General Response to the Review Comments

The authors are grateful for the time and effort of the two reviewers. Their comments are very helpful in improving the overall quality of the report. We attempt to address each comment below.

Response to the review comments by Dr. Brian Barkdoll

The following are the responses (in red) to the questions in the section "Comments for Transmission to Authors"

1. *Section 2.2.1 needs justification for the use of these equations. Are they applicable to river bends, or just for straight river sections? What are the conditions for which they were developed? Please justify?*

There is no Section 2.2.1 in the report. The reviewer might be referring to Section 2.1.1. This section deals with the calculation of hydraulic resistance. The formulas for Cz and Cf are applicable to river bends as long as the depth-averaged flow velocity is properly modeled.

2. *Justify the use of "the value of nk is fixed as 2". Why this seemingly arbitrary value?*

In open channel hydraulics, it is very hard to estimate the exact value of roughness given the complexity of the natural river. For engineering purpose, it is a common practice, with satisfactory accuracy, to relate the roughness to some sediment diameter. The nk value is not arbitrary, but takes a value in certain range. For example, Kamphuis (1974) evaluated nk as equal to 2, which is the value used in this study as well as in many others. Also, this value for roughness is only a starting point for the calibration process.

Reference:

Kamphuis, J. W., 1974, Determination of sand roughness for fixed beds, *Journal of Hydraulic Research*, 12(2): 193-202

3. Please show the locations of Thalwegs 1 through 4 referred to in Table 1.

Brief descriptions of the locations and the source of the data have been added. Reference to the report by Bommanna Krishnappan is given for more details.

4. *Explain how you came up with the Hydraulic Condition Sets for Table 3. Was it based on certain return period flows or what? Now it seems arbitrary.*

The three sets of hydraulic conditions were chosen for the calibration from the flow measurements. They represent characteristic low, medium, and high discharge conditions, which span the whole flow duration curve. They are not arbitrary. Special care was taken to make sure the river was under relatively stable conditions when we chose the three dates.

5. *Please explain results of Figure 2. It seems like the predicted match the observed for Hydraulic Condition Set 1 only. Is this acceptable or not? Please discuss.*

Figure 2 shows the calibration results for roughness. The model results match the Hydraulic Condition Sets 1, 2, and 3 using only roughness condition Set 1. This is the reason that roughness condition Set 1 is chosen for the calibration result.

6. *Table 5 and Fig. 3 do not seem to agree with each other in the sense that Table 5 mentions grid spacing of up to 800 m, but Fig. 3 seems to show a much denser grid. Please clarify.*

Fig. 3 shows a mesh with the spacing of Mesh ID B in Table 5, which is much denser. I changed the title of Fig. 3 to clarify this.

7. *In Table 5 it is unclear what "mesh size" means. Is that an 800m by 800m grid, for example?*

The "mesh size" here is a parameter associated with mesh generation. The whole domain is covered by triangles. The boundary of the domain is first meshed at 800 m segments, for example. Then the internal region is triangulated by algorithms of the grid generation software. The "mesh size" controls the average size of the mesh (which can be thought of as the side length of a triangle).

8. *Try other turbulence closure models, such as k-τ and k-ω. Compare and contrast results from the various turbulence closure models.*

The turbulence model used in our study, i.e. the k-epsilon model, is the most widely used model for engineering applications. Comparison with other turbulence closures for large rivers like the St. Clair River would be of interest in a general sense. However, for the scope of this work, we believe the k-epsilon model is enough for estimations of use for the present purposes.

9. *Give the source of values in Table 6.*

The Shields diagram in Table 6 is based on the fit in Parker et al. (2003)

$$\tau_c^* = 0.5[0.22\,\mathbf{Re}_p^{-0.6} + 0.06 \cdot 10^{(-7.7\,\mathbf{Re}_p^{-0.6})}]$$

I added the reference accordingly in the report.

10. *Demonstrate that "The level drop is about 9 to 10 cm for all the cases. This number is also consistent with the results from other studies". Cite the other studies and give specific values.*

The level drops for all the cases are listed in Table 7, which shows a range of 9 to 10 cm. For a similar study using Telemac-2D, the level drop is reported to be around 13 cm comparing 1971 and 2007 (Canadian Hydraulics Center, 2008).

