up to the Stage 2 sampling event and deemed acceptable as it is difficult to meet all of the necessary criteria for a sampling event.

6.3.1.1 Bacteria

Bacterial levels during Stage 2, as compared to Stage 1, were significantly reduced over the 35 km reach downstream of the causeway, and increased upstream of the causeway. There are also three anomalies of interest:

1) enterococci levels exceeding *E. coli* levels in Stage 2;
2) elevated levels for enterococci at Boundary Creek on both tides (though a more pronounced difference at low tide); and
3) a “dip” in bacteria levels at the Gunningsville Bridge site.

6.3.1.2 Turbidity

Turbidity data (NTU) were not collected in 2009. Secchi disk measurements, collected for both Stage 1 and 2 suggest that bacteria levels generally increase with increasing turbidity, and decrease with decreasing turbidity. These results are consistent with observations made during the EIA (AMEC 2005).

6.4 ANALYSIS

The concentrations of bacteria upstream of the causeway in Stage 2, can be attributed in part to the changed hydraulic conditions. The gate opening has changed the former freshwater headpond environment into a more natural estuary, and allows for the movement of downstream waters and sediments into the upstream sites. Therefore, an increase in turbidity and salinity levels at the upstream sites is consistent with the other ecosystem related Project objectives.

The largest point source of bacteria in the Estuary is the effluent from the GMSC, although many other sources exist above the Causeway. The results consistently show the highest bacteria levels nearest to the GMSC facility, regardless of tidal conditions. The waters at the Outhouse Point site are consistently saline, never dropping below 25 ppt during Stage 2. As such, it would be expected that higher concentrations of bacteria at upstream sites would be associated with elevated salinity levels if the only source of bacteria was effluent of the GMSC. The results do not support this hypothesis. On the contrary, enterococcus levels at Boundary Creek were at their highest during low tide conditions when salinity was near 0 ppt.

There is also increasing concern being voiced by researchers, regulators and plant operators about the utility of enterococcus and e.coli as accurate indicator organisms for identification of human wastes. A primary underlying assumption for indicator organisms is that they not replicate in nature. This has been found not to be the case for both enterococcus and e. coli, as both have been shown to replicate in receiving waters, particularly in water bodies containing high suspended solids levels. This phenomenon may cause false positive results and inaccurate representation of risks to public health. In view of this concern the sampling protocols used in the Stage 2 Follow-Up Program are continuing to be reviewed with the regulatory agencies.
The lack of correlation between salinity and bacteria levels at the Boundary Creek site suggest that those bacteria are either:

a) not originating from the GMSC; or
b) remnants from previous high tide events when GMSC waters may have reached this far upstream that have survived and/or regrown for many days or longer; or
c) a combination of (a) and (b); and.
d) inaccurate representations of risk to public health resulting from limitations in the utility of bacterial indicators in high suspended solid environments.

6.5 COMPARISON TO BASELINE CONDITIONS

The Stage 2 objective was to obtain interim surface water quality data following gate opening, to give an indication of how the environment is trending towards EIA predictions. The results clearly show a substantial net reduction to overall bacteria levels in the Estuary, particularly in the downstream stations from Gunningsville Bridge to Hopewell Cape, where *E. coli* concentrations decreased by a combined total average of 189,104 MPN/100 ml, and enterococcus decreased by a combined total average of 18,392 MPN/100 ml. Upstream locations experienced an overall net increase in bacteria concentrations, where *E. coli* concentrations increased by a combined total average of 3,845 MPN/100 ml, and enterococcus increased by a combined total average of 35,132 MPN/100 ml. The net change in bacteria concentrations for both bacteria groups in all locations was a decrease of 168,519 MPN/100 ml. A reduction of this magnitude suggests that the surface water quality is trending towards EIA predictions.

The results of surface water quality sampling during the Stage 1 Follow-up Program indicate that *E. coli* bacteria concentrations in the headpond were generally not suitable for recreational use, due to the following factors:

1) Sources of sewage effluent upstream of the causeway.
2) Partially restored tidal prism allowing some water containing GMSC effluent to reach upstream locations.
3) Reduced channel volume upstream of the causeway resulting from sediment infilling caused by the flow-restrictive gate opening thereby reducing assimilative capacity.
4) Increased survival and/or replication of bacteria in the fine-grained sediments that are re-suspended during periods of increased flow (rising and falling tides).

