Chapter 5: St. Clair River Hydraulic Regime – Dr. C. Rennie Comments and Study Response

I have reviewed Chapter 5 of the Draft Report, except Section 5.6 on isostatic rebound. I found the summary to reflect the original reports that I reviewed. I had the following comments.

Page 104 footnote is incorrect: "laminar" is not equivalent to subcritical

> The text in the footnote correctly defines the flow regime based on the Froude Number.

Page 105 description of hydraulic radius is incorrect. The phrase "inverse of the" should be removed. It would be simpler to say that hydraulic radius is the ratio of cross-sectional area to wetted perimeter.

> The traditional definition of hydraulic radius as the ratio of area to wetted perimeter will be used to avoid confusion.

Page 105. Please continue use of "US customary units" instead of "conventional units".

> The report has been revised accordingly.

Page 113. This reviewer found Bruxer's analysis of actual head-discharge data to be the most compelling indication of conveyance change. Inclusion here of the observed difference in required head for equivalent discharge would be worthwhile. Such a statement is provided in the summary on p118, wherein 8-10 cm change in required head is specified. Bruxer's Figure 6-5, supplemented by Figure 3 in Bruxer's response to review comments, suggest conveyance change resulted in an observed change in required head ranging from 7 cm to 20 cm to produce equivalent discharge.

> The authors appreciate the comments from the reviewer regarding the analysis of actual head-discharge data provided in Bruxer (2009); however, the reviewer's suggestion that an observed change in required head ranging from 7 cm to 20 cm to produce equivalent discharge is inaccurate and is addressed below.
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> As explained previously (Bruxer, 2009), in this analysis all measured flows (ADCP and conventional) from the St. Clair River and corresponding measured water levels at the time of measurement were sorted in order of their time of collection. Each flow measurement was then compared to all other measurements taken at some time after it, and similar pairs were identified in one of two ways: first, all pairs of flow measurements separated by more than one year and having a difference in downstream water level at St. Clair Shores on Lake St. Clair of less than 5 cm and a difference in measured discharge of less than 100 m3/s were identified ("Dataset 1"); second, all pairs of flow measurements separated by more than one year and having a difference in downstream water level at St. Clair Shores of less than 5 cm and a difference in upstream water level at Fort Gratiot of less than 5 cm were also identified ("Dataset 2"). Each of these two resulting sets of paired measurements can be considered to have the same boundary

conditions, and the difference in their measured Fort Gratiot water level or measured discharge, respectively, can be used to help identify possible changes in conveyance over time, without the use of a hydrodynamic model. The results indicated that between 54.3 and 69.0 percent of all measurement pairs showed a significant increase in conveyance, whereas between 12.6 and 17.9 percent showed a decrease in conveyance, based on the criteria specified (see Bruxer, 2009). This was suggested as evidence that conveyance changes have indeed occurred, and that the result has been an overall increase in conveyance.

However, the author deliberately avoided attempts at conclusively quantifying the magnitude of the conveyance changes observed in the flow measurement comparisons due to the great deal of uncertainty in the analysis and the measurement data itself. These issues include: possible biases resulting from differences in measurement technologies and methods; the water levels at the time of measurement, since it has been observed that the fall between Lake Huron and Lake Erie is greater during periods of high water levels than during periods of low water levels; the time of year, since weed growth could affect the measured flows, and differences in weed growth during the time of measurement could affect any pairs of flow measurements being compared; and meteorological factors, such as wind in particular, which is known to cause differences in water level and flow in large channels such as the St. Clair River. These issues are amplified by the lack of measurements during many years, particular during the 1980’s and early 1990’s, which correspond to a period of high water levels.

To further illustrate these issues, it must be understood that because there are only a small number of flow measurements from the early-1980’s to mid-1990’s, only a small number of pairs having similar boundary conditions were obtained from this era. This era also corresponded to a period of relatively high water levels, whereas the periods of the 1960’s and 2000’s, for which there are a great deal more measurements available, correspond to periods of relatively low water levels. Because of this, there are far more matching pairs of measurements between the 1960’s and 2000’s, and these tended to occur during periods of low water levels and flows. This fact in itself will bias any estimate of the magnitude of the conveyance change based on flow measurements towards the low side. Additionally, if one measurement in a pair were taken in early spring and the other in late summer, differences in weed growth could cause differences in flow resistance, which would significantly impact the comparison. Furthermore, many flow measurements are compared multiple times to other flow measurements, so if one such measurement were biased for any reason, it could have a disproportionate affect on the estimated magnitude of conveyance change if it were compared to multiple other measurements. Add in the differences in measurement techniques (conventional vs ADCP) _and methods being compared, and one can understand why it was impossible to separate these issues out from the flow measurement comparisons. Therefore, the author did not give estimates of the magnitude of the changes in conveyance, neither in terms of changes in flow nor changes in hydraulic head.

