ENVIRONMENTAL MANAGEMENT OF AGED BRIDGE STRUCTURES IN PEI

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ABSTRACT

Prince Edward Island (PEI) is located in Eastern Canada and comprises one of the four Atlantic Provinces. It has a population of 130,000 with a land area of 5,660 sq. km and boasts highly productive river systems and brackish estuaries fed from a network of stream and creeks flowing almost exclusively from ground water.

In the early to mid-1950's, the Province embarked on a new era of structure replacement, that included the then-popular creation of man-made fresh water lakes. At several watercourse crossing locations, aged large open-span bridge structures were replaced by constructing earthen road bed berms (i.e. causeways) complete with engineered hydraulic control structures which measured approximately 6.0 metres in span. This was the preferred method of structure replacement at that time since infilling was by far cheaper than replacing entire structural members.

Coincident with the timing of this replacement program, land-based applications of fertilizers and pesticides to assist in farm crop production began to increase significantly.

Approximately two or three decades following their installation, water quality issues began to emerge in the impoundments and waterways located upstream of most these control structures. In the worst cases, eutrophic conditions emerged in the upstream water bodies. The Province has recognized te need to consider removal of the control structures, and restoration of full tidal passage at these locations in conjunction with their Structure Replacement Program. Restoration of tidal passage at these locations has been accomplished successfully by a number of engineered methods including AASHTO girder bridges, pre-cast box span, steel box girders, etc.

The Province has been replacing these structures on an ongoing basis since the mid 1980's with significant, and surprisingly quick, beneficial effects on water quality and associated environmental components including socioeconomic and fishery resources. Today, a few such structures remain, with one of these slated for replacement this Fall of 2003. As part of their Structure Replacement Program, the Department assesses tidal passage requirements at structure replacement locations and also develops Environmental Effects Monitoring Programs to assess associated environmental criteria, such as Total Suspended Solids (TSS), before, during and after construction project to monitor and confirm the effects of the new structures.

The integration of environmental management and design into the Department's Structure Replacement Program has been a natural progression; one which has been very well received by regulatory agencies and the public.

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1.0 INTRODUCTION

In the early to mid 1950's, the Province embarked on a new era of structure replacement that included the then-popular creation of man-made fresh water lakes. At several watercourse crossing locations, engineered hydraulic control structures which measured approximately 6.0 metres in span were constructed. This was the preferred method of structure replacement at that time since infilling was by far cheaper than replacing entire structural members.

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Approximately two or three decades following their installation, water quality issues began to emerge in the impoundments and waterways located upstream of most these control structures. In the worst cases, eutrophic conditions emerged in the upstream water bodies. The Province has recognized the need to consider removal of the control structures and restoration of full tidal passage at these locations in conjunction with their Structure Replacement Program.

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2.0 BACKGROUND

Prince Edward Island (PEI) is located in Eastern Canada and comprises one of the four Atlantic Provinces. It has a population of 130,000 with a land area of 5,660 sq. km and boasts highly productive river systems and brackish estuaries fed from a network of streams and creeks flowing almost exclusively from ground water.

With approx. 5600 km of roadway (3800 km paved, 1800 km unpaved) combined with approximately 5500 km of finfish-bearing watercourses, the Provincial transportation network includes a large number of structures at watercourse crossing locations. There are approximately 1280 structures in PEI. This represents approximately one structure for every 109 persons, or one structure for every 4 square km. By comparison, New Brunswick has one structure for every 250 persons (one for every 295 sq. km of land area), while British Columbia has one structure for every 730 persons (one for every 1300 sq. km of land area).

In their original state, Island estuaries are typically well stratified systems with good water quality. Historically, Island river systems had deeper channels providing transportation routes to upstream ports for the large boats from the shipping era. Through time, impoundments have been created in the upper reaches of some systems and most Island river systems have been challenged through human-induced sedimentation, nutrient loading, natural oceanographic and erosion processes, and other factors. Tidal exchange within the river systems effects water quality, and the south shore of the Province benefits from twice the available tide as compared to the north shore. Thus, water quality issues associated stagnant water are more challenging to address on the north shore of the Province.

