R.V. Anderson Associates Limited
engineering · environment · infrastructure

445 Urquhart Crescent
Fredericton New Brunswick E3B 8K4 Canada
Tel 506 455 2888 Fax 506 455 0193
www.rvanderson.com

February 4, 2010 091971

Stantec
3 Spectacle Lake Drive
Dartmouth, NS
B3B 1W8

Attention: Ms. Shannan Murphy, B.Sc., Project Manager

Dear Ms. Murphy:

Re: Hydrotechnical Review of Additional Highway 104 Antigonish West River Bridge Options

At the request of Mr. Dwayne Cross, P.Eng., Senior Highway Planning Engineer with the Nova Scotia Department of Transportation and Infrastructure Renewal, R.V. Anderson Associates Limited performed a hydrotechnical review of the proposed new bridges over the West River on Highway 104 at Antigonish, Nova Scotia. The objectives of this assignment were to identify the hydrologic, hydraulic and fluvial effects associated with shortening the span of the proposed new bridges, to provide design recommendations for the hydraulic opening of the proposed new bridges, and to give a “specialist opinion” for presentation to regulatory agencies. Our hydrotechnical review included consideration of the components listed below, the results of which are presented in the following sections:

- the determination of design flows and an assessment of the predicted effects of climate change,
- a review of the potential effects of tides and storm surges at the project site,
- an assessment of the effects of the proposed new bridges on local flood levels,
- an assessment of the scour potential at the site of the proposed bridges, and
- a review of the local ice regime and an assessment of the expected effects of the proposed new bridges on ice and debris passage.

Our report issued “Hydrotechnical Review of Highway 104 Antigonish West River Bridge Options” dated October 23, 2009, a minimum span of 70 m for the proposed new bridges on Highway 104. For 70 m bridge spans, it was concluded that:

- the proposed bridges would increase the local flood level elevation during a 100 year return period flood (with allowances for climate change) by 0.26 m,
- the scour depths during flood events could be up to 2.0 m and formation of a 0.3 m to 0.4 m deep permanent pool would occur at the crossing site, and
- the proposed bridges are not expected to affect the local ice regime or the local movement of ice, and the proposed bridges are not expected to aggravate the local ice related flooding in Antigonish.

In summary, the hydrotechnical effects of shortening the span of the proposed new Highway 104 bridges over the West River near Antigonish from 241 m to 70 m were not predicted to be major. No hydrotechnical reasons were found why the Nova Scotia Department of Transportation and Infrastructure Renewal could not consider reducing the span of the proposed bridges. A copy of the report is attached (Attachment One).

A disposition document has been prepared by R.V. Anderson Associates Limited in response to comments arising from the review by regulators at the Department of Fisheries and Oceans, Nova Scotia Natural Resources and the Highway 104 at Antigonish Community Liaison Committee of our *Review of Highway 104 West River Bridge Options* report (see Attachment Two). Additional clarification or discussion is provided with respect to the comments made by the regulators. In our opinion, the comments made by regulators do not invalidate the findings of the previous report.

At the request of Mr. Dwayne Cross, P.Eng., Senior Highway Planning Engineer with the Nova Scotia Department of Transportation and Infrastructure Renewal, R.V. Anderson Associates Limited has performed additional hydrotechnical analyses for bridges with a span length of 140 metres (2 - 70m spans for each bridge), in addition to the original bridge design - 241m. In so doing, we reviewed our results for the spans in the original report and created new summary tables of water levels for no new bridge, bridges with a 241 m span (original bridge design), bridges with a 140 m span, and bridges with spans presented in our original report. We also evaluated scour for these bridge spans. The remainder of this letter addresses the results of the additional analyses.

1.0 Flood Levels

Tables 1 to 5 below provide water levels derived for the West River using HEC-RAS model. For the additional analyses presented in this report, no changes were made in the design flows presented in our previous report. Although the HEC-RAS model was not calibrated with field measurements of water levels during high flows, and there were constraints on the available information and modelling approach, we believe the information presented below should be adequate for defining the expected flood levels near the proposed bridges for the purposes of an environmental assessment.

Table 1 provides estimates of flood levels at a model cross-section approximately 84 m upstream of the proposed site of the upstream bridge for the eastbound lanes. These represent the water levels upstream of the proposed bridges. The estimates presented In Table 1 are generally within 0.1 m of those presented in our original report, with the differences due to slight refinements in modelling, i.e., the definition of bank stations.

