St. Clair River Task Team

HYDRAULIC & SEDIMENT MODELLING STRATEGY

April 2008
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Primary Science Issues</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Science Questions Framework</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Project Matrix and Timeframe</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Hydraulic &amp; Sediment Modelling Strategy</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>Evaluation of Uncertainty</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>Assessment and Integration of Results</td>
<td>9</td>
</tr>
<tr>
<td>8</td>
<td>References</td>
<td>10</td>
</tr>
<tr>
<td>9</td>
<td>Tables and Figures</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td><strong>Annex</strong></td>
<td></td>
</tr>
<tr>
<td>P1</td>
<td>Bathymetry of St. Clair River 1971-2007</td>
<td>19</td>
</tr>
<tr>
<td>P2</td>
<td>Review of St. Clair &amp; Detroit River Rating Curves &amp; Hydraulic Performance Graphs</td>
<td>21</td>
</tr>
<tr>
<td>P3</td>
<td>Development of a Basic 1-D Modelling of St. Clair River Using HEC-RAS</td>
<td>23</td>
</tr>
<tr>
<td>P4</td>
<td>1-D Conveyance Analysis of the St. Clair River Using the Standardize HEC-RAS Model</td>
<td>25</td>
</tr>
<tr>
<td>P5</td>
<td>Application of 2-D Modelling Using Existing RMA2 Model of the St. Clair River with Different Bathymetric Data Sets</td>
<td>28</td>
</tr>
<tr>
<td>P6a</td>
<td>Application of 2-D Model of the St. Clair River Using TELEMAC Modules with Different Bathymetric Data Sets</td>
<td>31</td>
</tr>
<tr>
<td>P6b</td>
<td>Extend the model developed in P6a to the outlet of Lake Erie</td>
<td>34</td>
</tr>
<tr>
<td>P7</td>
<td>Discharge Computation of the River Using the Standardize HEC-RAS Model</td>
<td>35</td>
</tr>
<tr>
<td>P8</td>
<td>Ice Effects of Flows and Levels Using Standardized Geometry Model of HEC-RAS</td>
<td>36</td>
</tr>
<tr>
<td>P9</td>
<td>Video Transects of River Bed, Monthly Sediment Load Measurements, Cross-section Surveys, Grab samples of Bed Material - Sarnia-Pt Lambton</td>
<td>37</td>
</tr>
<tr>
<td>P10</td>
<td>1-D Conveyance Analysis of the St. Clair River using the Mobile Bed MOBED Model</td>
<td>37</td>
</tr>
<tr>
<td>P11</td>
<td>History of St. Clair River and Detroit River Dredging and Compensation Works</td>
<td>39</td>
</tr>
<tr>
<td>P12</td>
<td>Sediment Coring and Physical Testing of Substrate in the ST. Clair River</td>
<td>41</td>
</tr>
<tr>
<td>P13</td>
<td>Analysis of Bathymetric and Planform Changes in the Past 130 years and Registration into Common GIS</td>
<td>43</td>
</tr>
<tr>
<td>P14</td>
<td>Obtain and Analyze the Bottom Velocity Data from ADCP</td>
<td>45</td>
</tr>
<tr>
<td>P15</td>
<td>New Coincident ADCP and Multi-beam Data for Hydraulic/sediment Model Verification</td>
<td>46</td>
</tr>
<tr>
<td>P16</td>
<td>Analysis of Ship Effects, Both Movement and Sinking on Sediment and Erosion Regimes</td>
<td>47</td>
</tr>
<tr>
<td>P17</td>
<td>Conduct Sedimentation Studies of the St Clair River Delta</td>
<td>48</td>
</tr>
<tr>
<td>P18</td>
<td>Glacial Isostatic Adjustment</td>
<td>49</td>
</tr>
<tr>
<td>P19</td>
<td>Net Basin Supplies Comparison and Water Balance Closure</td>
<td>50</td>
</tr>
<tr>
<td>P20</td>
<td>2-D Conveyance/Morphological Analysis of the St. Clair River using SED2D or equivalent</td>
<td>51</td>
</tr>
</tbody>
</table>

*Scope of work for these projects is currently being developed*

1. Introduction

The International Upper Great Lakes Study (IUGLS) is a five year binational Study. One of its key objectives is to assess whether there is ongoing erosion in the St. Clair River and whether this may have altered the conveyance of the river. Establishing whether there was a change in conveyance, and its contributing causes is the crux of the inquiry, because there is a belief, by some, that there has been a steady increase in conveyance capacity that was triggered by the dredging of 1962, thereby lowering the levels of Lake Huron-Michigan. If no evidence can be found of a steady, progressive, or even episodic erosion, then there is no need to define causality. This objective was added to the Plan of Study for the purposes of determining the validity of the findings from a recently completed engineering study (Baird & Associates Ltd., 2005). The Study was officially launched in March, 2007, with the formation of the Study Board. Fundamental field work was subsequently approved by the Study Board. Over the following six months, Technical Working Groups (TWGs) were established and helped in the development of more comprehensive work plans. These groups are comprised of experts from both countries. Additional projects were then vetted through the TWGs and Study Board. More details on the mandate, study organization, Plan of Study, Baird & Associates report, etc. are available at www.iugls.org.

In the initial Plan of Study the St. Clair work was to be completed over three years. As a result of public and political pressure, the time frame was reduced to two years with the concurrence of the International Joint Commission (IJC). This in turn has resulted in the fast tracking of the work and basically leaves one year to complete the numerous analyses. Time restraints, utilization of applied science and technologies, available expertise, etc. have significantly impacted and shaped the Study’s work plans. An analytical strategy needed to be developed, which optimized the data collection system, use of existing models, and techniques to address the basic questions raised by the IJC and the public. These questions then, had to be transformed into a series of scientific and technical tasks and projects that would enable the Study to answer them with a high degree of confidence, despite the known inherent uncertainties.

2. Primary Science Issues

There are two primary science questions that are being addressed:

- Has the conveyance of the St. Clair River changed since the 1962 dredging?
- Has the morphology of the St. Clair River been altered after the 1962 dredging?

The term “Conveyance” is a measure of discharge carrying capacity of a channel (after Chow, V.T., 1959). In uniform flow assumptions it is sufficient to define the conveyance at a channel cross-section. On the other hand, when this definition is extended to gradually varied flows under sub-critical regimes, conveyance is defined by the reach (a linear segment of the channel) properties rather than the
section properties. The reach conveyance is commonly defined as the geometric mean of a number of section conveyances. For this Study, the term “Conveyance” is defined to encompass the reach properties.

The mathematical expressions defining “Conveyance” are:

For uniform flow consideration – the discharge is given by the Manning’s equation is:

\[
Q = \frac{1}{n} AR^{2/3} S_f^{1/2} = KS_f^{1/2} = KS_o^{1/2}
\]

And:

\[
R = \frac{A}{WP}
\]

Where:

- \( Q \) = Discharge, m³/s;
- \( A \) = Cross-sectional area, m²;
- \( R \) = Hydraulic Radius, m;
- \( WP \) = Wetted Perimeter, m;
- \( n \) = Manning’s roughness;
- \( S_f \) = Water surface slope, m/m;
- \( S_o \) = Channel bed slope, m/m. For uniform flow conditions \( S_o \) is same as \( S_f \).

In situations of gradually varied flow, a geometric mean conveyance is computed as (after, French, R. H., 1985):

\[
R = \sqrt[n]{K_1 \cdot K_2 \cdot K_3 \cdot K_4 \cdots K_{m-1} \cdot K_m}
\]

Where \( K_1, K_2, K_3, K_4\ldots, K_{m-1}, K_m \) are the section conveyances in a reach with “\( m \)” cross-sections; and, as the bed and water surface slopes differ, \( S_f \) is used as the slope.

Similar equations can be developed for the Chézy’s flow equation, if one chooses to use this formulation. It should be understood, that these equations are mathematical approximations of discharge, and assume that the flow is constant throughout the cross-section, and the cross-sectional boundaries are rigid within the reach. There are other models that will be employed by the study, where the flows will be modelled with ‘mobile beds’. The two models will be compared and calibrated using the same cross-sectional data, flow measurements and ‘hydraulic performance indices’.

Morphology refers to the bed elevation, channel topography and bed-forms, and composition (type of material, size of particles) of the bed and suspended material. Understanding of changes in morphology requires information on the processes of sediment transport, erosion and deposition by the river. Analysis of morphological change requires knowledge of:

- bathymetric changes over time;
- bed material characteristics and distribution;
- rates of sediment transport and areas of erosion and deposition;
- changes in flow rates and patterns of local velocity at the bed;
- surficial geology below and adjacent to the river channel; and
- the potential influence of factors such as shipsinkings and shoreline alterations.
3. **Science Questions Framework**

To address the primary science questions and better understand cause and effects, various hypotheses or secondary science questions need to be addressed. Table 1 contains the science questions framework and identifies which question(s) each project is addressing. More details on how exactly each project plans to address the question are available in the project descriptions that can be found in the Annex.

