Petitcodiac River Causeway project

Stage 2 Follow-up Program
Year 2 Results

Executive Summary

Submitted to:

New Brunswick Department of Supply & Services

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1.0 INTRODUCTION

1.1 PURPOSE

This document is a summary of the results of Year 2 of the Stage 2 Follow-up Program (S2FUP) for the Petitcodiac Causeway Project (the “Project”). Year 2 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 2 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 Aerial photos

Aerial photography complements the cross-section surveys and is useful when assessing potential areas where bank protection may be required. The main report presents a sequence of figures illustrating changes that can be documented from aerial photos taken between May 1999 through the spring and fall of 2010, and the fall of 2011.

- **Immediate vicinity of the control structure** - the channel upstream is becoming well developed and extensive mudflat development is evident on the north side of the channel with small tributary rivulets developing on the flats.

- **Immediately downstream of the Gunningsville Bridge** - substantial erosion is evident on the major bend below the bridge on the south side. Bank erosion has also occurred on the north side below this bend where additional protective riprap was placed in the fall of 2011.

- **Near the Greater Moncton Sewage Commission outfall** - the west bank has eroded in the order of 20.0 - 30.0 m±; however, the outfall has remained stable as it is protected by riprap. The east bank is moving laterally substantially by 40.0 - 60.0 m and has cut off some of the small tributary streams. The flood channel is enlarging at a greater rate which is attributed to the increased tidal inflow.

- **About 10.5 km downstream** - the flood channel is both enlarging and migrating upriver substantially widening at this point by about 200.0 m. However, slightly upstream the widening is substantially less in the order of 40.0 - 50.0 m.

2.2.2 Sediment Movement

No new satellite spring-season images were acquired in Year 2 of Stage 2 due to the lack of available cloud-free images. Therefore, no additional qualitative assessment of TSS characteristics of the Petitcodiac River sediment plume was made and no comparison to Stage 1 baseline or Stage 2 Year 1 conditions can be completed.

2.2.3 Cross-sections

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

2.2.3.1 Upstream of the Causeway

- **At km 1.1:** The channel bed elevation has decreased from elevation +1.0 m to between -0.6 to -3.0 m depending on the season. At the same time extensive mudflats have developed on both sides of the channel to elevation +5.5 to 6.0 m±, a rise of 2.5 to 4.5 m. The channel itself has narrowed to about 190 m from its initial width of 440 m.
- **At km 6.1:** (just downstream of the confluence of Turtle Creek) The channel bottom has varied between elevation 1.0 m and -1.0 m± depending on the season. Mudflats have formed on the left to an elevation of 5.0 m± increasing in height by about 2.0 m. The river channel has narrowed from greater than 230 to about 130 m.
- **At km 15.2:** The channel bed has varied from +2.0 to +2.8 m compared to the pre-gate opening elevation of 1.0 m. Fairly substantial seasonal silt accumulations occurred up to September 2010. Mudflats have formed on the left bank to elevation 6.0 m±, a depth of about 2.0 m; however, the main channel width remains relatively unchanged at 110 m±.

2.2.3.2 Downstream of the Causeway

- **At km 0.9:** The seasonal accumulation of silt has been substantially reduced and the channel has widened by about 16 m on the right bank.
- **At km 5.1:** The seasonal accumulation of silt has been greatly reduced and the section has widened on the left bank by about 25.0 m.
- **At km 7.3:** (Chartersville area), The channel bed elevation has varied from -1.0 to -3.5 m as opposed to +0.4 to -1.8 m prior to gate opening. The left bank has widened by about 70.0 m.
- **At km 10.5:** This section has widened on the right bank by about 250 m. The seasonal accumulation of silt is substantially less than prior to the gate opening. This section is located in a zone where separate ebb flow and flood flow channels are developing.
- **At km 19.5:** (about 4 km upstream of Stoney Creek) The river bed has deepened by about 2.0 m. The left bank below elevation +2.0 m has widened by about 20.0 m.
- **At km 35.9:** (Hopewell Cape) A sequence of erosion and deposition is occurring in the estuary bed below low tide level; probably due to sediment which is being eroded from the banks upstream and is continually moving downstream towards Shepody Bay.