The figures given in the original response to the peer review comments showing differences in flow profiles along the river were two selected among hundreds of comparisons of measurements made in this analysis. The two selected do not give an accurate representation of the range of the change in head-difference required to convey flow over time. The original figure was meant solely for illustration purposes to show that it may be possible to identify where changes have occurred in the river, including whether those changes have occurred partly in the St. Clair River Delta, which could not be investigated with the hydrodynamic modelling analysis performed. It is again stressed that these diagrams were not meant to give an accurate estimate of the magnitude or even a range of the observed change in head required to convey flow.

Table 1 below shows more representative statistics of the magnitude of the change. For example, for measurements separated by 35 years of more (highlighted), the total number of pairs found to have similar boundary conditions (in this case downstream water level difference of 5 cm or less and measured discharge of 100 m^3/s or less) was 714. The change in head over time required to convey the equivalent flow was found to be 14 cm on average with a standard deviation of 6 cm, and a minimum change of -4 cm and a maximum change of 35 cm. Therefore, if it is assumed that all measurements and comparisons of pairs having similar boundary conditions are valid, it could be suggested that rather than a change in head of between 7 and 20 cm, as the peer reviewer suggests, the change ranged from -4 to 35 cm.

Minimum time between measurement pairs (yrs)	Measurement Pairs	Change in Head Required to Convey Equivalent Flow (m)*			
		Avg.	St. Dev.	Max.	Min.
40	347	0.15	0.05	0.29	0.04
35	714	0.14	0.06	0.35	-0.04
30	845	0.13	0.07	0.35	-0.13
25	845	0.13	0.07	0.35	-0.13
20	899	0.13	0.07	0.35	-0.14
15	932	0.12	0.08	0.35	-0.17
10	1001	0.12	0.08	0.35	-0.17
5	1080	0.11	0.09	0.35	-0.22

Table 1: Statistics regarding change in head-difference required over time. * Note that these numbers are subject to uncertainty and contain biases as explained in the text.

The spread of these estimates, the uncertainty in the analysis, and the additional factors affecting measured flows that could not be separated from the analysis prohibit a quantifiable estimation of the magnitude of the conveyance changes that have been observed over time. Therefore, the authors do not feel comfortable providing a quantified estimate of the magnitude of conveyance changes observed at this time for inclusion in the final St. Clair River Task Team report. That being said, going forward, if given a more frequent and continuous measurement program, standardized measurement methods and techniques, and quantification of flow measurement uncertainty, the authors suggest that this type of analysis may be useful for monitoring and identifying any possible future or ongoing changes in the channel conveyance of the St. Clair River.

Page 122-123. The justification for model approach appears to consider only the question of conveyance. This may be due to the specific science questions posed for Chapter 5, but the overall study objectives were not limited to an evaluation of conveyance change. 1D modelling may be appropriate for conveyance estimates, but not for local sediment transport and morphodynamic modelling. Further, the justification for 2D versus 3D focuses entirely on the (lack of) importance of vertical velocities. This discussion fails to recognize that 2D models do not readily predict cross-stream currents in channel bends due to inadequate consideration of momentum exchange, as was previously stated by the review team. Accurate prediction of secondary currents is important for sediment transport and morphodynamic modelling in channel bends. The study team, supported by the review team, considered 3D modelling to be excessive to address the study objectives. However, limitations of 2D modelling should be acknowledged. A 3D model study was in fact also conducted, but this was not mentioned in the Draft Report. Liu and Parker compared shear estimates from their 2D model to shear estimates from a 3D model. The results were comparable. It would be useful to mention this in the Draft Report, as further justification for the 2D approach.

At a practical level, the comment is valid. In the draft report, aspects related to hydraulics were dealt with in Chapter 5. Any issues related to morphodynamics were discussed in Chapter 4 including sediment transport using 2-D and 3-D modelling. In the final report, the section dealing with model justification has been strengthened to explain the rationalization and issues in the selection process.

Page 129. This reviewer previously raised an issue regarding the model bathymetry uncertainty analysis performed by Bruxer and Thompson. Bruxer and Thompson employed random bathymetry errors, whereas bathymetry errors would have been greater in non-surveyed areas of the river bed where interpolation was required. This criticism was acknowledged by Bruxer and Thompson as a weakness of the uncertainty analysis. Perhaps some discussion is required in the Draft Report.

At the peer review on uncertainty, the practical considerations were raised and discussed. The Study clearly were interested in tackling the uncertainty issues as best and as practical as possible. The Study did carry out exhaustive uncertainty analysis as part of the needs identified and documented the impact of bathymetric uncertainty on conveyance change estimate. The Study also tried to capture the essence of uncertainty by conducting detailed sensitivity analysis. It is acknowledged, that the ideal would be to conduct the analysis on all potential sources of uncertainty in the model like Manning's roughness, interpolation schemes, surface representation, etc. With the time compression on this part of the Study, a calculated decision was made to restrict the analysis to the key source of uncertainty.