The Study is basically tackling the St. Clair issue from three distinct but interrelated perspectives. The first is the *hydraulic* perspective which focuses on understanding the flow regime and determining if it has shifted or not. The second is the *morphologic* perspective which addresses whether the bed is stable or eroding and the implications on flows. And finally the *hydrologic* perspective which looks at the net basin supplies to determine if changes in head elevation differences between Lakes Michigan-Huron and Erie can be explained through regional shifts in supplies.

It should be understood that many of the questions raised about increased conveyance and the potential causes deal with information and changes that are small, and within the current margin of uncertainties, that are inherent in the nature of the physical data collection, models and methods that have been historically employed to deal with these issues. The Study has embarked on a strategy that is viewing the information with a higher degree of accuracy and precision than ever before. But, there will still be uncertainty associated with every aspect of the analysis, albeit reduced considerable. One of the ways of increasing the confidence of the analyses and conclusions is to examine the issues from different methodological perspectives, and compare results. This is a key aspect of the overall strategy.

It is anticipated that approaching the St Clair issue from these three different but complementary perspectives and lines of reasoning will help to provide a more comprehensive understanding of the physical environment. It will help the Study Board determine if the channel has been altered, what may have prompted any changes and what are the implications of any changes. The findings should converge or be complementary, reducing the inherent uncertainties in the various models, and increasing the confidence of the conclusions, and thus make for a more thorough assessment.

4. **Project Matrix and Timeframe**

The project matrix (Table 1) illustrates the relevancy, redundancy and interdependency of the projects, and Table 2 shows what work has been completed to date. The critical path (Figure 1) required in delivering the results within the proposed timeframe. It is important to note that the hydraulic and sediment modelling are dependent on a number of projects for providing basic information required for calibration and verification purposes. Considerable attention is being paid to provide the same quality assured/quality controlled data and boundary sets for use in the different models.
5. **Hydraulic & Sediment Modelling Strategy**

The key issues are handled from two fronts – understanding the hydraulic processes from rigid boundary conditions and the morphologic processes from a mobile bed setting. These modelling efforts are supported through detailed geometry and hydraulic data collection programs, in-situ velocity measurements, channel bed videography, side sonar measurements, etc.

The strategy adopted by the Study in addressing the conveyance issue of the St. Clair River is to approach hydraulic and sediment modelling as the key and driving components. In order to have confidence in the simulation capabilities of the models, it was decided to use multifaceted approach to establish the modelling strategy. The proposed strategy is presented in Figure 2 for hydraulic modelling and Figure 3 for the sediment modelling.

The Study strategy is based on the premise that comprehensive modelling should be built upon accurate data, applying tested and peer reviewed tools to address the problem at hand, interpreting the results in light of various sources of uncertainty. To achieve this objective each of the projects was related back to the primary and secondary science questions. A structured set up was adopted to ensure that the modelling had the data required and that could be collected within the shortened time frame. Initially, the projects funded were directed at collecting basic field data, verifying data and establishing stream flow gauges to help develop the geometric models. Another project, utilizing videography, commenced in the early stages to examine the bottom of the channel bed and provides a visual reference and also to help in determining the appropriate bed roughness to use in the models. The following schematic (Figure 4), illustrates the concept of structured modelling.

The next aspect of modelling was the dimensionality of the hydraulic and sediment models. The question of conveyance is one that can largely be answered with a 1-D model. To properly account for ineffective/inactive flow areas, eddy zones information is developed from the 2-D modelling being carried out in previous investigations and this study.

The Plan of Study had earlier considered limited 3-D modelling of selected reaches of the St. Clair River. After considering the limited availability of data for any such application, time required for properly setting up and running such models within the shortened time constraints and more importantly, the conveyance issue is an entire reach related phenomenon, it was decided to take a graduated approach to determine the incremental improvement in explaining the variance achieved with each order of complexity of model.

The Study is employing a variety of hydraulic and sediment transport models to address the science questions as noted in Table 1. A brief rationale as to why a particular model is being used is given here:

a. **1-D Hydraulic Modelling:** The main program used is Hydrologic Engineering Center – River Analysis System **HEC-RAS** version 4.0.1 Beta2. This is a standard analysis tool used globally for developing water surface profiles for flood risk mapping projects. The program operates in two different modes steady state and unsteady flow mode. For this
Study the program was used in the unsteady mode. There are four analytical scenarios employing HEC-RAS (or same engine-based model). In the first scenario the base HEC-RAS model with 2007 bathymetry was developed. This will serve as a baseline condition that will be used to compare other scenarios to assess the conveyance and study the impact of ice build up on flow properties.

b. **2-D Hydraulic Modelling with RMA2:** This model is built upon the earlier work of USGS. This model was employed by Baird & Associates (2005) in deriving their conclusion that the conveyance of the St. Clair River had been modified due to ongoing erosion. For this Study, the project is using the new multi-beam bathymetry collected in 2007 and quality controlled versions of single-beam bathymetry from 1971 and 2000. This will allow comparing the conveyance and discharge delivery curves over this period.

c. **2-D Hydraulic Modelling with TELEMAC 2D:** This model is being developed by using a different formulation of the Navier-Stokes equations assuming rigid boundary and open water conditions similar to the RMA2 code based model. Initially this will provide an independent check of the RMA2 model and secondly the model will be expanded to include the Detroit River system. This will allow the Study to assess the impact of water level changes in Lake Erie and its backwater effects on Lake Huron. This model will also help in closing the mass balance at the outlet (i.e. Lake Erie). It is also envisioned that the flow fields generated by TELEMAC for various scenarios will be used by the sediment transport modelling described below.

d. **1-D Mobile Bed Model: MOBED** model was developed by Environment Canada and has been used extensively. The model is based on coupling sediment routines with a hydrodynamic solution of any study reach. By extension MOBED has incorporated algorithms to simulate zones of erosion and deposition in a cross-section as pseudo 2-dimensional analysis. Further, it has routines to address armouring processes and determine the bed stability. Data have already been collected at 35 transects covering the entire reach and on regular time intervals bed material and depth integrated suspended material samples are being collected to help in calibrating and validating the model.

e. **2-D sediment transport modelling using SED2D or equivalent model:** This project is designed to examine the hydrodynamic fields and outputs from the TELEMAC 2D modelling efforts and used the information to derive the sediment routines to identify zones of active erosion and sedimentation. This is aimed at providing a further assessment as to the St. Clair sediment regime.
6. Evaluation of Uncertainty

Like in all water resources management systems, hydraulic/sediment transport models use relatively simple mathematical equations to conceptualize and aggregate the complex, spatially distributed, temporally integrated and highly interrelated water and sediment mass, energy, and momentum processes in a river channel. A consequence of this aggregation is that the model parameters often do not represent directly measurable quantities and must therefore be estimated. During this model calibration stage, the parameters are adjusted so that the model replicates, as precisely and consistently as possible, the observed response of the hydraulic or sediment transport system over some historical period of time. In practice, however, there are uncertainties in the observations used to supply boundary conditions, calibrate and validate the models, model parameters derived through calibration, and in the model structure itself. These component uncertainties lead to uncertainties in the model predictions. The Study recognizes the importance of quantifying uncertainty and so all the projects have a component of their work plan that addresses this aspect.

By definition, the term uncertainty refers to a situation in which no reasonable probabilities can be assigned to the potential outcomes. Thus, uncertainty is the inability of a model to determine the true state of affairs of a system (after Haimes, Y.Y, 2004). For the purpose of this Study various component sources of variability and knowledge uncertainties are shown in Figure 5 (after, Haimes, Y.Y, 2004). These may be handled, depending upon the situation, by the “Uncertainty Sensitivity Index Method” (USIM) or through the “Monte Carlo Simulation” using multi-objective simulation method (MSM) and assigning Probability Density Functions (PDF) to the model parameters.

The International Standards Organization (ISO) defines uncertainty as a parameter, associated with the results of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measurement. The parameter may be, for example, a standard deviation or multiple of the standard deviation to establish a coverage factor (i.e. 95 % confidence interval). Measurements of numerous quantities are utilized in the development of models and each of these measurements has uncertainty associated with it. The uncertainty propagates through the model to the quantities that are calculated by the model. Model parameters and the simplifications inherent in the model’s characterization of the system also contribute to uncertainty in the modelling results. This study will rely on the results of numerous models.

There are several broadly accepted standards available for estimating measurement uncertainty including the International Standards Organization standard (ISO 1993), the American Institute of Aeronautics and Astronautics standard S-071-1995 (AIAA 1995), and the American Society of Mechanical Engineers performance test code ANSI/ASME PTC 19.1-1998 (ASME 1998). The three standards rely of the same statistical principles for the propagation of uncertainties. Essentially, to determine the uncertainty inherent in a model, the component uncertainties must first be quantified and then the combined effect of the component uncertainties is determined.
Component uncertainties, generally characterized as standard deviations, can be determined from the statistical distribution of the results of series of measurements. Alternatively, component uncertainties can be evaluated from assumed probability distributions based on experience or other information. The combined uncertainty is then equal to the positive square root of a sum of terms, the terms being the variances or co-variances of the component uncertainties weighted according to how the model result varies with changes in these quantities.