2.2.3.3 Upper Bay of Fundy

- **At km 39.2:** (Calhoun Flats) Most of the change occurred from the centre of the section to the left bank looking upstream where a deposition of about 1.1 to 1.5 m occurred over a length of about 800 m.

- **At km 42.8:** (Grand Anse) The bed level in the central portion of the section ("Middle Ground") has risen about 0.5 to 2 m over a width of about 2500 m. This rise is attributed to the erosion of sediment from the estuary upstream of Hopewell Cape, which is being transported eastward and is being deposited in the upper part of Shepody Bay.
- **At km 48.8:** (Daniels Flats) A deposition of about 3 m over a width of 1000 m in the deepest part of the Bay is occurring.
- **At km 74.9:** (Cape Enrage) There is no measurable change at this location, indicating that the downstream limit of sediment going into and out of storage is between Shepody Flats and New Horton.
- **At km 85.2** (Alma), There is no measureable change at this location.

2.2.4 Channel profiles Along the Estuary

2.2.4.1 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 a maximum of about 3.0 m in the first 28 km downstream of the causeway and has risen a maximum of about 2.0 m from 32 to 35.9 km downstream. Upstream of the causeway the maximum increase in thalweg elevation was about 2.6 m at a point about 12 km upstream of the causeway at the end of the first summer in 2010 and was about 2.9 m at the same point at the end of the second summer in 2011. The increase in thalweg elevation during the summer is modified significantly in response to the high flows from the land during the fall and spring.

"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. The thalweg elevation decreased about 0.3 m below the level on December 2010 between 200 m and 600 m upstream of the control structure. The bed has risen by as much as 2.0 m between December 2010 and November 2011 between points about 750 m and 1000 m upstream. The former water line located approximately 160 m upstream of the causeway is a control point in the channel. During 2011 the channel bed locally eroded at the site of the former water line to an elevation of -2.0 m on the Riverview bank of the approach channel.

Scour Hole: Since the control structure was designed for flow in the downstream direction only, no extended apron was placed on the upstream side of the control structure. A short concrete slab does extend 8.7 m upstream of the location of the bridge deck. It is noted that the peak flows associated with each tidal cycle is in excess of the 100 year flood flow from the land.

Immediately upstream of the control structure, rough estimates of the maximum depth of the scour hole ranged from 5.4 m to 11.5 m with an average of 8.7 m, the lower estimate being for scour in weak rock. The development of the scour hole over time was monitored for the period April 2010 (8 days before the gates were opened) until November 2011. Much of the scour took place within the first two weeks after the gate opening. The maximum depth of the scour hole was 5.5 m in May 2011 with reference to the initial bed level.

Immediately downstream of the control structure, the structure was built with a concrete apron extending 18.0 m downstream of the ends of the piers. The original design recognized that the structure had to pass high flows from the land in the order of 1000 m3/sec. Once the gates were opened, the tidal outflows were in the order of 1000 to 1500 m3/sec twice a day. The bottom of the scour hole in November 2011 was at elevation -7.8 m and located 25 m downstream of the lip at the end of the apron. There is a cutoff wall extending to a depth of -4.5 m at the end of the apron. The effective depth of scour below the cutoff wall is 3.3 m and the slope of the scour hole towards the apron is about 1V:7.5H. The crest of the mound associated with the scour hole is at elevation of -0.8 m at a point about 100 m downstream of the end of the apron and about 1.2 m above the top of the lip at the end of the apron.

2.2.4.2 Tidal Flats

When the gates were opened, there was a significant net upstream transport of fine grained suspended sediment. Some of this sediment is deposited on the channel bed and on the tidal flat; the latter is “locked” in place and is not entrained in the ebb tide flow. When the tidal flat is below mean high tide elevation, a deposit of about 3 mm occurs during each tidal cycle. Most of the tidal flat development is occurring between the control structure and the confluence of the Petitcodiac estuary with Turtle Creek. The maximum deposition over the 13 month period monitored varied between 3.3 m and 1.8 m. The mean tide elevation at the control structure at the causeway is about 6.1 m (geodetic). Once the tidal flats build to that elevation, the rate of increase of the surface of the tidal flats will decrease with time. It is estimated that the tidal flats upstream of the causeway will continue to increase in elevation from 5.7 m, observed May 2011 to about 7.1 m within the next decade. Based on historic observations downstream of the causeway, it is anticipated that the tidal flats upstream of the causeway will start to become colonized by vegetation by about 2018.