Reference:

Canadian Hydraulics Center (2008). Preparation of a hydrodynamic model of St. Clair River with Telemac-2D to Study the Impacts of Potential Changes to the Waterways, Controlled Technical Report CHC-CTR-074.

11. *Explain why the sudden discontinuities in Fig. 13.*

This is not a sudden discontinuity but a visual effect associated with distortion in the plot. The scales of the horizontal and vertical axis are different. The water elevation dropped only about 2-3 cm over a length of kilometers.

12. Give the calculation procedure for the following statement: "The calculation results are shown in Table 9. For 0.5%, 1%, and 5% changes of the St. Clair River conveyance, it takes 110, 55, and 11 years to lower the lake level by 0.8 m."

The following text has been added for the purpose of clarification: "*The total water volume loss is calculated by multiplying the lake area by 0.8 m of level drop. Then the time to lose that extra amount of water equals the water volume divided by the conveyance change.*"

13. In the discussion regarding draining time of Lake Michigan-Huron due to conveyance increases, is that assuming no new inflow to the Lake from precipitation and tributaries? If so, that should be stated. The lake would not really drop that fast if it was being replenished.

It is assumed that everything else is kept constant, as stated in the report. What we are calculating here is the time to drain 0.8 m depth of water in Lake Michigan-Huron by means of 0.5%, 1%, and 5% of conveyance increase in the St. Clair River.

14. In the statement "In this study, since HydroSed2D is used to calculate the shear stresses on the river bed, normal flow assumption is not necessary." What is meant by "normal flow"? Do you mean uniform flow?

"Normal flow" here is the same as "steady, uniform flow", where the bed resistance perfectly balanced by gravity force. Unsteady, uniform flow rarely exists. I changed "normal flow" to "uniform flow" in the report, since it seems that the referee prefers this, but it should be understood that we imply flow that is steady as well.

15. In Fig. 28, "Long Profile" is confusing. Do you mean "Longitudinal Bed Profile"?

They are the same. I changed "long profile" to "longitudinal bed profile" in the report.

16. The phrase "in the upstream" and similarly for downstream, would be clearer if it read "in the upstream section."

Changed.

17. Typo in Section 5.2 "Figure 1Figure 30 shows the four different bed material coverage for transect TN07-03."

Corrected.

18. Justify the use of the Engelund-Hansen sand transport method. Why not others?

Brownlie (1981) tested the performance of large number of sediment transport formulas. He found that only a few of these relations performed well at both laboratory and field scale. Among these relations, that of Engelund and Hansen is the simplest.

19. Does the range of data used in its analysis match those of the St. Clair River? Compare with other models.

If "its" means the Engelund-Hansen relation, that relation is compared against an extensive set of field data for sand-bed rivers, over a range of sizes. There are very few sediment transport relations that have been verified for streams with slopes as low as the St. Clair River. Parker and colleagues, however, have used the Engelund-Hansen relation in a morphodynamic model of the Wax Lake Delta, a subsidiary delta of the Mississippi River system. The relation was able to predict the growth of this delta over a ~ 30 year span. The river slopes in question are in the same range as the St. Clair River. In the case of the St. Clair River, however, the bed has only a discontinuous cover of sand. We cannot say for sure that the Engelund-Hansen relation is the appropriate one for such a case, but the same can be said about any other sand-bed transport relation. Rather, it seems the simplest reasonable choice.

20. *Either complete or remove the section entitled "5.3 Glacial Till Erosion Test and Analysis (To be finished by Jose Mier)"*

It is completed.

21. *Figure caption for Fig. 31 is repeated in the middle of a paragraph by mistake.*

Corrected.

22. *Give your basis for the critical wave height in the statement "Base(d) on the 0.5 ft wave height as the critical value for sediment movement, ".*

This is an assumption used by Wuebben et al. (1984). We just listed their conclusions as a starting point for discussion.

23. *Describe efforts of mesh size studies for 3D and 1D models in addition to the 2D model.*

3D modeling was only done for the upper portion of the river at the first two bends. The mesh size (1.5 million cells) used in this study reaches the limit of which our computer could accommodate. Special care was taken to have at least 2-3 layers of fine cells close to the river bottom to capture the law of the wall, which is very important in the computation of bed shear stresses. The 1D model is used only for the backwater curve analysis. The spatial step size was refined and tested to give mesh-independent free surface profiles.