Using this type of approach the uncertainty in the results from the numerous models applied in the study can be determined. For example, the uncertainty in the discharge in the St. Clair River as computed by the one-dimensional HEC-RAS model is a function of the uncertainties in the channel width, depth (bathymetry), upstream (Lake Huron) and downstream (Lake St. Clair) water levels, manning’s roughness (characterizing bottom roughness, vegetative effects, viscosity effects), and expansion/contraction coefficients. To determine the combined uncertainty in the discharge as a function of the uncertainties in these components first the uncertainty in each component is evaluated, second the sensitivity the computed discharge to changes in each component is determined, third the correlation between these components is evaluated and finally the combined uncertainty is computed.

7. **Assessment and Integration of Results**

As the Study is employing a multipronged approach in testing the null hypothesis on conveyance and morphological changes issues, the results will also be integrated at two levels.

a. By definition the term “Conveyance” is one-dimensional in nature. The Study, therefore, will employ the results from HEC-RAS as the standard against which other modelling efforts are tested. A caution is required when the results from MOBED are projected on the Hydraulic Performance Graphs (HPG). If there are differences in the results beyond model parameter uncertainty, these will be rationalized. Other 2-D modelling efforts will also be resolved by computing the discharge at the boundaries.

b. At the primary level an objective framework has been developed that will test the null hypothesis (*there is no progressive erosion or change in conveyance since 1962*). In this Study, the HPG will be required from all hydraulic and sediment modelling efforts. The HPG is the centre-piece of normalization and integration of the results of each model that will provide a mechanism to quickly compare the outputs of each model on a comparable basis. A typical hydraulic model will produce an HPG diagram similar to the one shown in **Figure 6**. The graph depicts results from several HEC-RAS runs based on scenario data where the flows in the connecting channel can vary from a low of 3500 m³/s to a high 8500 m³/s. For HEC-RAS similar HPG diagrams will be developed using geometry data from different time periods. The differences among the HPG will determine the change in conveyance.

c. At the secondary level expert subjective interpretation will be required for a variety of products the Study has embarked upon. For example, the videography project is providing channel bottom images. Further image analysis tools are being used to give
the bed material distribution. This will allow a visual interpretation of the stability or erosion potential of bed material. Similarly, quality controlled products from bathymetry dated 1971, 2000 and 2007 will be available. Expert opinions will be drawn by taking differential surfaces and cross-section slices from the same locations. There are other projects/products that will lend to similar interpretations. These are shown in Figures 2, 3 and 7 of this paper.

8. **References:**


## Table 1 - Result Integration - St. Clair River Tasks

<table>
<thead>
<tr>
<th>No.</th>
<th>Science Questions Framework</th>
<th>Has the &quot;Conveyance&quot; of the St. Clair River Changed since the 1962 dredging?</th>
<th>Has the &quot;Morphology&quot; of the St. Clair River altered since the 1962 dredging?</th>
</tr>
</thead>
<tbody>
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<td></td>
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</tr>
<tr>
<td>P21</td>
<td>Net Basin Supplies Comparison and Water Balance Closure</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P22</td>
<td>Glacial Isostatic Adjustment</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P23</td>
<td>Review of St. Clair &amp; Detroit River Rating Curves and Develop Hydraulic Performance Graphs</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P24</td>
<td>Discharge Computation of the River Using the Standardized HEC-RAS Model</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P25</td>
<td>Development of a Basic 1-D Modelling of St. Clair River Using HEC-RAS</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P26</td>
<td>1-D Conveyance Analysis of the St. Clair River Using the Standardized HEC-RAS Model</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P27</td>
<td>Ice Effects of Flow and Levels Using Standardized Geometry Model of HEC-RAS</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P28</td>
<td>1-D Conveyance Analysis of the St. Clair River using the Mobile Bed MOBED Model</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P29</td>
<td>2-D Conveyance / Morphological Analysis of the St. Clair River using SEED2 or equivalent</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P30</td>
<td>Application of 2-D Modelling Using Existing RMA2 Model of the St. Clair River with Different Bathymetric Data Sets</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P31</td>
<td>Application of 2-D Model of the St. Clair River Using Telemac Modules with Different Bathymetric Data Sets</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P32</td>
<td>Quantification of Uncertainties in 1-D and 2-D Modeling</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P33</td>
<td>Bathymetry of St. Clair River 1971 - 2007</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P34</td>
<td>Analysis of Bathymetric and Planform Changes in the Past 130 years and Registration into Common GIS</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P35</td>
<td>Obtain and Analyze the Bottom Velocity Data from ADCP</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P36</td>
<td>New Coincident ADCP and Multi-beam Data for Hydraulic/sediment Model Verification</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P37</td>
<td>Extract Bed Movement Velocity from Existing or New ADCP Data</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P38</td>
<td>Side-scan Sonar and Video of Substrate in Upper St Clair River</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P39</td>
<td>Sediment Coring and Physical Testing of Substrate in the St. Clair River</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P40</td>
<td>Video Transsects of River Bed, Monthly Sediment Load Measurements, Cross-section Surveys, Grab samples of Bed Material - Sarnia - PI Lambton</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P41</td>
<td>Analysis of Strip Effect, Bulk Movement and Shifting on Sediment and Erosion Regimes</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P42</td>
<td>Reports and Data on Surficial Geology, Littoral Transport, St Clair River and Delta</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P43</td>
<td>Conduct Sedimentation Studies of the St Clair River Delta</td>
<td></td>
<td>❌</td>
</tr>
<tr>
<td>P44</td>
<td>History of St. Clair River and Detroit River Dredging and Compensation Works</td>
<td></td>
<td>❌</td>
</tr>
</tbody>
</table>

**Legend:**
- Primary focus
- Secondary focus
- Tasks not initiated - projected to start this Spring
<table>
<thead>
<tr>
<th>No.</th>
<th>Tasks</th>
<th>Status</th>
<th>Key Output &amp; Next Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bathymetry of the St. Clair River from 1971 to 2007</td>
<td>The project was completed – delayed to ensure quality control</td>
<td>• Corrected data for input into hydraulic and sediment models.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Slices of cross-sections for visual interpretation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Temporal differences in volumetric changes</td>
</tr>
<tr>
<td>2</td>
<td>1-D basic hydraulic model of the St. Clair River</td>
<td>The calibrated and verified model is ready for hand over to other investigators</td>
<td>• A basic hydraulic model for checking changes in conveyance</td>
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<td></td>
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<td></td>
<td>• The model will be used for developing Hydraulic Performance Graphs (HPG)</td>
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<td></td>
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<td>• The model will be used for studying the impact of ice on flow and conveyance</td>
</tr>
<tr>
<td>3</td>
<td>2-D hydraulic modelling of the St. Clair River with RMA2</td>
<td>The draft final report was submitted</td>
<td>• Preliminary results on water levels under different time periods</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• A measure of conveyance issue addressed</td>
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<tr>
<td></td>
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<td></td>
<td>• Further work required for HPG</td>
</tr>
<tr>
<td>4</td>
<td>2-D hydraulic modelling of the St. Clair River with TELEMAC</td>
<td>The draft final report was submitted</td>
<td>• Preliminary results on water levels under different time periods</td>
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<tr>
<td></td>
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<td>• A measure of conveyance issue addressed</td>
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<td></td>
<td>• Further work required for HPG</td>
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<tr>
<td>5</td>
<td>Video Transects, sediment data collection</td>
<td>The project is progressing without delays. It achieved several milestones</td>
<td>• Movies and still shots from videography of river bottom</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>• Sediment samples and interpretation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• The results from repeated experiments from 1967 and 1987 will begin</td>
</tr>
<tr>
<td>6</td>
<td>1-D sediment modelling with MOBED</td>
<td>The project is slightly behind due to capacity issues. The base model was set up and ready for calibration/validation</td>
<td>• This is the basic sediment model for evaluating conveyance, deposition and erosion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Further work required for HPG</td>
</tr>
<tr>
<td>7</td>
<td>Glacial Isostatic Adjustments Study</td>
<td>The study is complete and preliminary findings submitted in a draft report</td>
<td>• The lake-to-lake relationship was rationalized</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>• There is a better understanding on the estimate for use in the study</td>
</tr>
<tr>
<td>8</td>
<td>Net Basin Supplies (NBS) Comparison and Water Balance Closure</td>
<td>The draft report of the analysis was submitted – awaiting the final version</td>
<td>• The analysis explains the uncertainties and errors in estimating NBS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Aid understanding residual values</td>
</tr>
<tr>
<td>9</td>
<td>Gridded Hydrologic Data set for 1997-2006</td>
<td>The draft data set of estimated precipitation, evaporation and preliminary analysis received</td>
<td>• The analysis compares gridded data with GLERL estimates</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• The difference need to be rationalized</td>
</tr>
</tbody>
</table>
ADCP Measurements