Table 1: Water Level Elevations Upstream of Proposed New Bridges (X-Sect 10.280)

	Return Period of Flows			
Bridge Span (m)	**2 year**	**20 year**	**50 year**	**100 year**
50 m	6.72 m	8.16 m	8.67 m	9.08 m
70 m	6.70 m	8.09 m	8.57 m	8.94 m
90 m	6.69 m	8.07 m	8.54 m	8.91 m
140 m, one 2.5 m wide pier, sloping abutments	6.68 m	8.03 m	8.49 m	8.84 m
241 m, three 2.5 m wide piers, sloping abutments	6.67 m	8.00 m	8.44 m	8.77 m
No Bridge	6.67 m	7.99 m	8.42 m	8.76 m

Table 2 provides estimates of differences in flood levels compared to the no bridge scenario at the same cross section as Table 1. Water levels associated with a 1:100 year flood event would be approximately 0.3 m higher with a 50 m bridge compared to the situation with no new bridges. The information presented in the table below supports the statement in the previous report that the local increase in flood level elevation during a 100-year return period flood (with allowances for climate change) due to the proposed bridges with 70 m spans would be less than 0.3 m (with estimates of approximately 0.3 m in the previous report and 0.2 m in the table below).

Table 2: Increases in Water Level Elevations Upstream of Proposed New Bridges (X-Sect 10.280) Compared to No New Bridges

	Return Period of Flows			
Bridge Span (m)	**2 year**	**20 year**	**50 year**	**100 year**
50 m	0.05 m	0.17 m	0.25 m	0.32 m
70 m	0.03 m	0.10 m	0.15 m	0.18 m
90 m	0.02 m	0.08 m	0.12 m	0.15 m
140 m bridge, one centered 2.5 m wide pier, sloping abutments	0.01 m	0.04 m	0.07 m	0.08 m
241 m bridge, three 2.5 m wide piers, sloping abutments	0.00 m	0.01 m	0.02 m	0.01 m

2.0 Scour Potential

Our previous report titled *Review of Highway 104 West River Bridge Options* contains an extensive discussion of scour potential. As pointed out in that report, the scour that could occur at the site of the proposed bridges consists of: degradation scour, the movement of bed forms, contraction scour and pier/abutment scour. Degradation scour and the movement of bed forms are natural processes that would occur if a bridge is present or not, and were discussed and quantified in the original report.

a. Contraction Scour

As part of the additional analyses presented in this report, contraction scour was evaluated. Contraction scour occurs when flow in a stream at flood stage is contracted. It results from increased flow velocities associated with the contraction of the channel width at the bridge sections. Contraction of flow at the bridge site would result if the bridge is constructed in a narrow river reach compared to adjacent upstream and downstream reaches. The contraction of flow, however, at a bridge site more likely would be the result from the flow area of the channel being blocked by piers, by abutments encroaching on the channel, or by the bridge approaches cutting off flood-plain flow.

Contraction scour, unlike longer term degradation, is often cyclical, with scour occurring as the flood stages increase and filling of the scour holes as the flood stages drop. Nonetheless design must consider the maximum depth of contraction scour.

Contraction scour is estimated using various empirical and semi-empirical equations. We applied primarily the Laursen and CSU equations during our work. The results depend upon whether live-bed or clear-water scour is assumed. Under live-bed scour conditions, scour holes created during a flood event will fill in with mobile bed material from upstream channel reaches after the flood flows recede; while under clear-water scour conditions little or no mobile bed material is available from upstream channel reaches to fill in the scour holes after the flood flows recede, and these scour holes are more permanent. For HEC-RAS, we generally assumed live-bed conditions with respect to the channel and clear-water scour with respect to the overbank areas.

Based on our evaluation of contraction scour, we estimate that the depths of general scour would be approximately 1.5 m, 0.5 m, and 0.3 m for bridges with overall spans (top of abutment to top of abutment) of 70 m, 140 m, and 241 m respectively (the latter two bridges containing piers). Therefore, we believe the statement “Preliminary model indications from RV Anderson are that scour may occur due to the contraction of flood flows, potentially resulting in a temporary scour depth of approximately 1.5 m following a 1:100 year event.” (as made in reference to the 70 m span bridges) remains valid.

Contractions scour would likely not be of uniform depth across the channel. If a bridge is located at or near a bend, the contraction scour may be greater near the outside of the bend where the depth of flow is greater (this effect is minor for the proposed bridge locations). The thalweg (the line of maximum flow velocity and depth down a channel) likely shifts in a transverse direction across the channel going though the river bend, so the location of maximum scour across a channel may differ in a longitudinal direction. Furthermore, the thalweg may change during a major flood event.