24. *Justify use of Parker gravel transport method including assumptions and applicability for the St. Clair River.*

The bed surface of the St. Clair River is covered predominantly by gravel and shells, especially in its upper reaches. There is no accepted bedload transport equation for shells. In the case of gravel, the Parker relation, which is based on field data, is one of the four gravel transport relations for mixtures recommended in the American Society of Civil Engineers Manual 110, Sedimentation Engineering. It would appear to be appropriate for the gravel-bed St. Clair River. Another option would have been the relation of Wilcock and Crowe (2003). This relation, however, specifically requires information about the sand sizes in the surface layer. The sampling techniques used for the St. Clair River appeared to be insufficient for this purpose.

Specific comments:

Legends in graphs are too small many times.
The size of the legends has been increased.

There are many grammar corrections to be made. Some follow here, but there are many others. A careful editing is needed.
The following grammar corrections have been done accordingly.

1. *Modify "The roughness is important since it is the parameter which defines the drag force experience by the flow." To read "The roughness is important since it is the parameter which defines the drag force experienced by the flow."*

2. *Modify "The roughness of the first two bends area is determined by sediment sizes based on the analysis of the under water images." To "The roughness of the first two bend areas is determined by sediment sizes based on the analysis of the underwater images."*

3. *Modify "The zones for roughness: (a) the whole river (b) the upstream part In each zone, the Manning's n is adjusted to match the simulated water surface elevations with the measurements." To "The zones for roughness are (a) the whole river and (b) the upstream part. In each zone, Manning's n is adjusted to match the simulated water surface elevations with the measurements."*

4. *The calibration section seems disjointed with no connected phrases telling why each equation is mentioned or how they are used in the calibration process.*

5. *Modify "Table 1. Roughness calculation based on sediment size distribution from images analysis" to read "Table 1. Roughness calculations based on sediment size distribution from image analysis"*

6. *Modify "For a large, as well as complicated, lake-river system of the Lake Huron-St. Clair River-Lake St. Clair, a decent mesh with high quality is important for the creditability of the simulation results. The mesh needs to be as fine as possible to capture most of the geometry and bathymetry details." To read "For the large, as well as complicated, lake-river system of the Lake Huron-St. Clair River-Lake St. Clair, a decent mesh with high quality is important for the creditability of the simulation results. The mesh needs to be as fine as possible to capture most of the geometry and bathymetry details."*

7. *Modify "The reason has two folds. First, there are a lot changes around the bends (such as the big scour hole, the tongue features, and historical ship wreckages).*

Second, there are numerous changes around the bends (such as the big scour hole, the tongue features, and historical ship wreckages)."

8. *Modify "As shown in the shear stress analysis, the contraction from the Lake Huron to the St. Clair River makes the bottom shear stresses highest in this area." To "As shown in the shear stress analysis, the contraction from Lake Huron to the St. Clair River makes contains the highest bottom shear stresses."*

9. *Modify "This might lead to the explanation of the tongue features of the sand bars and their effects in terms of conveyance. Mesh is also refined in the area of the delta in Lake St. Clair. Refined mesh is needed to well represent the narrow navigation channel which controls the water surface elevation throughout the St. Clair River." to "This might explain the tongue features of the sand bars and their effects in terms of conveyance. The mesh is also refined in the area of the delta in Lake St. Clair. A refined mesh is needed to well represent the narrow navigation channel which controls the water surface elevation throughout the St. Clair River."*

10. *Modify "However, the fine mesh has more double the cell number than the intermediate mesh which makes the computational time much longer. The coarse mesh (mesh ID A) seems not representing the domain and bathymetry well and it gave a result with high level of error." to "However, the fine mesh has more than double the cell numbers of the intermediate mesh which makes the computational time much longer. The coarse mesh (mesh ID A) seems to not representing the domain and bathymetry well and it gave a result with a high level of error."*

Response to the review comments by Dr. Colin Rennie

Technical Content

1) *Section 2.1. The authors acknowledge that the model roughness was not recalibrated when running the 1971 model. As noted in the review of the Bruxer and Thompson report, a river will adjust such that it can convey its flow and sediment load. This adjustment can occur via changes in channel gradient, channel section, and/or channel roughness. It is important, therefore, to consider simultaneous changes in bathymetry and roughness. When Bruxer and Thompson evaluated the influence of recalibrating roughness in their Addendum report. Their Table 6-11 shows a small longitudinal trend in roughness change between survey years.*

We agree with the reviewer that the roughness of the river changes with time. The overall roughness might have increased thanks to the armoring of the bed. As discovered in the Bruxer and Thompson report, increasing the roughness in the river raised the water level in Lake Huron. Nevertheless, they found the change in roughness to be minimal except in the area near the St. Clair delta, where the discrepancy is most likely due to measurement uncertainty at Algonac. However, we believe that the effects of bathymetry change are far more important than the roughness change.