It is important to note that, despite the absence of causeway structures to impede or effect tidal exchange and flushing action, water quality issues exist in several Island water systems, especially north shore systems. These natural river systems, under the stress of sedimentation, nutrient loading, industrial effluents and other human-induced and typically land-based activities, have developed water quality problems. Research and assessment of Island watersheds and river systems has found that the presence of a causeway or other tidal passage restriction is but one of several factors potentially effecting water quality.

3.0 TYPICAL CAUSEWAY CONSTRUCTION

3.1 Structural

Prior to the Second World War, construction of bridges were typically carried out using timber piles substructures with either timber superstructures or steel superstructures with concrete decks.

In the late 1950's, early 1960's, the Province embarked on a new era of structure replacement. The structures were very simple, consisting of two parallel lines of steel sheet pile (SSP) wall embedded into the bedrock utilizing cantilevered construction. A concrete slab was then cast on top of the SSP wall spanning the opening, which typically was approximately 6 metres (20 ft.) in span.

This method was preferred at the time, since the post war availability of steel was meagre, but earth certainly was abundant and infilling was by far cheaper than replacing entire structural systems. As well, the potential effects of causeway installation were scientifically not well known at the time, and so causeways with control gates were installed to maintain the road network.

The basic construction practice would be to end-dump material from the back of a truck and continue to infill the river, up until such a point as the structures would be installed. This proved to be a cost effective and reasonably simple construction method.

3.2 Socio-Economics and the Environment

Perceived Benefits

Environmentally, the potential effects of causeway construction on upstream water quality was not well known at the time of their installation. Socially, the upstream impoundments or freshwater lakes were wanted by the public as they were seen to offer numerous benefits. Residents and communities welcomed the development of the large impounded water bodies that provided aesthetically pleasing environments and a range of recreational opportunities including recreational boating, fishing and swimming.

Resultant Environmental Problems
However, approximately two or three decades following their installation, it became apparent that at most control structure locations, water quality issues including eutrophic conditions existed in the upstream impoundments and waterways. Typical water quality issues in water bodies located upstream of the causeways include stratification and stagnation. Salt water that passes through the control structure on a flood tide to upstream freshwater areas is denser than the freshwater and sinks to the lower part of the water column. Natural channel bed pockets and sills assist in trapping the salty water, impeding its desired flushing action and significantly increasing it's residence time. While the freshwater moves across the surface and through the control structure during ebb tides, the salty water does not get flushed and becomes stagnant. Additional resultant water quality issues include oxygen depletion, reduced photosynthesis and eutrophication of the upstream impounded water bodies.

Again, it is important to remember that coincident with the timing of this causeway construction program, expansion of a range of land-based activities increased significantly including land-based applications of fertilizers and pesticides to assist in farm crop production. Monitoring of selected Island waterways reports that their nitrate levels have increased at least three-fold over the past 30 to 40 years.

4.0 CAUSEWAY REPLACEMENT PROGRAM

4.1 General Description

Over the past few years, the Province has made efforts to replace these causeways and remaining control structures with bridges which provide for adequate tidal flushing. The Province has recognized the benefit in considering removal of the control structures and restoration of sufficient tidal passage at these locations in conjunction with their Structure Replacement Program.

These new structures range in span length, size and construction type, from steel & concrete superstructures, to pre-cast Hy-Span® Structures. Some overviews of some select sites and construction types follows Environmental Design Considerations.

4.2 Environmental Design Considerations

The primary environmental objective in the causeway replacement program is to provide a replacement structure that provides adequate passage of the available tide; most often times, this is complete, or 100%, passage of the available tide. A systematic process has been implemented to determine this objective at each project site

As a first step, a tide monitoring assessment is conducted that identifies several important factors. Typically, bottom pressure gauges are installed at locations immediately upstream and downstream of the existing control structure. The bottom pressures are converted to water levels and a resultant water level time series is plotted that illustrate a superimposed plot of the upstream and downstream water levels visually and numerically identifying their differences or the *hydraulic control*.