The GMSC is the largest source waste water discharge into the River, but there are many other known effluent discharges above the causeway, which must also be considered when discussing fecal concentrations. The primary systems observed include the following:

- Boundary Creek Sewage Treatment Lagoon;
- Killam Mobile Home Park Enclosed Sewage Treatment System;
- Village of Salisbury Sewage Treatment Lagoon;
- 5 Municipal Pump Station Overflows; and
- numerous storm water overflow outfalls.
The treatment lagoons and enclosed sewage treatment system provide settlement and biological treatment for sewage. Effluent and overflow from these systems is discharged directly to the River. The pump stations are designed to pressurize the collection line and move sewage to the GMSC. During heavy precipitation events the system can become overwhelmed and overflow can be discharged from these stations. The storm water overflow outfalls direct all surface water being managed on properties adjacent to the former headpond to be discharged to the River.

Since the completion of the outfall survey in 2010, the Haldor Mobile Home Park sewage collection and treatment facility has been decommissioned and the Park is now connected to the GMSC system.

There are also indirect effluent sources associated with agricultural activity upstream of the causeway which can contribute fecal bacteria to surrounding surface water. Tributaries to the Estuary, including the Petitcodiac River above Salisbury, Pollett River, Little River, and Turtle Creek all pass through agricultural lands and can transport E. coli and enterococcus bacteria from animal pastures and feedlots, as well as from seasonal manure applications.

6.6 CONCLUSION

Any comparison between Stage 1 and Stage 2 water quality data should be done qualitatively and cautiously. The EIA predictions regarding bacteria levels were specific to comparison of Stage 3 (bridge) with Stage 1 (baseline) data. Therefore, no attempt should be made to verify the EIA predictions with these Stage 2 data beyond a qualitative comparison.

7.0 ENGINEERED ENVIRONMENTAL PROTECTION WORKS

7.1 OBJECTIVES

The objective of this component was to ensure that erosion protection installed at the former Moncton landfill, the GMSC outfall, along the Riverview riverfront, along the Moncton riverfront near Westmorland Street, and along the Chateau Moncton shoreline performed as required.

7.2 RESULTS

7.2.1 Armoured Areas

Visual inspections identified some minor issues, including areas where geotextile became exposed, or rip rap material shifted, but generally the erosion protection was observed to function as was anticipated, providing adequate protection to these areas of concern.

7.2.2 Dykes and Aboiteaux

Generally, the dykes and aboiteaux appeared to be functioning properly, preventing estuarine water from impacting the protected areas and allowing surface water drainage as planned. Ground surveys identified areas of erosion, cracking, or slumping throughout the dykes, as well as areas requiring additional re-vegetation. These issues, which have been rectified, are expected during the first few years until the unconsolidated material used to build the dykes has settled and the surface vegetation is
able to stabilize. Some mitigation was required at several aboiteaux structures to repair erosion resulting from water levels above the causeway remaining lower than the elevations that are expected to be typical of conditions during Stage 3 (which were the basis for aboiteaux design).

7.2.3 Traffic Circle Drainage Improvement and Starter Dyke

Some banks have collapsed or settled and silt has deposited in the drainage channel inside the starter dyke. Overall, water is flowing correctly though the primary and secondary channels, and subsequently no follow-up has been completed or is recommended at this time. Some seepage has also been observed under the starter dyke flap gate which will be remedied.

7.2.4 Watermain

Some limited erosion was observed along the valve chamber access road, which has subsequently been repaired. The watermain has functioned as planned and no problems are anticipated.

7.2.5 Additional Erosional Areas

The following erosional areas adjacent to existing infrastructure were identified:

- downstream from existing rip-rap at the GMSC;
- southern shoreline immediately upstream of the causeway;
- between Chateau Moncton and Roger’s Building; and
- upstream of Chateau Moncton exposing and undermining the crib work on which the boardwalk is situated.

Appropriate mitigation is being considered and repair measures (additional rip rap) implemented where necessary.