2) *Section 2.1.1. The roughness calibration considered only three possible sets of roughness values. Reasonable results were obtained when comparing to observed water levels. Still, further fine tuning is probably possible. Also, presumably, roughness set #1 was selected (no statement is made in the report).*

We did do some *pre-calibrations* using a much broader range of roughness sets. As a result, the three most reasonable candidates were chosen. To reduce the length of the report, only these three were documented. Although further fine-tuning is definitely possible, the roughness set #1 gave very reasonable results, making further tuning unnecessary given the large uncertainties of other variables.

3) *Section 2.2 The mesh sensitivity results are not shown.*

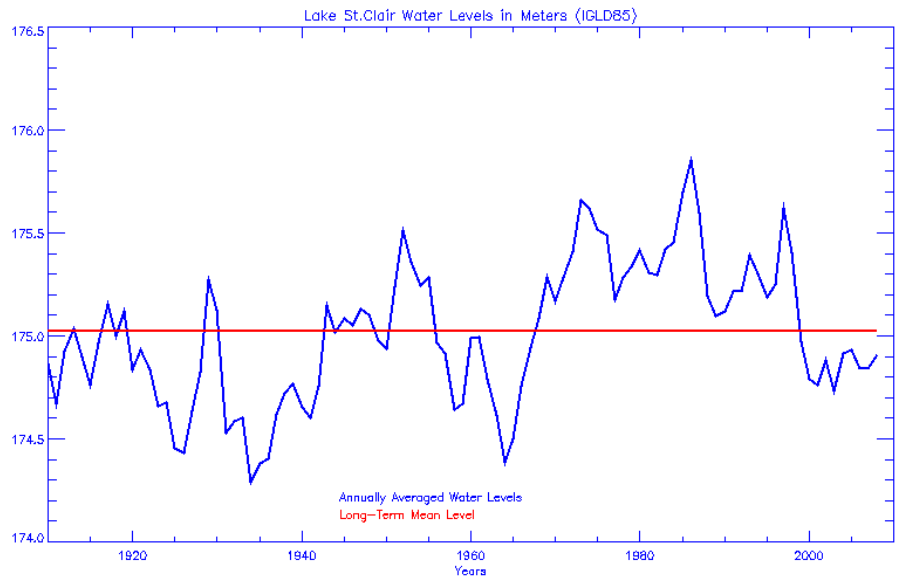
The mesh independence study was based only on visual inspection of results and comparison with measurements. We have added a comparison figure to the report.

4) *Section 4.2.1. The method to generate the mesh from the survey data is not described. Similarly, errors in the mesh bathymetry are not evaluated. The accuracy of the mesh is the single most important element of 2D or 3D model development. Estimates of mesh accuracy would be useful.*

We added information to the report to briefly describe the mesh generation process. Please also refer to our response to Dr. Brian Barkdoll’s comment #23.

5) *) Section 4.2.3. The analysis of the influence of conveyance change on Lake Huron water level (Table 9) has assumed no change in Lake St. Clair water level. Has there been a change in Lake St Clair level?*

The long-term average Lake St. Clair level has remained constant, as shown in the following figure.



(source: http://www.glerl.noaa.gov/data/now/wlevels/lowlevels/plot/St.Clair.gif)

6) *There has been no attempt to estimate model errors or the significance of observed changes. While the results appear to be reasonable, an assessment of confidence intervals would be helpful.*

We acknowledge that no model is perfect and errors do occur due to many factors. The purpose of our calibration process was to minimize model errors as much as possible. Even though no attempt was made to quantify model errors in detail, the agreement between the calibrated model and the measurements shows that our model is reasonable, in light of many other factors with even larger uncertainties.