2.2.4.3 Channel Width Relationships

In order to assess the changes in the channel both upstream and downstream of the causeway, width at elevations 2.0 m and 4.0 m were measured.

At 5 km upstream of the control structure the channel width at elevation 2.0 m decreased over the one year period from November 2010 to November 2011 and the widths are narrower than in May 2009 before the gates were opened. In general the channel width at elevation 2.0 m from 2 km to 5 km has increased from its initial width on May 2009. This is primarily a result of the lowering of the channel bed in this area. Between May 2009 and November 2011 the channel width at elevation 4.0 m has decreased appreciably; the greatest changes occurring in the first 6 km upstream.

Downstream of the control structure the channel width at elevation 2.0 m increased along the first 19.5 km downstream with very little change after that point. The greatest increase in width at elevation 2.0 m occurred between 5.0 km to 14.1 km downstream. Although the channel appears to have increased by over 100 percent at this location, it is related to the development of separate ebb flow and flood flow channels. The changes at locations of 7.3 km and at 14.1 km are more representative of the maximum channel widening between the causeway and Hopewell Cape. At these sites the channel widening is in the order of 30 to 50 percent of the width before the gates were opened.

The rates of change were generally most rapid during the first 200 days. There is a tendency for the rates of change of channel widening to decrease with time as the estuary slowly adjusts to the opening of the gates.

2.2.5 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.

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

Sub-surface Current Velocities: The current velocities measured during the Year 2 and Year 1 of Stage 2 show similar magnitudes, suggesting that the hydraulic regime of the channel is moving towards a stable condition. In the downstream direction, measurements conducted during these events show similar current velocities that were maintained after the opening of the causeway gates. In the upstream direction, the latest measured current velocities decreased slightly when compared to the Stage 2 Year 1 event; however, the decrease can be attributed to seasonal factors including high flows from the upstream sections of the Petitcodiac River. Overall, the latest current measurements confirm the predictions of the EIA.

Total Suspended Solid (TSS) Measurements: For Stage 2 Year 2, TSS concentrations remained similar to the previous year, increasing during the arrival of the tidal bore which is a direct consequence of an increase in water current velocities. The magnitude of the TSS concentrations were very similar between both years of Stage 2 and also lower overall when compared to Stage 1, with smaller peak concentrations and lower magnitudes during the tidal cycles. This is likely due to an increase in water volumes after the opening of the causeway gates that creates a dilution effect with a corresponding decrease in sediment concentrations.

Suspended Sediment Transport: Sediment transport estimates indicate that during Stage 2 – Year 1 the sediment flux was positive (in the downstream direction). When compared to Stage 2 – Year 1, a change in the direction of the sediment flux was observed for Stage 2 Year 2, which overall was negative (i.e. upstream direction). These results indicate that even when the hydraulic regime appears to be approaching a stable condition, there are fluctuations in channel conditions that affect the sediment transport regime over time.

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

2.2.7 Ground-level Observations

Ground level observations were carried out on both the left and right bank of the Petitcodiac River Salisbury to Hopewell Cape seasonally from May 2010 to December 2011. Site visits were also made to the Hopewell Cape Park (The Rocks) to determine if changes in the river flows have resulted in noticeable siltation build up.

No discernable changes in the shoreline at the lower portions of the estuary were noted. Furthermore, flow from the land in the small creeks flowing into the Petitcodiac appear unaffected by the opening of the gates, and the silt build up in the mouth of Halls Creek and Jonathan Creek immediately downstream from the causeway was less than was observed seasonally prior to opening of the gates, 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 the gate opening. This widening is ongoing as evidenced by the sloughing vegetation along the riverbanks.

Upstream of the gates rapid siltation has occurred, most evident by the increase in elevation of the mudflats in the former headpond area. The elevation of these mudflats has increased from an average 3.5 m when the gates were opened to an estimated 6 m by the spring of 2011. As a result lower tides no longer cover the mudflats.