Establish Dimensionality of Flow

Identify Critical Reaches for 3-D Modelling

Rigid Boundary Hydraulic Modelling

1971 & 2000 Single Beam Bathymetry

2007 Multi-beam Bathymetry

Uncertainty Analysis & Visualization

Integration & Visualization - Figure 7

Rigid Boundary Hydraulic Modelling

1-D HEC-RAS Base Model

2-D Modelling

Establish Water Levels and Flow Scenarios

SMS RMA2 Modelling

TELEMAC 2D Modelling

Verify RMA2 & TELEMAC 2D Results

Extend TELEMAC Based Model to Lake Erie

Establish Water Balance Through the System

Hydraulic Performance Graphs

3-D Modelling Needs & Issues discussed in the report

Conveyance Issue Answered

Review of St. Clair River Rating Curves

Conveyance Analysis

Estimating St. Clair River Discharges

Normalization & Integration of 1-D & 2-D Model Results

Conveyance Issue Answered

Uncertainty Analysis

For Bathymetry & Other Hydraulic Data

For Modelling

Flow Field - To Figure 3

Figure 2. Resolution of Conveyance Issues with Hydraulic Modelling Strategy

Figure 3. Resolution of Morphology Issues with Sediment Studies Strategy
Figure 4 - Structured Modelling Approach

Basic Data for Model Input

Verify Rating Curves | Stability of Channel Regime

Data for Model Calibration and Verification

Videography | ADCP Measurements

Application of Hydraulic & Sediment Models

Rigid & Mobile Bed | One & Two Dimensional

Figure 5. Component Sources of Uncertainty

Uncertainty

Variability

Temporal

Flow in summer - weeds
Flow in winter - ice

Individual Heterogeneity

Conditions at Lake Huron outflow
Conditions in middle reaches
Conditions in the delta

Spatial

Knowledge

Model

Surrogate variables
Excluded variables
Approximations
Incorrect form
Disagreement

Parameter

Measurement
Systematic
Sampling error
Unpredictability
Linguistic implication

Decision

Risk measurement
Social cost of risk
Quantification of social values

1 Adopted from Haines, Y.Y., 2004
Figure 6 - Hydraulic Performance Graph for the St. Clair River (Metric units)
Ven Te Chow Hydrosystems Laboratory
University of Illinois at Urbana - Champaign
February 14, 2008

Figure 7. Results Integration, Analysis, Visualization & Interpretation

## P1 - Bathymetry of St. Clair River 1971-2007

### Project Name:
Geographic Information System Analysis of Fluvial Geomorphic Changes in the St. Clair River and Lake St. Clair over the past 130 years using Historic Bathymetric Data

### Principal Investigator:
David Bennion, USGS Great Lakes Science Center

### Project Abstract (A short description of the project)
The objective of this project is to compare various bathymetric data sets and try to understand the geomorphic changes of the river and lake over the past 130 years. The study will focus on creating geo-referenced bathymetric data sets from a variety of past and current bathymetric surveys; using these to estimate river bottom surfaces; and comparing these surfaces to determine location and amounts of change in the river bottom over time.

### Which primary science questions your project addresses? (listing attached)

2. Has the morphology of the St. Clair River changed? *By comparing bathymetry from various years can identify areas of major changes in the river bed. Because of the density of more recent bathymetric data, may be able to identify smaller changes in the river bed.*

### Which secondary science questions your project addresses? (listing attached)

9. Can the project establish zones of active erosion and deposition? *By comparing bathymetry from different recent years (2007, 2006, 2005, 2002, 2000) it may be possible to identify areas of presently active erosion and deposition.*

12. Can the project explain the impact of large object sinking? *By comparing bathymetry from years before and after the sinking of a large object, may be able to determine the effects the object had/has on the bathymetry.*

### Describe scenarios you will run for each of the science questions (if applicable)
Datasets will be compared to determine changes in depth, volume and shape of the river bed. Bathymetric data sets that will be compared include 2007, 2006, 2005, 2002, 2000, 1971, 1954, and other partial surveys and earlier data as acquired.

### What are your exact outputs from the project?
Geo-referenced historic maps; raster files of interpolated historic bathymetry; raster surfaces illustrating geomorphic changes; error analysis of interpolated surfaces; digitized shoreline dataset and shoreline change analysis; and technical report of methods, results and conclusions. The raster files of interpolated bathymetry will include, at a minimum, data from bathymetric surveys made in 2007, 2006, 2005, 2002, 2000, 1971, and 1954.
List any issues/concerns/linkages?

Also supplying digital bathymetry data sets to meet needs of Hydraulic modellers – which sometimes requires different processing and changes in time schedule.

There are limits as to how fine a resolution can be assumed from the bathymetric data, because of survey error and the density of the measured data, which is different for different surveys over the years.

Enumerate your timelines and milestones in the embedded spreadsheet below:

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<tr>
<th>Activities &amp; Milestones</th>
<th>Duration (Months)</th>
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<td>Data prep and interpolation</td>
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<td>Cut/Fill analysis of recent datasets</td>
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<tr>
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<td>Final analysis and report</td>
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### Project Name: Review of Discharge Measurements, Rating Equations and Computed Flows on the St. Clair and Detroit Rivers since 1962

### Principal Investigator: Arthur R. Schmidt, University of Illinois at Urbana-Champaign

**Project Abstract (A short description of the project)**

The objectives of this analysis are to determine whether the present set of equations used to estimate flows in the St. Clair and Detroit Rivers and the method of interpreting them is valid for use in determining the flow in these rivers; to evaluate the quality and uncertainty in measured discharges; to evaluate how well historic flows since 1962 represent actual flow; and evaluate whether historic flows (or revised historic flows) indicate changes in the flow regime since 1962.

### Which primary science questions your project addresses? (listing attached)

1. Has the "conveyance" of the St. Clair River Changed in the past 50 years? A good set of rating equations, representing present channel conditions, compared to measured discharges could indicate whether changes have occurred in the channels since the completion of the 1960s dredging.

### Which secondary science questions your project addresses? (listing attached)

3. Has the lake-to-lake relationship changed from conveyance perspective? Changes in the stage-fall-discharge relationships over time would indicate changes in conveyance which would translate to changes in the lake-to-lake relationship. This project will attempt to see if there have been changes in the stage-fall-discharge relationships since 1962.

4. Has the discharge relationship of the St. Clair River from the stage-fall equations changed? This is one of the basic questions this project is designed to address.

11. Can the project help seek closure on mass-balance through the system? Better flow estimates will lead to better supply estimates, which can be used to evaluate the mass-balance of the system.

### Describe scenarios you will run for each of the science questions (if applicable)

### What are your exact outputs from the project?

Review of present rating equations; documentation of proposed revisions to rating equations; estimates of uncertainty in measured and computed flows, recommendations for improvement in flow determinations; calculated historic flows for 1962-2006; evaluation of flow regime(s) 1962-2006.
List any issues/concerns/linkages?
Revision of rating equations will depend on hydraulic models being developed by others in the study. Evaluation of possible changes in channel conditions depends on quality and quantity of historic discharge measurements and water level records.

Enumerate your timelines and milestones in the embedded spreadsheet below:

<table>
<thead>
<tr>
<th>Activities &amp; Milestones</th>
<th>Duration</th>
<th>M</th>
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<tbody>
<tr>
<td>Evaluate the measured flows since 1962</td>
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<td>Revise the rating equations based on best available flow data and methods, to represent present conditions</td>
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<tr>
<td>Evaluate the rating equations against the measured flows</td>
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<tr>
<td>Calculate revised historic flows for 1962-2006 and evaluate</td>
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<tr>
<td>Using revised historic flow estimates, evaluate whether changes in flow regime can be seen over time, since 1962</td>
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</table>

P3 - Development of a Basic 1-D Modelling of St. Clair River Using HEC-RAS

**Project Name:** Develop Standard 1-D HEC RAS model, and utilize model to assess possible conveyance changes in the St. Clair River.

**Principal Investigator:** Jason Giovannettone, HEC

**Project Abstract (A short description of the project)**

The purpose of this project is to develop a standard 1-D HEC-RAS model of the St. Clair River that will be used as a base model for all 1-D modeling efforts of the IUGLS. The base model will extend from Lake Huron downstream to Algonac, just above the delta in the St. Clair River and will be based on the 2007 bathymetry set. The model will be extensively calibrated with available water level and flow measurement data. Once the model is calibrated, bathymetry data from previous years, including 1954, 1971, 2000, and 2002, 2005, and 2006 will be substituted into the model in order to determine the sensitivity of the model in terms of water level and flow changes in bathymetry. Any changes in flow may indicate a possible change in conveyance over the years. Stage data from before and after 1962 will be used to determine the ability of the 1996-2006 model to replicate water levels from that period. If not, this may indicate some change since 1962.