We believe that contraction scour on the left and right bank sections would be less than contraction scour in the main channel. We do not provide estimates of the scour in these overbank areas as we do not consider the model results to be adequate for this purpose.

b. Other Scour

As previously mentioned, types of scour include degradation scour, the movement of bed forms, contraction scour and pier/abutment scour. Degradation scour and the movement of bed forms are natural processes discussed and quantified in our original report. Abutment and pier scour (local scour immediately in front of piers and abutments due to local flow turbulence) are discussed briefly below.

Pier scour applies only to the 140 m and 241 m bridges. Estimates of the pier scour depend upon a number of factors, including the size and shape of the piers and most importantly their location in the bridge cross section. As design changes may be made to pier configuration, we performed only rough estimates for two cases to illustrate the range of pier scour depths that could be encountered. To do this, we used Figure 4 titled “Comparison of Scour Formulas for Variable Depth Ratios (y/a) after Jones[32]” as presented in the US Department of Transportation’s Evaluating Scour at Bridges Second Edition” dated February 1993. For the 241 m total span downstream bridge (eastbound lanes), the ranges of pier scour depth associated with the 1:100-year return period flood for the left bank, center and right bank piers was estimated as 4.0 m to 4.5 m, 4.0 m to 5.4 m ,and 3.8 m to 5.0 m respectively for 2.5 m wide piers. We expect the pier scours would be similar for the upstream bridge. For the upstream 140 m span bridge with a centre pier, which would be located on the right flood plain, the range of pier scour during a 1:100 year flood for a 2.5 m wide pier would be in the range of 2.1 m to 4.7 m. The lower range limits are from the Laursen equation and the upper limits from the Melville and Sutherland equation.

In the previous report, no abutment scour was expected for the proposed new bridges of 70 m and 90 m. This estimate was based on the equation developed by T.W. Sturm and N.S. Janjua (ASCE Journal of Hydraulic Engineering, 120 (8): 956-972). The application of this equation also predicts no abutment scour for the bridges with spans of 140 m and 240 m. Using the Froehlich equation and the output from the HEC-RAS model, depths of abutment scours more comparable to the estimates of pier scour above were estimated. However, we believe that these estimates are over-estimated due to the relatively course data from the HEC-RAS model. In the interpretation of the above scour depths, it should be noted that means to mitigate scour were not considered in the modelling.

Pier and abutment scour are of primary concern during bridge design. Measures can be taken during design and construction to greatly reduce the possibility of occurrence and the magnitude of these types of scour.

We believe that our pervious total scour estimate of between 1.1 m to 2.0 m, excluding consideration of pier scour, remains valid for all bridge scenarios considered. This opinion is based on field observations and calculations done during the course of the study.

3.0 Ice Regime

Generally the selection of larger bridge spans (140 m and 240 m) would allow for greater passage of ice. As the bridges with a span of 70 m were not deemed to interfere with the local ice regime, this conclusion also stands for the larger bridge spans. In summary, the local ice regime is not expected to have significant effects on the proposed bridges, the proposed bridges are not expected to affect the local ice regime or the local movement of ice, and the proposed bridges are not expected to aggravate the local ice related flooding in Antigonish.

4.0 Conclusions

Based on the above information, we have drawn the following conclusions:

1. Conclusions presented in our previous report are supported by the additional analyses.

2. The proposed bridges with a 70 m span are predicted to increase the local flood level elevation during a 100-year return period flood (with allowances for climate change) by approximately 0.2 m compared to the situation with no bridges. For proposed bridges with total spans (top of abutment to top of abutment) of 140 m and 241 m, the increases in local water levels upstream of the bridges are estimated to be 0.08 m and 0.01 m respectively.

3. The proposed new bridges are predicted to result in the formation of a 0.3 m to 0.4 m deep permanent pool at the crossing site. The depth of this pool is predicted to increase temporarily to between 1.1 m and 2.0 m during large flood events.

4. The local ice regime is not expected to have significant effects on the proposed bridges, the proposed bridges are not expected to affect the local ice regime or the local movement of ice, and the proposed bridges are not expected to aggravate the local ice related flooding in Antigonish.

I trust this information serves your current needs. If you have any questions or require additional information, please contact us at your convenience.