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 2010 and November 2011 approximately 3.5 million cubic metres (m^3) of silt accumulated in the former reservoir mainly in the form of mudflats which have reached an elevation of 6.0 - 6.5 m±. In addition to the permanent infilling, about 1.0 million cubic metres of sediment moves into the upstream area in the summer and is eroded out in the subsequent fall or spring.
- **Causeway to Hopewell Cape** - Between May 2010 and November 2011 a net erosion of approximately 29.1 million m^3 has occurred in this reach. The most active widening of the river seems to be for the segment from Dieppe to Upper Dover.
- **Shepody Bay** – The deposition in Shepody Bay should theoretically equal the erosion downstream less the reservoir deposition. It appears that the major portion of the deposition is occurring in an area shown as the “Middle Ground” on the hydrographical charts. This area was dry at low water in 1965, but subsequently disappeared and is now rebuilding.

2.2.9 Estuary Volume and Tidal Prism

From the date the causeway was built in 1968 to 2002 a total of about 170×10^6 m^3 of sediment infilled the channel downstream of the causeway. It is estimated that between October 1965 and May 2010, in excess of 76×10^6 m^3 of material had been removed from Shepody Bay, primarily from the area known as the “Middle Ground” (it would appear that this was a major source of the sediment which contributed to infilling the river channel).

When the gates were initially opened 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 20.4×10^6 m^3 or about an 8% increase from the 2002 value due to the increased tidal volume in the former headpond. This has decreased by November 2011 to about 17.5×10^6 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 20.0×10^6 m^3 and the total volume by 35.5×10^6 m^3.

The total tidal prism in the estuary has increased to about 37.5×10^6 m^3 or 16.3% 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 2 S2FUP survey:

- an average of 41.3 people visited Boreview Park each day;
- the average visitor group size was 3.0 persons per group;
- most visitors (81.6%) to Boreview Park were from outside of the Province;
- most visitors (79.8%) were at Boreview Park to view the tidal bore;
- most visitors (79.8%) indicated that they would return to Boreview Park to view the tidal bore; and
- most visitors (96.5%) said that they would recommend visiting Boreview Park to view the tidal bore to others.

The results from the first two years of Stage 2 indicate that visitation to Boreview Park to view the tidal bore has increased by 50% since the gates were opened and tidal exchange upstream of the causeway was restored. 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. The eel fishery in the estuary was recommended for compensation for loss of fishing opportunity. This matter will be settled shortly and the follow-up program was not conducted for the American eel fishery in Year 2.

4.2 RESULTS

4.2.1 Total Suspended Solids

In Stage 2 Year 2 (both during and outside lobster fishing season), water samples for TSS were collected from lobster fishing grounds in Chignecto Bay and Advocate Harbour/Minas Channel, as well as on route to and from the lobster fishing grounds. It appears that the highest suspended sediments are observed in surface water with a flooding tide. The TSS data for Stage 1 and Stage 2 Year 1 show similar trends for pre- and post-gate opening conditions: flooding tides appear to have higher concentrations of TSS when compared to ebbing tide concentrations. Additionally, TSS concentrations are similar, if not less overall, in Stage 2 (Years 1 and 2) when compared to Stage 1.

4.2.2 Sediment in Lobster Traps

Of the 16,046 traps (fall 4,260 commercial; spring 9,052 commercial; out of season 1,837 commercial; and 897 FSRS recruitment traps) examined during the 2011 commercial and out of season monitoring program, 25 traps contained sediment deposits substantial enough to be visually identified by the fishers. The distribution of locations of traps with sediment over the course of the Stage 1 and Stage 2 (Year 1 and Year 2) monitoring periods is similar. The pre- and post-gate opening conditions appear to have resulted in similar locations for which sediment has been observed in lobster traps

4.2.3 Sediment Plume Delineation

Three programming attempts were made to acquire a cloud-free image captured during a low tide within the spring season of Stage 2 Year 2. No image was acquired during either attempt that met the required conditions. Two satellite images were successfully sourced to support the development and testing of a TSS quantification method using remotely sensed data.

The comparison between Stage 2 Year 2 sedimentation results with Stage 2 Year 1 conditions and Stage 1 baseline conditions confirms that sedimentation in the Upper Bay of Fundy does not appear to be greater post-gate opening than pre-gate opening. This is based on the total suspended sediment sampling results and the distribution of lobster traps observed to contain sediment. Concentrations of TSS are similar, if not less in Stage 2 (Years 1 and 2) when compared to Stage 1. These observations on sedimentation support the EIA prediction that accumulated sediment in the Petitcodiac River is not likely transported over a larger area in the Upper Bay of Fundy.