7) *Section 5. The sediment transport modelling did not appear to utilize the routines available within HydroSed2D. Instead, sediment transport was calculated at stations distributed across a few sections, using the model output for bed shear stress. Presumably, HydroSed2D would have been able to estimate sediment transport at all model grid cells, which would have provided a full map of sediment transport. This map could be used to surmise or calculate changes in morphology. Why was this not done?*

The routine in HydroSed2D has the capability to calculate the sediment transport rate over the whole river domain if sediment (sand and gravel) information is also available for the whole river. To be more precise, the sediment information in the substrate is also need to generate a full map. However, this information is not available for the St. Clair River. We only have sediment size distribution at a very limited number of transects. This is the reason we did not use the full capacity of the HydroSed2D model.

8) *Section 5.1. The coarse fraction (gravel) transport was estimated to be essentially zero using the Parker (1990) model. This result is reasonable given the relatively low bed shear stresses estimated for the reach, and the fact that low transport and a heavily armoured bed are expected for a channel with limited sediment supply. The shear stress is below critical shear stress for gravel, so it is unlikely that any bedload model would predict significant gravel transport. However, bedload computations*

are highly uncertain, and different models yield drastically different results. It is common practice to employ multiple models in order to overcome some of this model uncertainty. It might be useful to check transport calculations using another model, particularly if bed shear in some locations of the river exceeds local critical shear stress.

It would have been possible to perform similar bedload transport calculations using, for example, the relations of Wilcock and Crowe (2003), Hunziker and Jaeggi (2001) or Powell et al. (2001, 2003). These relations are known to predict values that are similar to the relation of Parker (1990) at relatively high shear stresses. Such shear stresses are realized in only limited regions in the upstream part of the river. The main conclusion of the bedload transport analysis is that gravel transport rates are so low that the St. Clair River is, for all practical purposes, morphologically inactive. The same result would have been obtained using the other relations.

9) *Section 5.2. The criticism of the sand transport is more serious. The sand transport was estimated for a given section assuming that the entire section had a sand bed, transport was calculated for each station across the section using the local model estimate for bed shear stress, and the transport across the section was summed. The actual transport for the section was then calculated by multiplying the summed transport by the percentage of the section observed to have a sand bed (Table 14). This last step is faulty because sand is less likely to occur in locations with high shear stress, and the error is exacerbated by the fact that transport is non-linear with shear stress (see the Engelund-Hansen equation). If high bed shear were observed at a gravel bed or bedrock location in the section (a likely scenario) then very high transport would be estimated for the section, whereas actual transport could have been minimal because sand was only present in low shear areas of the channel margins. It is likely, then, that estimated sand transport rates are too high. Why wasn't sand transport estimated across the section only for locations that actually had sand bed? Nevertheless, despite this likely positive bias, total transport rates were estimated to be low.*

The criticism is valid, but the main point here is that there are no good methods to predict sand transport over a gravel bed that is only discontinuously covered with sand. As far as no clear methodology exists, we chose the simplest reasonable formulation. The reviewer is correct in noting that the sand is likely to deposit in zones of relatively lower shear stress. To the extent that these zones tend to be concentrated near banks, however, they are subject to secondary flow (more specifically, corner secondary flow) which could suspend the sand even under conditions of lower shear stress. If the reviewer wishes a more detailed resolution of the problem, however, we are willing to repeat the calculation according to the suggestion.

10) *Section 6.2. The influence of ice cover was considered qualitatively. It could have been possible to utilize a numerical model that considers ice cover (such as River2D).*

We would be glad to continue the study of the effects of ice cover if time and budget allow for this.

Presentation

1) *The manuscript could be better presented. There is no abstract, pages are not numbered, references are not sorted, figures are insufficiently labeled, and the writing could be improved.*

We did more editing work. For the abstract, we have a short accompanying summary of the report. Page numbers have been added, and references are now sorted properly.

2) *Figure 3. Which mesh is this? Presumably, it is mesh C.*

The information has been added to the figure caption.

3) *Figure 6. A colour scale is required.*

The main idea of this figure is to illustrate secondary flow in the bend. We believe that a color scale is not necessary to convey this information.

4) *Figure 11. Some lines in this figure are masked, which heads changes between years.*

This figure uses color to distinguish the original and post-dredging river bottom and water surface. Sometime the original and post-dredging lines overlap because of the lack of much change. However, the color difference allows some difference to be detected.

5) *Figures 11, 12. The distance axis label is distance from where?*

For this simple 1D backwater curve calculation exercise, the distance is from the mouth of the river. This point has been clarified in the figure captions.