Additional analyses include filling in different reaches of the channel in order to see the effect of changing the cross-section of the river on discharge. The results will indicate where conveyance will be most sensitive to changes in channel area. In particular the simulation results will give an idea to the effect dredging would have on conveyance. Another issue is holes that have been observed near the locations of shipwrecks and the associated scour that occurs. Filling in these holes will fill in another piece of the puzzle as to whether shipwrecks have any significant effects on conveyance. One other type of simulation that will be conducted involves changing the slope of the river in order to quantify the sensitivity of the model to changes in surface elevation caused by isostatic rebound. All analyses will be conducted at low and high flows to determine the sensitivity of the overall flow on the results.

**Which primary science questions your project addresses? (listing attached)**

Has the “Conveyance” of the St. Clair River changed in the past 50 years.

**Which secondary science questions your project addresses? (listing attached)**

*You may wish to add other secondary issues your projects may address.*

- Has the Lake-to-Lake relationship changed from conveyance perspective? *This project will estimate water levels in the St. Clair River and Lake Huron, for a given combination of channel discharge and Lake St. Clair water level. This will be done for a complete range of realistic channel discharge and Lake St. Clair water level scenarios, for each of the years for which bathymetry data is available.*

- Has the discharge relationship of the St. Clair River from the stage-fall equations changed? *This project will derive stage-fall-discharge equations in the St. Clair River using a modelling approach, for each of the different historic bathymetric data sets for the St. Clair River. These can be used to help verify existing equations, while also providing an alternative method for estimating discharge.*

- Will the project reduce the uncertainty in estimation of St. Clair River flows? *This project*
will provide an alternative method for estimating discharge, which can be compared to existing methods to verify their accuracy. Subsequent work (future project) will be required to assess the uncertainty in the discharge computed using this approach.

- Can the project explain the impact of large object sinking? This project will examine how potential scour holes that may or may not have been the result of large objects sinking affect conveyance in the St. Clair River. The project will not explain whether the possible holes were in fact the result of large objects sinking, but rather it will explain whether any of these holes, which are potentially the result of scour, affect conveyance.

Describe scenarios you will run for each of the science questions (if applicable)

- A full range of hydrological scenarios will be run for model geometries created for each of the different years to determine the net impact on conveyance in the channel.
- Simulated single-beam datasets will be generated from the 2007 multi-beam dataset to cover the same extent as both the 1971 and 2000 data in order to determine how changes in measurement technology and bathymetry data density affect model results.
- Different areas of the river will be progressively raised and lowered to determine how changes in the bathymetry data at certain areas of the river affect channel conveyance.
- Different areas of the river, such as possible scour holes or accretion zones, will be filled in to determine how these changes affect conveyance.
- A sensitivity analysis will be completed by modifying various model parameters, including bathymetry data, roughness coefficients, water levels and flows, to determine how changes or uncertainty in these parameters affect results.

What are your exact outputs from the project?

- A base HEC-RAS 1-Dimensional model that can be used by other 1-D modelers.
- A report documenting the findings of the hydraulic analysis, which will address each of the science questions outlined above.
- Model input, output, and metadata files submitted to the study SharePoint system to provide access to study participants and public interests.

List any issues/concerns/linkages?

- Modelling efforts have extensive linkages to Data Verification and Reconciliation group. QA/QC’d data must come from this group, including bathymetry, water level and discharge data. Therefore, some modelling tasks cannot proceed until required data has been obtained in this way.

Enumerate your timelines and milestones in the embedded spreadsheet below:

<table>
<thead>
<tr>
<th>Activities &amp; Milestones</th>
<th>Duration</th>
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</table>
### P4 - 1D Conveyance Analysis of the St. Clair River Using the Standardize HEC- RAS Model

**Project Name:** One-Dimensional Hydrodynamic Modeling of St. Clair River to Assess Possible Conveyance Changes since 1962 and to Compute Unsteady Flows During Open-Water Conditions

**Principal Investigator:** David J. Holtschlag

**Project Abstract (A short description of the project)**

A one-dimensional hydrodynamic model of the St. Clair River is being developed on the basis of the generic HEC-RAS (Hydrologic Engineering Center-River Analysis System) code. The HEC-RAS model extends along the St. Clair River from NOAA (National Oceanic and Atmospheric Administration) water-level gauging stations near the head at Fort Gratiot downstream to a point near the mouth at Algonac, Michigan, a distance of about 26 miles. Water levels at the upstream and downstream stations will be used as boundary conditions for unsteady-flow model simulations at hourly time steps. The model consists of longitudinally-referenced cross sections describing transverse distances and channel elevations along transect normal to flow. Channel elevations will be based on the results of a 2007 bathymetry survey, and augmented, where necessary, with data from a 2000 bathymetry survey near Algonac, Michigan. The standard version of the model identifies effective flow areas within each cross section and Manning’s “n” roughness parameters, describing the effective flow resistance of the channel, that are generally applicable during open-water conditions.

This project will modify the parameterization of the standard model on the basis of the water-level and flow measurements using inverse modeling techniques implemented by the universal parameter estimation code (UCODE). St. Clair River will be divided into seven or more sub-reaches delineated by U.S. and Canadian water-level gauging stations or bifurcations around Stag and Fawn Islands. Within each sub-reach, Manning’s “n” value, considered a sensitive parameter associated with overall reach conveyance, will be systematically modified to improve the match between measured and simulated water-level and flow conditions for selected scenarios representing distinct time periods. Significant changes in model parameterization between scenarios and sub-reaches will be used as an indicator of possible changes in local conveyance. Variations in Manning’s “n” with season and with flow magnitude will be assessed to the extent supported by the data. In addition to investigating possible historical conveyance changes, the utility and accuracy of model simulations for computing flow during open-water conditions will be assessed.

**Which primary science questions your project addresses? (listing attached)**

*Has the conveyance of the St. Clair River changed in the past 50 years – This project will determine if the historical water-level and flow measurement data available on St. Clair River are consistent with the hypothesis that no significant changes in conveyance have occurred from the end of dredging in 1962 to the bathymetry survey in 2007?*

This project will also determine if versions of the HEC-RAS model calibrated with water-level and flow data before and after 1962 are sensitive to known conveyance changes associated with the 1962 dredging?

**Which secondary science questions your project addresses? (listing attached)**

*You may wish to add other secondary issues your projects may address.*
Has the discharge relationship of the St. Clair River from the stage-fall equations changed? – This project will help determine if NOAA water-level data on St. Clair River near the head at Fort Gratiot and near the mouth are sufficient to compute unsteady flow during open-water periods using the HEC-RAS one-dimensional hydrodynamic model?

Will the project reduce the uncertainty in estimation of St. Clair River flows? This project will determine if the uncertainties of parameters associated with HEC-RAS model versions calibrated from different periods of historical water-level and flow data can be used to accurately express the uncertainty of flows simulated for those respective periods?

Describe scenarios you will run for each of the science questions (if applicable)

Four scenarios will be run to address the science questions:

1. Pre-Dredging Scenario: Using water-level and flow data from about 1957 to 1961, UCODE will be used to parameterize a version of the HEC-RAS model for pre-dredging conditions.

2. Post-Dredging Scenario: Using data from 1963 to 1967, UCODE will be used to parameterize a version of the HEC-RAS model for post-dredging conditions. Reach specific parameters will be compared for the pre- and post-dredging versions to assess model sensitivity to known changes in conveyance.

3. Pre-Measurement Gap Scenario: Using water-level and conventional flow measurements from about 1968 to 1985, UCODE will be used to parameterize a version of the HEC-RAS model for the pre-measurement gap conditions. The measurement gap refers to the period from about 1986 to 1995 when no flow measurements are available on St. Clair River. Both flow and water-level measurements are needed to parameterize the HEC-RAS model.

4. Post-Measurement Gap Scenario: Using water-level and acoustic Doppler current profiler (ADCP) flow measurements from about 1996 to 2007, UCODE will be used to parameterize a version of the HEC-RAS model. Estimated Manning’s “n” values will be compared for the Pre- and Post Measurement Gap Scenarios to assess possible reach-specific changes in conveyance.

What are your exact outputs from the project?

1. Four versions of the St. Clair River HEC-RAS model parameterized for the four scenarios discussed above.

2. Evaluation of the sensitivity of the HEC-RAS model to known changes in conveyance resulting from the 1962 dredging.

3. Evaluation of conveyance changes indicated by changes in estimated Manning’s “n” values between the Pre- and Post Measurement Gap Scenarios.

4. A positive indication of model sensitivity for the 1962 dredging and significant changes between estimated Manning’s “n” values between the Pre- and Post Measurement Gap scenarios will provide a basis for rejecting the null hypothesis of no changes in conveyance for specific subreaches.