4.2.4 Lobster

Overall the catch per unit effort of legal lobsters in commercial traps during Stage 2 (2010 and 2011) in both the control and exposure areas has increased or has remained similar to the CPUE of legal lobsters in Stage 1 (2008 and 2009).

The change in CPUE of sub-legal lobster is not as clear. A lower catch rate in of sub-legal lobsters in the exposure area was observed during the spring and out-of-season sampling from both commercial and FSRS juvenile traps. It is possible that the decrease in the catch of sublegal lobsters is within the natural year-to-year variation

Judging from catch rates over the various seasons and trap types, berried lobster numbers have been increasing in the control zone, but not in the exposure zone. The cause and implications of this are unclear.

The results of the Stage 2 monitoring program to date do not identify a negative effect of the project on the lobster fishery.

4.2.5 Scallop

In both Year 1 (AMEC 2011a) and Year 2 of the Stage 2 follow-up program (2010 and 2011), there was no statistical difference in meat weight at shell height between the control zone and exposure zone. This suggests that scallop meat weight at shell height was similar in both zones before the opening of the gates, as well as after the opening. The results of the Stage 2 monitoring program to date 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

The 2011 Stage 2 Year 2 Follow-up Program included a visual survey of 33 areas by a permitted archaeologist, limited mitigation of four archaeological sites, and desktop research on Halls Creek and two archeological sites. The 33 survey areas included eight potential high erosion areas, 24 archaeological sites identified in 2009-10, and the Halls Creek area in the vicinity of proposed riverbank armouring. At least 12 of these areas appear to be experiencing accretion rather than erosion. Of the four archaeological sites that were assessed as requiring mitigation measures, three were reburied and one was investigated and reburied. A wood and stone crib feature with a dendrochronology date of 1845 was interpreted to be a small post-Acadian wharf feature. Investigations conducted regarding the Halls Creek area indicate prehistoric and historic use of this area; however, no heritage resources were identified during the visual survey.

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 PREAMBLE

Undertaking the Stage 2 Year 1 and Year 2 water quality sampling programs with the same environmental conditions as were present at the time of the Stage 1 sampling was not possible due to the nature of the Project (changing the environment from a freshwater headpond to a tidal estuary above the Causeway). Therefore, any comparison between these data should be done qualitatively and cautiously. Also, it is important to note that the EIA predictions regarding bacteria levels (*E. coli* only) were specific to comparison of Stage 3 with Stage 1 (baseline) data. Therefore, no attempt should be made to verify the EIA predictions with these Stage 2 data beyond the qualitative comparison of the current data trends with the EIA predictions specific to Project Option 3 and 4B, as applicable.

The largest direct source of bacteria in the Petitcodiac River Estuary is the effluent from the GMSC, although many other sources exist above the Causeway. Effluent and overflow from treatment lagoons and sewage treatment 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 to the river. The storm water overflow outfalls direct all surface water from properties adjacent to the former headpond to be discharged to the river. In addition to direct sewage sources, there are indirect sources associated with agricultural activity upstream of the Causeway which can contribute fecal bacteria to surrounding surface water. Tributaries to the Petitcodiac River 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.

6.3 RESULTS

6.3.1 E. coli and Enterococcus

Bacterial levels during both years of Stage 2, as compared to Stage 1, were significantly reduced downstream of the causeway, and increased upstream of the causeway. The reductions downstream of the causeway were significant and occurred over a 35 km reach of the estuary, where there is significantly more water volume compared to the 20 km reach upstream. The results include the following key observations:

- *E. coli* levels during low tide were higher in Stage 2 Year 2 then in Stage 2 Year 1.
- The elevated levels for enterococci at Boundary Creek on both tides (though a more pronounced difference at low tide) that were observed in Stage 2 Year 1 did not occur in Stage 2 Year 2.
- The “dip” in bacteria levels at the Gunningsville Bridge site that was observed in Stage 2 Year 1 did not occur in Stage 2 Year 2.