Yours very truly,

R.V. ANDERSON ASSOCIATES LIMITED

Hans Arisz, M.Sc.E., P.Eng.
Associate Director

Encls. Attachement One, Attachment Two

ATTACHMENT ONE

ORIGINAL REPORT ISSUED ON OCOBER 23, 2009

ATTATCHMENT TWO

RESPONSES TO REGULATORS

Response to Comments: Review of Highway 104 West River Bridge Options

This disposition document has been prepared by R.V. Anderson Associates Limited in response to comments arising from the review by regulators at the Department of Fisheries and Oceans, Nova Scotia Natural Resources and the Highway 104 at Antigonish Community Liaison Committee of the *Review of Highway 104 West River Bridge Options* report.

Comment No.1:

Charles MacInnis, Area Chief of the Oceans and Habitat Division for the Gulf Area of Nova Scotia, Fisheries and Oceans Canada	we should be careful using data from watersheds with different flows. and one more point, my experience tells me that wrights river and west are very close and have similar watersheds and development and is 11% enough given the kind of damage we have seen the last 10 years especially to your departments infrastructure?

Response:

In our hydrologic investigation, flood flows, as derived for different statistical distributions using the CFA-3 computer package, are averaged to estimate the 2-year, 20-year, 50-year and 100-year return-period flood flows at five hydrometric stations. The design flows for the West River at the site of the proposed bridges are based on the average of the flood flows prorated by the ratio of drainage areas for each of the five stations. The resulting value for the 100-year flood is 645 m^3/s.

The values of 100-year flood for the five hydrometric stations range from 326 m^3/s for station 01EO001 St. Marys River at Stillwater to 1300 m^3/s for station 01DR003 Rights River near Antigonish. The flood estimate for station 01DR003 is more than twice the estimated flood flow for any of the other stations (and is based on four distributions, as one distribution is discarded since it results in much greater values of flood flows than the other distributions). Some justification exists for discarding station 01DR003 altogether: it is the smallest in drainage area of the five basins and smaller than the West River drainage area at the proposed bridge site, it has a short period of record reducing the reliability and increasing the uncertainty of any estimates of flood flows over 20 years, and its basin is believed to be more developed and therefore more flashy (more likely to have higher peak flows) than more rural watersheds such as the West River above the site of the proposed bridges. Nevertheless, flood-flow estimates for station 01DR003 Rights River near Antigonish (as one of the five stations) are used in our determination of design flood flows. Therefore, as the other stations have much lower estimates of flood flows, we believe we are conservative (higher flows) in our estimation of design floods.

Other combinations from the five stations provide different results. If only stations flowing to the Gulf of St. Lawrence are chosen, the 100-year flood flow estimate is 768 m^3/s. This is higher, but reflects the high values of station 01DR003. If we use only the three stations with 20 or more years of record, probably a better approach from a statistical standpoint, the 100-year design flood flow is 444 m^3/s. Our recommended 100-year design flow of 645 m^3/s is between the other two 100-year flood flow estimates.

Flood estimation is the application of statistical methods to inadequate data sets. As with many engineering problems, judgement must be used. Based on observed flows and our statistical analyses (further supported by the observation that the water levels and extent of flooding are relatively insensitive to changes in flood flow magnitude), we believe that the information provided by the reviewer does not justify a change to our design flood estimates and that the design flows are satisfactory.

The multiplication factor for climatic change of 1.108 (i.e. 11%) is based on the 2086 anomaly of 5-day maximum precipitation for longitude -62.14° and latitude 45.62° based on GCM AR4.NCARPCM model output for Scenario SR-B1 (extremes) as derived from website http://www.cccsn.ca/Scenarios/Scatter-Plots/tools/Scatter-plot-e.phtml. Different values could be obtained from different models and different scenarios, but we use the model and scenario that we believe provide a reasonable site-specific estimate of climate change. Please note that we are applying the 11% climate-change multiplier to what we believe are conservative flood flow estimates.

In summary, we agree with the observations that the hydrology near Antigonish is variable and that the effects of climate change are evident in the project area, but are confident that the design flow magnitudes selected for our assignment are appropriate, and are confident in our findings as presented in our original report.

Comment No.2:

Dwayne Cross" <CROSSDW@gov.ns.ca>	Part c. Contraction scour: - Large difference in model results. Please expand and explain.

Response:

The estimated depths of contraction scour cannot be considered absolute, and are provided as an indication of expected magnitude of contraction scour. Equations for estimating scour are empirical or semi-empirical, and based on different information requirement s and underlying premises. . The results depend upon whether live-bed or clear water scour is assumed, the latter was used for calculations of channel contraction scour. During a flood event, bridges on coarse bed rivers can be subject to clear water scour at low discharges, live bed scour at higher discharges and then clear water scour as water levels fall. Furthermore, some contraction scour equations do not take into consideration bed material size
Re-examination of the calculations support our original contention that the contraction scour depth from bridge construction should be less than 1.5 m.