5. An assessment of the utility and accuracy of the HEC-RAS model for computing flow of St. Clair River on the basis of water-level data at Fort Gratiot and Algonac gauging stations.

6. A peer-reviewed article documenting the analysis.

List any issues/concerns/linkages?

1. Availability of water-level and flow data for scenarios.


Enumerate your timelines and milestones in the embedded spreadsheet below:

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<tr>
<td>Preparation of the manuscript</td>
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</table>

*Draft - Hydraulic and Sediment Modelling Methodological Report – April 01, 2008*
Project Name: Application of Two-Dimensional RMA2 Model of the St. Clair River to Investigate the Impacts of Potential Channel Changes on Water Levels and Flows

Principal Investigator: Jacob Bruxer, Environment Canada

Project Abstract (A short description of the project)

The purpose of this project is to adapt and apply an existing two-dimensional RMA2 model of the St. Clair-Detroit River system to investigate the impacts of potential channel changes on water levels and flows in the St. Clair River. The model was developed in 2001 by Holtschlag and Koschik (http://mi.water.usgs.gov/pubs/WRIR/WRIR01-4236/). For this application, the original model will be modified by terminating the model in Lake St. Clair, increasing the model mesh density, and converting the units of measurement from imperial to metric. The original model was extensively calibrated and validated against observed water levels, velocities and flow distributions. The modified model will be compared against the original model to verify that the same degree of accuracy has been maintained. Once satisfied with the model results, a set of additional model representations of the St. Clair River will be created from bathymetric surveys collected in the past including multi-beam data from 2007, and single beam data from 2000 and 1971, as well as partial river, multi-beam surveys conducted in 2006, 2005 and 2002, supplemented by the 2000 single beam bathymetry data. Each of these models will be executed over a complete range of realistic hydrological scenarios to determine the net impact on conveyance in the St. Clair River. In addition, a sensitivity analysis will be conducted to determine how changes and/or uncertainty in the bathymetry data, roughness coefficients, boundary condition water levels and flows, among other parameters, affect the results. Lastly, rating curves and hydraulic performance graphs (HPG) will be developed to assess whether the conveyance in the St. Clair River has changed and to help summarize project results.

Which primary science questions your project addresses? (listing attached)

This project will address the question “Has the conveyance of the St. Clair River changed in the past 50 years”.

Which secondary science questions your project addresses? (listing attached)

You may wish to add other secondary issues your projects may address.

- Has the Lake-to-Lake relationship changed from conveyance perspective? This project will estimate water levels in the St. Clair River and Lake Huron, for a given combination of channel discharge and Lake St. Clair water level. This will be done for a complete range of realistic channel discharge and Lake St. Clair water level scenarios, for each of the years for which bathymetry data is available.

- Has the discharge relationship of the St. Clair River from the stage-fall equations changed? This project will derive stage-fall-discharge equations in the St. Clair River using a modelling approach, for each of the different historic bathymetric data sets for the St. Clair River. These can be used to help verify existing equations, while also providing an alternative method for estimating discharge.

- Will the project reduce the uncertainty in estimation of St. Clair River flows? This project will provide an alternative method for estimating discharge, which can be compared to existing methods to verify their accuracy. Subsequent work (future project) will be
required to assess the uncertainty in the discharge computed using this approach.

- Can the project seek closure on mass-balance through the system? This project will provide an alternative estimation of discharge in the system, which can be used to help verify stage-fall discharge equations used in the residual net basin supply methods.

- Can the project explain the impact of large object sinking? This project will examine how potential scour holes that may or may not have been the result of large objects sinking affect conveyance in the St. Clair River. The project will not explain whether the possible holes were in fact the result of large objects sinking, but rather it will explain whether any of these holes, which are potentially the result of scour, affect conveyance.

Describe scenarios you will run for each of the science questions (if applicable)

- A full range of hydrological scenarios will be run for model meshes created for each of the different years to determine the net impact on conveyance in the channel.
- Simulated single-beam datasets will be generated from the 2007 multi-beam dataset to cover the same extent as both the 1971 and 2000 data in order to determine how changes in measurement technology and bathymetry data density affect model results.
- Different areas of the river will be progressively raised and lowered to determine how changes in the bathymetry data at certain areas of the river affect channel conveyance.
- Different areas of the river, such as possible scour holes or accretion zones, will be filled in to determine how these changes affect conveyance.
- A sensitivity analysis will be completed by modifying various model parameters, including bathymetry data, roughness coefficients, water levels and flows, to determine how changes or uncertainty in these parameters affect results.

What are your exact outputs from the project?

- A report documenting the findings of the hydraulic analysis, which will address each of the science questions outlined above.
- Model input, output, and metadata files submitted to the study SharePoint system to provide access to study participants and public interests.

List any issues/concerns/linkages?

- Modelling efforts have extensive linkages to Data Verification and Reconciliation group. QA/QC’d data must come from this group, including bathymetry, water level and discharge data. Therefore, some modelling tasks cannot proceed until required data has been obtained in this way. The initial phase of this project has a deadline with deliverables that are due on or before March 31st, 2008, as per MOU and Annex with Environment Canada.
- It is anticipated that a secondary Annex with Environment Canada will be developed to complete the second phase of the project. Within the second phase the uncertainty of the modelling results will be quantified. Uncertainty of data is needed and must be documented (for example, uncertainty of bathymetry soundings specified as an elevation plus or minus some value is required in order to determine the impact this uncertainty has on modelling results).
Enumerate your timelines and milestones in the embedded spreadsheet below:

<table>
<thead>
<tr>
<th>Activities &amp; Milestones</th>
<th>Duration</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
<th>J</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determining initial estimate of changes in conveyance over time (deterministic answer)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Testing and documenting sources of uncertainty and their effect on results (probabilistic answer)</td>
<td>3</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
P6a - Application of 2-D Model of the St. Clair River Using Telemac Modules with Different Bathymetric Data Sets

<table>
<thead>
<tr>
<th>Project Name:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use 2D model of St. Clair river with Telemac</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Principal Investigator:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thierry Faure</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Project Abstract (A short description of the project)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The purpose of this project is to develop and apply a two-dimensional Telemac model of the St. Clair-Detroit River system to investigate the impacts of potential channel changes on water levels and flows in the St. Clair River and to confirm/validate results from the RMA-2 model with a newer, more complex modeling system. This project will also bring in expertise from the Canadian Hydraulics Centre that will provide independent views and opinions. This model will extend from Lake Huron, into Lake St. Clair. The model will be extensively calibrated and validated against observed water levels, velocities and flow distributions. Multiple model scenarios will be developed utilizing bathymetric surveys collected including multi-beam data from 2007, and single beam data from 2000 and 1971, as well as partial river, multi-beam surveys conducted in 2006, 2005 and 2002, supplemented by the 2000 single beam bathymetry data. Each of these models will be executed over a complete range of realistic hydrological scenarios to determine the net impact on conveyance in the St. Clair River. In addition, a sensitivity analysis will be conducted to determine how changes and/or uncertainty in the bathymetry data, roughness coefficients, boundary condition water levels and flows, among other parameters, affect the results. Lastly, rating curves and hydraulic performance graphs (HPG) will be developed to assess whether the conveyance in the St. Clair River has changed and to help summarize project results.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Which primary science questions your project addresses? (listing attached)</th>
</tr>
</thead>
<tbody>
<tr>
<td>This project will address the question “Has the conveyance of the St. Clair River changed in the past 50 years”.</td>
</tr>
</tbody>
</table>

Has the morphology of the St. Clair River changed? Blue Kenue, a visualization tool used with Telemac, will be used to attempt to answer this question.

<table>
<thead>
<tr>
<th>Which secondary science questions your project addresses? (listing attached)</th>
</tr>
</thead>
<tbody>
<tr>
<td>You may wish to add other secondary issues your projects may address.</td>
</tr>
<tr>
<td>• Has the Lake-to-Lake relationship changed from conveyance perspective? This project will estimate water levels in the St. Clair River and Lake Huron, for a given combination of channel discharge and Lake St. Clair water level. This will be done for a complete range of realistic channel discharge and Lake St. Clair water level scenarios, for each of the years for which bathymetry data is available.</td>
</tr>
<tr>
<td>• Has the discharge relationship of the St. Clair River from the stage-fall equations changed? This project will derive stage-fall-discharge equations in the St. Clair River using a modeling approach, for each of the different historic bathymetric data sets for the St. Clair River. These can be used to help verify existing equations, while also</td>
</tr>
</tbody>
</table>
providing an alternative method for estimating discharge.