6.3.2 Bacteroidales (Human) Markers

The BacH analysis shows trends that are consistent with increasing dilution of GMSC discharge with increasing distance from the GMSC outfall. BacH is present at high tide at least as far as the Boundary Creek station, though at low tide is not observed at Turtle Creek or upstream of that location. During low tide, the distribution of BacH is more limited than at high tide and the peak value occurs at the

Gunningsville Bridge. At high tide, the peak value occurs at the causeway. The average number of BacH markers in an equivalent volume of raw sewage is 794,000,000 copies/100 ml (Silkie and Nelson 2009). The highest value recorded (taken from Gunningsville Bridge at low tide) during Stage 2 Year 2 was 199,691 copies/100 ml, or approximately 1/4000 of the raw sewage value.

6.3.3 Salinity

Salinity is determined by the percentage of marine versus fresh water. In Stage 1, the water upstream of the causeway was maintained as freshwater and the salinity was near zero. In Stage 2 Year 1, the rapid change from marine-dominated salty water to freshwater occurred 20 km upstream as compared to Stage 1 demonstrating that the saltier marine waters were passing through the open gates upstream to Boundary Creek. The Stage 2 Year 2 salinity is in between Stage 2 Year 1 and Stage 1. This is unexpected given the similar tidal conditions of these two years, but may be a result of increased infilling upstream of the causeway diminishing the influx of marine waters above the causeway.

6.3.4 Turbidity

Higher turbidity is exhibited in the freshwater portion of the estuary compared to lower turbidity in marine waters. At high tide, turbidity values decrease sharply between Outhouse Point and Dover. At low tide, turbidity remains elevated to Hopewell Cape, reflecting an increased proportion of freshwater at these downstream locations during the falling tide.

6.3.5 Relationship Between E. coli and Enterococcus and Turbidity

A comparison of the *E. coli* and enterococcus levels with turbidity for Stage 2 Year 2 reveals that the bacteria levels increase with increasing turbidity, and decrease with decreasing turbidity. This is particularly the case with enterococcus levels which seem to directly relate to turbidity under both tidal conditions.

6.3.6 Relationship Between E. coli and Enterococcus and Salinity

A comparison of the *E. coli* and enterococcus levels with salinity for Stage 2 Year 2 indicates that there is no obvious relationship between salinity and these bacteria. This is seen most clearly in comparing low tide with high tide results. For the Stage 2 Year 2 high tide, the levels are relatively consistent from Boundary Creek to Outhouse point, despite the fact that the salinity changes from 9 to 23 ppt.

6.3.7 Relationship Between Bacteroidales (Human) Markers and Total Suspended Solids

A comparison of the *BacH* marker analysis with TSS for Stage 2 Year 2 reveals that *BacH* marker counts do not appear to correspond with TSS during low tide. *BacH* does exhibit a similar trend to TSS during high tide, though this similarity is likely to be coincidental given the lack of similarity observed during low tide.

6.4 CONCLUSIONS

Many factors which vary daily and annually contribute to water quality, including bacteria levels, in the Petitcodiac River Estuary. Some of the factors are dependent on others, and some are independent. Further, the nature of the Project is such that the environmental conditions were significantly changed between Stages, particularly upstream of the Causeway. Attempting to determine which factors are responsible for water quality conditions is problematic given the complexity of the system, the limitations of the available data, and knowledge of how bacteria behave in suspended sediment-rich systems.

Nevertheless, there is sufficient evidence to support some trends. Most importantly, the overall levels of *E. coli* have greatly decreased in the system as the extremely high levels observed during Stage 1 between the Causeway and Dover have been significantly reduced. Also, bacteria levels appear to be influenced by the presence of suspended sediments in the water column (as measured by turbidity), while a weak relationship between salinity and bacteria levels were established. The channel volume (assimilative capacity) and residence time of the estuary remains the most controlling factor of bacteria levels. While Stage 2 has resulted in an increase to the channel volume downstream of the Causeway, the upstream migration of sediments and the average tide levels being less than the elevation of the former headpond has reduced the channel volume upstream at this time.

The concentrations of bacteria upstream of the Causeway in both years of Stage 2, as compared to baseline conditions observed during Stage 1, are attributed primarily to the changed hydraulic conditions. Most importantly, the opening of the causeway gates 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 objectives of the Petitcodiac River Causeway Project.

The results of the analytical methods comparison for *E. coli* and enterococcus support the lack of confidence in the use of enterococcus as an indicator in the Petitcodiac River Estuary, as suggested following the results of the Stage 2 Year 1 program (AMEC 2011). Further, the results suggest that the determined *E. coli* numbers may vary by up to 100% pending the analytical method. Such variation is problematic given the relatively low regulatory guideline threshold for *E. coli* as it relates to human recreational activities.