Comment No.3:

Randy Milton Manager Habitat Programs Kentville, NS	The report and recommendations by Stantec are based in-part upon the predicted hydrological results. We are in agreement with Stantec's recommendation (Section 3.0) on how to minimize impacts to sensitive terrestrial species and uncommon habitats with the proposed changes to the design of the crossing. However we are tempering our support with the caveat that hydrological responses to climate change, such as predicted sea level rise, increased frequency and height of storm surges, and changes in precipitation patterns, will not affect flood levels, scour potential, or ice regime or their impacts to sensitive species and uncommon habitats in the vicinity of the crossing. We recommend that TIR consider these impacts before making their decision.

Response:

With respect to the effects of increased rainfall due to climatic change on flow conditions at the proposed bridge sites, our approach was to adjust the flood flows by a multiplication factor for climatic change of 1.108 (i.e. 11%), which is based on the 2086 anomaly of 5-day maximum precipitation for longitude -62.14° and latitude 45.62° based on GCM AR4.NCARPCM model output for Scenario SR-B1 (extremes) as derived from website http://www.cccsn.ca/Scenarios/Scatter-Plots/tools/Scatter-plot-e.phtml. Different values could be obtained from different models and different scenarios. In our opinion, the model and scenario that we use provide a reasonable site-specific estimate of climate change.

We do not expect storm surges directly affecting the bridge sites, as the invert elevation of the West River channel at the site of proposed bridges is approximately +3.5 m (geodetic datum). Storm surges linked to pressure in the atmosphere coupled with shelf waves can cause a rise in the sea level of between 10 and 50 centimetres above predicted levels (reference: Fisheries and Oceans Canada. The Gulf of St. Lawrence - A Unique Ecosystem > 2. Overview of the Ecosystem. http://www.glf.dfo-mpo.gc.ca/os/goslim-gigsl/s-2-e.php Last accessed: February 3, 2010). It is our opinion that a change in downstream sea levels by 0.05 m would not cause a major increase in the 1:100 year water levels in the vicinity of the proposed bridges.

Considering static water changes of 1.13 mm/yr for Pictou, Nova Scotia, the water level rise at year 2100 would be 0.11 m above those of 2000. Based on approximate analyses using HEC-RAS, adding 0.11 m for sea level rise and 0.05 m for storm surges to downstream water levels a possible increase in the 1:100 year water levels in the vicinity of the proposed bridges was crudely estimated as roughly 0.4 m higher (in 2100) than if no changes in downstream water levels occur. This is due to the effect on flow conveyance through downstream bridges. Rigorous modelling work of the effects of storm surges and sea level rise (and evaluation of storm surge heights and sea level rise) on the water surface profiles was not performed to rigorous standards, and thus we feel the model results may over- estimate water level increases at the proposed bridge sites.

Comment No. 4:

CLC Position Statement on Proposed Changes to the West River Bridge, Highway 104 at Antigonish Project Date: November 20, 2009	• Modelling data taken from watersheds other than the specific area of West River under question; ……. • Use of 2005 data instead of more recent and up-to-date information. Subsequent

Response:

Without a hydrometric (stream gauging) station on the West River in the vicinity of the bridges, it is necessary to estimate flood flows by prorating (based on drainage basin areas) the results of single station frequency analyses done using flow data collected at nearby hydrometric (stream gauging) stations. Hydrometric data undergoes a review process before it is published in useable format. Recent hydrometric data (later than 2005) would have been useful, but a more important consideration is the length of the period of record. In any case, we believe the hydrometric data available to us was adequate for the purpose of estimating design flood flows for the hydrotechnical analyses of water level changes upstream of the proposed bridges.

Comment No. 5:

CLC Position Statement on Proposed Changes to the West River Bridge, Highway 104 at Antigonish Project Date: November 20, 2009	The geographical scope of the two consulting reports is not sufficiently large enough to fully assess upstream flooding impacts on agricultural land (e.g. Brierly Brook should be included).

Response:

The upstream flooding is beyond the scope of the present study concerned with the effects of the proposed bridges on water levels. In the interpretation of these water level increases it should be noted that these backwater effects are expected to be limited to the 1.0 km reach of the West River immediately upstream of the proposed bridges (i.e. they are reduced to near zero increases in water level elevations within this reach). In other words, the bridges will not affect flood levels upstream of this point 1.0 km upstream of the proposed bridge locations.

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