- Will the project reduce the uncertainty in estimation of St. Clair River flows? *This project will provide an alternative method for estimating discharge, which can be compared to existing methods to verify their accuracy. Subsequent work (future project) will be required to assess the uncertainty in the discharge computed using this approach.*

- Can the project predict the degree of dimensionality of the St. Clair River flows? *This project will provide an independent opinion on the need for 3 dimensional modeling.*

- Can the project seek closure on mass-balance through the system? *This project will provide an alternative estimation of discharge in the system, which can be used to help verify stage-fall discharge equations used in the residual net basin supply methods.*

- Can the project explain the impact of large object sinking? *This project will examine how potential scour holes that may or may not have been the result of large objects sinking affect conveyance in the St. Clair River. The project will not explain whether the possible holes were in fact the result of large objects sinking, but rather it will explain whether any of these holes, which are potentially the result of scour, affect conveyance.*

**Describe scenarios you will run for each of the science questions (if applicable)**

- A full range of hydrological scenarios will be run for model meshes created for each of the different years to determine the net impact on conveyance in the channel.
- Simulated single-beam datasets will be generated from the 2007 multi-beam dataset to cover the same extent as both the 1971 and 2000 data in order to determine how changes in measurement technology and bathymetry data density affect model results.
- Different areas of the river will be progressively raised and lowered to determine how changes in the bathymetry data at certain areas of the river affect channel conveyance.
- Different areas of the river, such as possible scour holes or accretion zones, will be filled in to determine how these changes affect conveyance.
- A sensitivity analysis will be completed by modifying various model parameters, including bathymetry data, roughness coefficients, water levels and flows, to determine how changes or uncertainty in these parameters affect results.

**What are your exact outputs from the project?**

- A report documenting the findings of the hydraulic analysis, which will address each of the science questions outlined above.
- Model input, output, and metadata files submitted to the study SharePoint system to provide access to study participants and public interests.

**List any issues/concerns/linkages?**

- Modelling efforts have extensive linkages to Data Verification and Reconciliation group. QA/QC’d data must come from this group, including bathymetry, water level and discharge data. Therefore, some modelling tasks cannot proceed until required data has been obtained in this way.
- It is anticipated that a second phase of this project will extend the Telemac model through the Detroit River to Lake Erie. This will help seek closure on mass-balancing through the system.
Enumerate your timelines and milestones in the embedded spreadsheet below:

<table>
<thead>
<tr>
<th>Activities &amp; Milestones</th>
<th>Duration</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
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<th>N</th>
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<td>More tasks to continue next fiscal year</td>
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</table>
**P6b - Application of 2-D Model of the St. Clair River Using Telemac Modules with Different Bathymetric Data Sets**

<table>
<thead>
<tr>
<th>Project Name: Extension of 2-D Telemac model form Lake Huron to Lake Erie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal Investigator: Thierry Faure</td>
</tr>
</tbody>
</table>

**Project Abstract** (A short description of the project)

_The scope of work and details for this project are yet to be developed, a general description follows._

The purpose of this project is to extend the Telemac 2-D model to Lake Erie. Having a 2-D model that extends from Lake Huron to Lake Erie would help close the mass balance of water through the system.

**Which primary science questions your project addresses?** (listing attached)

_Has the conveyance of the St. Clair River changed in the past 50 years?_

**Which secondary science questions your project addresses?** (listing attached)

_You may wish to add other secondary issues your projects may address._

Extending the 2-D model to Lake Erie would help narrow the uncertainties of the Lake to Lake relationships, the discharge relationships, and help seek closure on mass balancing of water through the system.

**Describe scenarios you will run for each of the science questions (if applicable)**

**What are your exact outputs from the project?**

A 2-D Telemac model that extends from Lake Huron to Lake Erie.

**List any issues/concerns/linkages?**

Enumerate your timelines and milestones in the embedded spreadsheet below:

<table>
<thead>
<tr>
<th>Activities &amp; Milestones</th>
<th>Duration</th>
<th>M</th>
<th>A</th>
<th>J</th>
<th>J</th>
<th>A</th>
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<tbody>
<tr>
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</table>

*Draft - Hydraulic and Sediment Modelling Methodological Report – April 01, 2008*
P7 - Discharge Computation of the River Using the Standardized HEC-RAS Model

Project Name: Revised approach to determine discharge through the St. Clair and Detroit River systems.

Principal Investigator: unknown at this time

Project Abstract (A short description of the project)

The scope of work and details for this project are yet to be developed, a general description follows.
Based on the results of the various 1D, 2D and 3D modeling projects, assess changing the CGLRRM or building an SVM to predict Lake Huron levels based on supplies and updated estimates of the discharge determined through hydraulic modeling or new stage-fall-discharge curves through the St. Clair – Detroit Corridor.

Which primary science questions your project addresses? (listing attached)

Has the conveyance of the St. Clair River changed in the past 50 years?

Which secondary science questions your project addresses? (listing attached)

You may wish to add other secondary issues your projects may address.

This project will help seek closure on the mass balance of water through the system.

Describe scenarios you will run for each of the science questions (if applicable)

What are your exact outputs from the project?

List any issues/concerns/linkages?

Enumerate your timelines and milestones in the embedded spreadsheet below:

<table>
<thead>
<tr>
<th>Activities &amp; Milestones</th>
<th>Duration</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
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</table>

Time in Months (2008/2009)

P8 - Ice Effects of Flows and Levels Using Standardized Geometry Model of HEC-RAS

Project Name: Ice effects on flows and levels

Principal Investigator: Steve Daly - suggested

Project Abstract (A short description of the project)
The scope of work and details for this project are yet to be developed, a general description follows.
The purpose of this project would be to develop a methodology and/or application that can be used to quantify the effects that ice and weeds have on the conveyance of the St. Clair River. Consult with the leads of the Hydrology TWG and also with David Fay and Nanette Noorbakhsh to assess how ice and weed retardation have been handled in past work on stage-fall-discharge equations. Results from this analysis will need to be able to be directly applied to the standardized HEC-RAS 1-D model. This effort will need to be closely coordinated with the other team members who are working with or will be working with the model.

Which primary science questions your project addresses? (listing attached)
Has the conveyance of the St. Clair River changed in the past 50 years?

Which secondary science questions your project addresses? (listing attached)
You may wish to add other secondary issues your projects may address.
Better understanding how ice and weeds affect the conveyance of the river will lead to more confidence in the Lake to lake relationships, stage-fall discharge relationships, and uncertainties of the model results.

Describe scenarios you will run for each of the science questions (if applicable)

What are your exact outputs from the project?
A report detailing the effects that ice and weeds have on St. Clair River conveyance.

List any issues/concerns/linkages?

Enumerate your timelines and milestones in the embedded spreadsheet below:

<table>
<thead>
<tr>
<th>Activities &amp; Milestones</th>
<th>Duration</th>
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<th>M</th>
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<th>N</th>
<th>D</th>
<th>J</th>
<th>F</th>
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<tbody>
<tr>
<td>report</td>
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<td>X</td>
<td>X</td>
<td>X</td>
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</tbody>
</table>

### P9 - Video Transects of River Bed, Monthly Sediment Load Measurements, Cross-section Surveys, Grab samples of Bed Material - Sarnia-Pt Lambton

### P10 - 1-D Conveyance Analysis of the St. Clair River using the Mobile Bed MOBED Model

<table>
<thead>
<tr>
<th>Project Name: Design and Implementation of a data collection program and modelling of flow and sediment transport in the St. Clair River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal Investigator: Dr. B.G. Krishnappan</td>
</tr>
<tr>
<td>Project Abstract (A short description of the project)</td>
</tr>
<tr>
<td>This project supports the International Upper Great Lakes Study in the investigation of sediment transport processes in the St. Clair River to ascertain if there is an ongoing river bed erosion at the upper part of the river and to examine the extent of possible changes in the conveyance of the St. Clair River and the likelihood of its continuation into the future. Potential changes in the St. Clair River discharge will have a direct impact on the regulation of water levels in the Upper Great Lakes system.</td>
</tr>
</tbody>
</table>

**Which primary science questions your project addresses? (listing attached)**

The project addresses both of the primary science questions, namely,

1. Has the “conveyance” of the St. Clair River changed in the past 50 years?
2. Has the “morphology” of the St. Clair River changed?

**Which secondary science questions your project addresses? (listing attached)**

You may wish to add other secondary issues your projects may address.

The secondary questions addressed are:

1. Has the composition of the bed material changed over the years?
2. Can the project ascertain the age of the armoured surfaces?
3. Can the project establish zones of active erosion and deposition?
4. Can the project predict the degree of dimensionality of the St. Clair River flows?
5. Can the project explain the impact of large object sinking?
6. Can the limitation on the dimensionality of hydraulic/sediment models be an issue?

**Describe scenarios you will run for each of the science questions (if applicable)**

Under the flow and sediment transport modelling part of this project, the mobile boundary flow model, MOBED will be calibrated and verified using the flow and sediment transport measurements that are being carried out under this project. The calibrated model will be run to investigate:

1. conveyance and river bed stability
2. armouring process
3. erosion and deposition zones
4. impacts of large objects

**What are your exact outputs from the project?**

1. Videography of the river bed to assess the river bed stability and bed roughness
2. Measured data on flow and sediment transport to assess the change over the years.
3. MOBED simulation of armouring of the river bed and river bed morphology
4. Impact of large scour holes on conveyance.