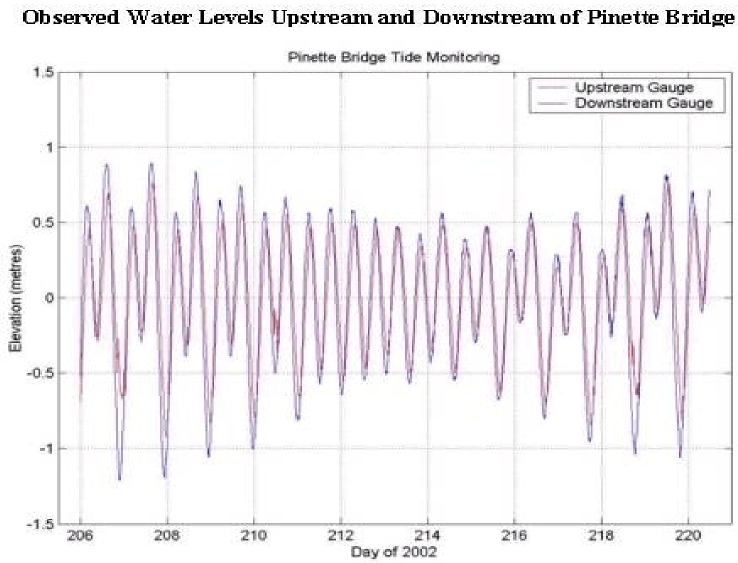

Figure 1 - Observed water levels upstream and downstream of Pinette Bridge

Hydraulic modelling is then conducted to verify field observations and to identify the required dimensions for the replacement bridge needed to provide for complete tidal passage. Using known width and depth dimensions for the existing bridge, and the observed tidal passage for those dimensions, hydraulic modelling generates various proposed bridge gap width and depth combinations that would provide complete tidal passage. The most practical width and depth combination is selected.

Other factors are also considered in design of the replacement structure in effort to maximize the environmental benefits. These are determined on a site specific basis, but may include alignment of the new bridge with the natural channel, and scheduling mitigation to avoid conflict with shellfishers and other stakeholders.

Appropriate regulatory approvals are also obtained and complied with, including approvals required under the Federal Navigable Waters Protection Act and Provincial Environmental Protection Act. Environmental Protection Plans are developed for each structure replacement project and, as required, Environmental Effects Monitoring programs are developed for implementation at the pre-construction, during-construction and post-construction phases of the project.

4.3 Replacement Project Sites

North River Causeway

North River Causeway was constructed in 1955 and consisted of two parallel lines of Steel Sheet

Pile (SSP) walls spanned by a concrete slab approx. 450 mm (18 inches) thick. Its predecessor was a steel through truss structure which spanned the entire river width of approx. 300 metres (985 ft.). The total watershed area is in the order of 7400 Ha with a total river area upstream of 175 Ha.

The replacement structure was constructed in 1996 and is comprised of a two-span continuous structure with a concrete deck on AASHTO Type III girders, founded on three sets of concrete piles. The total span length is 46 metres (23 metres each individual span) and incorporates 4 lanes of traffic.

West River Causeway

The West River Causeway was constructed in 1958 and the original structure which was constructed still exits today. It is a 18.3 metre (60 ft.) simply supported steel girder structure with a concrete deck. The structure is founded on steel piles with a SSP wall closed abutment system. There was no roadway network at this location prior to its inception and the river opening at this location was originally 500 metres (1640 ft.)

This structure constricted the flow from a watershed which is 4800 Ha in size with an upstream water area of 150 Ha.

Instead of replacing this structure, the Department constructed a new structure approx. 250 m north of the existing. The replacement structure was completed in 1986 and is a two-span continuous structure with concrete deck on two lines of steel box girders. The structure is founded on steel pipe piles at the abutments and a caisson with a concrete pile cap at the centre pier. The total span length is 8 metres (44 metres each individual span) and allows for two lanes of traffic.

Vernon Bridge

Vernon Bridge causeway was originally constructed in 1953 and consisted of two parallel lines of SSP walls spanned by a 450 mm (18 inch) thick concrete slab. The span length was approx. 6.1 metres (20 ft.) and its predecessor was a steel through truss structure which spanned the entire river width of approximately 150 metres (492 ft.). The structure constricted the flow from a watershed area of 6800 Ha in size with an upstream water area of 75 Ha.

The new replacement structure was completed in 1999 and consists of a 3-sided pre-cast concrete span (Hy-Span®) with a span length of 11 metres (36 ft.). The structure is founded on Steel Sheet Pile wall which also comprises the closed abutment system. Unique to this application, the Hy-Span® structure also acts as the brace mechanism for the SSP wall system (anchored). The new bridge allows for two lanes of traffic.