The results of the BacH marker analysis suggest that BacH may be a more accurate indicator of the presence of sewage effluent then the traditional indicators *E. coli* and enterococcus. At this time, regulator guidelines do not exist for BacH and so inferences to human health risk from exposure cannot be made using this indicator. However, the use of BacH to track effluent and estimate risks to human health is a rapidly developing field and it is possible that guidelines may be developed during the lifespan of the Project.

The results clearly show a substantial net reduction to overall bacteria levels in the Petitcodiac River Estuary, particularly in the downstream stations from the Gunningsville Bridge to Hopewell Cape, where *E. coli* and enterococcus concentrations decreased significantly. Comparatively, upstream locations experienced an overall, but substantively less, net increase in bacteria concentrations. The overall reduction of *E. coli* and enterococcus in the Petitcodiac River Estuary suggests that the surface water quality is trending towards the predictions contained in the EIA. The construction of a bridge during Stage 3 will further increase the tidal prism, and therefore the assimilative capacity, further reducing the bacteria concentrations below the Causeway and reversing some of the increases that were observed upstream of the Causeway during the first two years of Stage 2.

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

On-going inspection and monitoring of the armoured sections of shoreline protection continued throughout Year 2 of Stage 2. In September of 2011, the frequency of inspections was reduced from bi-weekly to monthly as conditions in the River were observed to have stabilized. Some minor issues were noted; including areas where geotextile became exposed, rip rap material shifted, or the river bank had slumped. These issues have been or are being addressed. Erosion protection is functioning as required.

7.2.2 Dykes and Aboiteaux

Due to the large spatial area where dykes are located, aerial surveys as well as ground surveys were completed. Aerial surveys were used to assess drainage patterns and verify that water is flowing through the dykes and aboiteaux and that they are functioning properly in keeping estuarine waters from flowing into the adjacent farmland, while allowing surface water accumulating behind the dykes to flow into the estuary. Ground surveys were also completed as part of on-going monitoring to assess the physical condition of the dykes and aboiteaux.

The dykes and aboiteaux generally appeared to be functioning properly, preventing estuarine water from impacting the protected areas and allowing surface water to drain as planned. There are identified areas of erosion, cracking, and slumping throughout the dykes, as well as areas requiring re-vegetation. These problems are expected throughout the first few years until the unconsolidated material used to build the dykes has settled and the surface vegetation has stabilized.

7.2.3 Traffic Circle Drainage Improvement and Starter Dyke

In Year 1 Stage 2 some of the banks along the drainage channel had collapsed or settled and silt deposited in the channel from erosion, however, because water was flowing correctly through the primary and secondary channels, no follow-up was recommended. A minor seepage was also observed under the starter dyke flap gate. During Year 2 inspections, water within the drainage channel was found to continue to flow correctly and the seepage under the flap gate was found to have ceased.

7.2.4 Additional Erosional Areas

The following erosional areas adjacent to existing infrastructure were identified during Year 1. These areas were inspected bi-weekly or monthly as part of the on-going Year 2 inspections:

- 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 adjacent to, and underneath boardwalk.

The risk to the Riverfront trail due to increased erosion along the Moncton shoreline was a concern. It was decided that additional erosion protection was necessary, and riprap was installed along a 155 m section adjacent to the Roger's building parking lot in September/October of 2011.

Increased erosion activity exposing the supporting cribwork located under the Moncton riverfront boardwalk, upstream of Chateau Moncton caused concern that the boardwalk and lookout building situated on top of this cribbing were not at risk. Thus, a 45 m long section was protected in September/October of 2011.

8.0 OVERALL CONCLUSION

The results of Year 2 of the Stage 2 Follow-up Program (S2FUP) for the Petitcodiac Causeway Project indicate that the mitigation measures put in place in Stage 1 are functioning as designed. The findings and conclusions relevant to the other five Valued Ecosystem Components indicate that these components are trending, from an environmental and socio-economic perspective, in a direction consistent with the predictions and conclusions contained in the EIA. However, it will not be possible to make a definitive statement in this regard until the completion of Project Option 4B.