**List any issues/concerns/linkages?**

**Enumerate your timelines and milestones in the embedded spreadsheet below:**

<table>
<thead>
<tr>
<th>Activities &amp; Milestones</th>
<th>Duration</th>
<th>Time in Months (2008/2009)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
</tr>
<tr>
<td>Flow and sediment transport measurements</td>
<td>Monthly</td>
<td>x</td>
</tr>
<tr>
<td>Bed videography and cross sections</td>
<td>Two week</td>
<td></td>
</tr>
<tr>
<td>Flow and sediment transport modelling using MOBED</td>
<td>7 months</td>
<td>x</td>
</tr>
<tr>
<td>Data synthesis and report</td>
<td>3 months</td>
<td></td>
</tr>
</tbody>
</table>
# P14 - History of St. Clair River and Detroit River Dredging and Compensation Works

<table>
<thead>
<tr>
<th><strong>Project Name:</strong></th>
<th>History of St. Clair River and Detroit River Dredging and Compensation Works</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Principal Investigator:</strong></td>
<td>Scott Thieme</td>
</tr>
</tbody>
</table>

## Project Abstract (A short description of the project)

This study will document (from literature and archive review) the historic changes in both the St. Clair and Detroit Rivers that have significantly affected, or are suspected to influence conveyance, due to dredging, associated compensation and sand and gravel mining, to the extent that credible information exists. An important aspect of this analysis will be to track the decision making processes and legislative history regarding authorization of projects. Also to be documented are past plans for compensation for various dredging projects that was never built.

## Which primary science questions your project addresses? (listing attached)

1. Has the "Conveyance" of the St. Clair River Changed in the past 50 years? The literature/archive review will identify areas of dredging and estimated dredge quantities, as well as discussions, before and after the projects, of their effects.

2. Has the morphology of the St. Clair River changed? The literature/archive review will identify areas of dredging and estimated dredge quantities.

## Which secondary science questions your project addresses? (listing attached)

You may wish to add other secondary issues your projects may address.

## Describe scenarios you will run for each of the science questions (if applicable)

## What are your exact outputs from the project?

Two reports will be generated: one to document the dredging and one to document the compensation studies. Maps of dredging and compensation locations in a geographic information system.

## List any issues/concerns/linkages?
Enumerate your timelines and milestones in the embedded spreadsheet below:

<table>
<thead>
<tr>
<th>Activities &amp; Milestones</th>
<th>Duration (Months)</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
<th>J</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interim report of findings</td>
<td>5</td>
<td></td>
<td></td>
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<tr>
<td>Draft final reports</td>
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<td>X</td>
<td>X</td>
<td></td>
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<td>6/10/08</td>
</tr>
<tr>
<td>Final reports</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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</table>
**P18 - Extract Bed Movement Velocity from Existing or New ADCP Data**

<table>
<thead>
<tr>
<th>Project Name: Upper St Clair River Bed and Flow Mapping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal Investigator: James Best, University of Illinois Urbana-Champaign</td>
</tr>
<tr>
<td>Project Abstract (A short description of the project)</td>
</tr>
<tr>
<td>Our aim here is to adopt a holistic approach to conduct high-resolution bathymetric surveys of the upper end of the St Clair River, and combine this with detailed cross-sectional acoustic Doppler profiling transects. We aim to establish maps of bathymetry, roughness, grain size, bottom classification and sediment transport direction, and assess the main features of primary and secondary flow within the channel.</td>
</tr>
</tbody>
</table>

**Which primary science questions your project addresses? (listing attached)**

Has the morphology of the St. Clair River changed?

**Which secondary science questions your project addresses? (listing attached)**

*You may wish to add other secondary issues your projects may address.*

- Can the project establish zones of active erosion and deposition?
- Can the project predict the degree of dimensionality of the St. Clair River flows?
- Has the composition of bed material changed?

**Describe scenarios you will run for each of the science questions (if applicable)**

**What are your exact outputs from the project?**

- Detailed bathymetric maps of the channel
- Geo-referenced surficial sediment maps
- Geo-referenced sonar backscatter image mosaics
- Analysis of mean and secondary flows at key cross-sections
- Assessment of the use of MBES for quantifying ship-wake erosion
- A technical report on methods, results and recommendations, to be delivered within 4 months of completion of the fieldwork

*Draft - Hydraulic and Sediment Modelling Methodological Report – April 01, 2008*
List any issues/concerns/linkages?

Links to work of Krishnappan and USGS Woods Hole.

Enumerate your timelines and milestones in the embedded spreadsheet below:

<table>
<thead>
<tr>
<th>Activities &amp; Milestones</th>
<th>Duration</th>
<th>Time in Months (2008/2009)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field surveys</td>
<td>1 week</td>
<td>M: x</td>
</tr>
<tr>
<td>Data analysis</td>
<td>3 months</td>
<td>A: x J: x S: x O:</td>
</tr>
<tr>
<td>Final report</td>
<td>1 week</td>
<td>N: D: J: F:</td>
</tr>
</tbody>
</table>

### P19 - Reports and Data on Surficial Geology, Littoral Transport, St Clair River and Delta

<table>
<thead>
<tr>
<th><strong>Project Name:</strong> St Clair River surficial geology synthesis – <strong>planned activity</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Principal Investigator:</strong> Tom Weaver (USGS, Lansing), Dr. Tom Morris (formerly Ontario Geological Survey) - <strong>suggested</strong></td>
</tr>
</tbody>
</table>

#### Project Abstract (A short description of the project)
Assembly and synthesis of all existing data (cores, maps, logs, reports) on surficial and Quaternary geology in vicinity of St Clair River. Will ascertain composition and stratigraphy of materials, depth to bedrock, and Holocene history of St Clair River outlet.

#### Which primary science questions your project addresses? (listing attached)
Has the morphology of the St. Clair River changed?

#### Which secondary science questions your project addresses? (listing attached)
*You may wish to add other secondary issues your projects may address.*

1. Which secondary science questions your project addresses? (listing attached)
2. Which secondary science questions your project addresses? (listing attached)
3. Which secondary science questions your project addresses? (listing attached)
4. Can the project ascertain the age of armoured surfaces?
5. Can the project determine the material below the armoured layer?

#### Describe scenarios you will run for each of the science questions (if applicable)

#### What are your exact outputs from the project?
Collection of materials available on SharePoint site, complete list of reports and papers, synthesis report addressing main issues of stratigraphy and sub-bottom materials

#### List any issues/concerns/linkages?
Will also aid planning and sampling by Woods Hole and UIUC groups.

#### Enumerate your timelines and milestones in the embedded spreadsheet below:

_Draft - Hydraulic and Sediment Modelling Methodological Report – April 01, 2008_
<table>
<thead>
<tr>
<th>Activities &amp; Milestones</th>
<th>Duration</th>
<th>Time in Months (2008/2009)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection of material</td>
<td>1 month</td>
<td>M  A  M  J  J  A  S  O  N  D  J  F</td>
</tr>
<tr>
<td>Summary report</td>
<td>1 week</td>
<td>X</td>
</tr>
</tbody>
</table>
P24 - Quantification of Uncertainties in 1-D and 2-D Modeling

Project Name: Quantification of uncertainties in 1-D and 2-D modeling

Principal Investigator: to be determined

Project Abstract (A short description of the project)
The scope of work and details for this project are yet to be developed, a general description follows.
The purpose of this project is to quantify the uncertainty of the modelling results. Uncertainty of data used in all of the 1-D and 2-D modeling applications will be determined, including the uncertainty of bathymetry soundings, water level data, and flow measurements. The results of this study will be used to understand the total uncertainty of the modeling results.

Which primary science questions your project addresses? (listing attached)
Has the conveyance of the St. Clair River changed in the past 50 years? Understanding the uncertainty in the data used to develop the hydraulic models as well as the uncertainty in the modeling results is critical in developing confidence in the conclusions reached by the various modeling projects.

Which secondary science questions your project addresses? (listing attached)
You may wish to add other secondary issues your projects may address.
Being able to quantify the uncertainties will add confidence in modeling results that answer all of the secondary questions outlined in current project strategy documents.

Describe scenarios you will run for each of the science questions (if applicable)

What are your exact outputs from the project?
A report documenting uncertainties of the Hydraulic TWGs modeling projects.

List any issues/concerns/linkages?

Enumerate your timelines and milestones in the embedded spreadsheet below:

<table>
<thead>
<tr>
<th>Activities &amp; Milestones</th>
<th>Duration</th>
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<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
<th>A</th>
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<th>N</th>
<th>D</th>
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<tbody>
<tr>
<td>Uncertainty report</td>
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