Mount Stewart Rails-to-Trails.

This is a rather unique situation in that the recommended amount of tidal passage required was in the order of 30 %, much less than the typically required 100 %.

The structures were constructed in 1920's by Canadian National, across the head of the Hillsborough River and consisted of two creosote box culverts with a 3.0 metre wide opening. We are not 100% certain as to the predeceasing structure type, but best guess is that it too was a steel through truss structure spanning the river width of approximately 125 metres (410 ft.). The size of the watershed is in the order of 5400 Ha with an upstream water area of 70 Ha.

The replacement structure consists of an 11 metre (36 ft.) single span structure with steel beams and semi-integral abutments, founded on steel pipe piles. There is also an anchored SSP wall closed abutment system which allows for an 8.0 metre (26 ft.) wide opening for the river. This structure is used primarily for pedestrian and bicyclists throughout the summer months, and snowmobiles during the winter months. The new structure replaced one of the two box culvert structures and allows for 35 % tidal passage. The other box culvert still remains in use, however; it is expected that once this second box has surpassed its service life, then it will be removed and/or infilled, leaving the new structure to act as the only available structure.

Pinette

This causeway structure was constructed in 1959 and it too has two parallel lines of SSP wall with a 450 mm (18 inch) thick concrete slab spanning the opening. The span is approx. 7.2 metres (23.5 ft.). The road alignment was newly constructed in 1959, and the predeceasing structure was a timber bridge with timber piled sub-structure. The watershed is approx. 2600 Ha in area with an upstream water area of 50 Ha.

The replacement structure is slated for construction this fall and consists of a 32 metre (105 ft.) clear span structure with New England Bulb-Tee pre-cast, pre-stressed girders with integral abutments founded on steel pipe piles. The new structure will be situated where the original channel was prior to 1959 and the existing structure is to be temporarily demolished and infilled.

5. SUMMARY

5.1 Environmental

From an environmental perspective, the causeway replacement program has been an unquestionable success. Post construction monitoring and more practical reporting from stakeholders, including shellfishers, recreational fishers, outdoors enthusiasts, and owners of land adjacent to the river systems, provide first hand confirmation of the program's environmental success. At sites completed under this program, upstream water quality has been rejuvenated and, accordingly, river environments including shellfish and finfish populations have rebounded.

Watershed stewardship groups and programs are becoming more prevalent across the Province, and various legislation aimed towards enhanced protection of the Island's waterways has also been enacted. The farming community has improved their practices and efforts towards environmental control. Management of the multiple sources of pollution of Island waterways must be done in concert with causeway replacements in order to achieve the desired goal of sustained water quality.

The integration of environmental management and design into the Department's Structure Replacement Program has been a natural progression; one which has been very well received by regulatory agencies and the public.

5.2 Structural

Once the Pinette structure is completed, a structure in Cardigan will be the last of the control structure types which remain on Prince Edward Island. It was constructed in 1959 and is comprised of two parallel lines of SSP with a concrete slab spanning the two with a span length of 6.4 metres (21 ft.). Currently, there are no plans to replace the existing structure, however; it is within our intermediate planning program to be reviewed within 6 to 10 years, or sooner as funding permits.

There are other structures located within the province which may not necessarily be control type structures, such as was the case in West River identified above. While these structures may play a part in water quality issues in our water courses and estuaries becoming eutrophic, they are by no means, as indicated previously, the only contributing factor.

The replacement structure sizes are typically defined by the amount of tidal passage required, which is determined through hydraulic modelling identified earlier. Aside from this, the Department does attempt to provide for adequate navigational passage by reducing water velocities through the openings, thereby enhancing stakeholder usage.

Structure types are chosen based on economics, material availability, proposed structure geometry, their intended usage (both traffic and stakeholder), environmental impacts on the structure (IE salt spray) and others. These structures are, typically, concrete deck-on-girder types, with some variation, such as pre-cast Hy-Span® structures.

6. CONCLUSION

The Design Section and the Environmental Management Division of the Prince Edward Island Department of Transportation and Public Works work very closely to determine factors which affect design, as well as provide stakeholder and public consultation to discuss perceptions, misconceptions and overall project benefits. The above noted projects identify success stories, not only structurally, but also environmentally in terms of water quality and stakeholder benefits.