A NEW LIFE FOR OLD CHARTS

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Historic cartography provides a snapshot of historic and spatial data that frequently cannot be sourced from written documents. Visualizing and interpreting these snapshots of different sizes and scales can be challenging. Today's 'digitally visual' society appreciates vivid graphic representations of reality. Many find that history and geography are easier to perceive and understand if they are rendered to be entertaining and fun. Using historic artifacts and cartography in partnership with GIS software (HGIS) is one way of turning history into a contemporary reality.

Sault Ste. Marie: Local History and Cartography

The St. Marys River, a constricted passageway of rapids and islands connecting Lake Superior with Lake Huron, was designated a Canadian Heritage River in 2000. More than two thousand years of archaeological evidence indicates that the St. Marys Falls (long rapids dropping 6.1m, or 90% of the total river gradient) at Sault Ste. Marie was the hub of Ojibwa culture. Seventeenth and eighteenth century European explorers and entrepreneurs used this watery arterial link in their quest for primary resources. The region was explored and mapped by Champlain's men long before Europeans were navigating Lakes Erie and Ontario. The local area was labelled Sault (French for rapids) de Gaston on Champlain's 1632 map, and French Jesuit Fathers Dablon and Claude changed the name to Sainte Marie du Sault after they arrived in 1641. The Fathers mapped the area during the 1650s. Louis XIV claimed the region as a Seigneury in 1671. The St. Marys River became part of the British/American border in the 1794 Jay's Treaty, although the exact boundary was not demarcated until 1913. After America began enforcing its borders in 1796, British sympathizers and the North West Company (established 1783) relocated to the swampy north (British) shore.

The St. Marys Falls block all river transportation. During the fur-trade era, North West Company (NWC) canoes transported four tons (3700 kg) of furs and freight each, between Grand Portage MN and Montreal (Arbic, 2003). The voyageurs ran the rapids going downstream, but portaged freight when upbound. Ergo in 1797, the NWC built (on the British shore) a canoe lock and canal with a drag road for oxen to pull the canoes around the

Table 1. Chronology of Pre-1855 St. Marys River Channel Modifications.

Year	Event	Description
1797- 1814	NWC canoe canal, and portage road	Canal: 795m long; canoe lock: 11.5 x 2.7 x 2.7m deep. A drag road (3.7m wide) ran parallel to the lock and canal. Oxen dragged canoes up 3.7m of elevation change.
1822	Fort Brady MI	Water race used as transportation canal.
1839	State of Michigan canal	Construction was halted—it destroyed part of Fort millrace and the Ojibwa burial ground.
1850	Horse-drawn strap railway, Sault MI	Railway made of metal-sheathed wooden rails could not meet transport demand. In 1850, 6,000 tons of freight was portaged through;1851 increased to 12,600 tons ($1,000,000).
1855	Michigan Tandem State Locks	State Lock:106 x 21m, 3.7m deep. Steamer locked through in 11 hours. Today a 302 x 32m lake freighter passes through the SOO Locks in 20 minutes.

rapids (Table 1). This first engineering marvel was destroyed in 1814, but is recorded with varying degrees of accuracy on most pre-1855 maps. Channel modifications occurred on the south shore with the establishment of Fort Brady MI, with a water millrace that doubled as a transportation canal. Cargos were floated up the race, unloaded, portaged around the rapids, and repacked at the head of the rapids onto waiting sailing vessels. Local historian, Dr. Bernie Arbic notes that more than one dozen ships (sailing and steam) were physically 'dragged' over the south shore around the rapids. By the late 1840s, the exploration and extraction of copper reserves on Lake Superior caused a monumental increase in freight volume past the rapids. Backlogs of 12,000 barrels of goods per season were common by 1851. Finally, the U.S. Congress approved the construction of toll-free shipping canals. The first tandem "State Locks" completed in 1855 (Table 1) evolved into the SOO Locks.

These engineering marvels and river bathymetry (water depths) are recorded on historic charts that are scattered across two continents and three nations, and tend to focus on only one side or the other of the St. Marys River. The British Admiralty conducted the first complete hydrographic *Survey of the* [Great] *Lakes* between 1816-1825 for navigation purposes (Winearls, 1991). Lieut. Henry Bayfield completed two charts of the St. Marys River portion of the survey in 1825 (Figures 1, 2). The charts include many lines of sounding depths that transverse the river's channel, and record excellent shore details. Soundings are exact water depths measured in feet from the water surface to the bed (Woodford, 1994). Historically, sounding measurements were obtained as a crew traversed the area in a cutter, logging and measuring the depths using either a lead line in deep water (lead weight is attached to a line and dropped), or from a sounding pole that is used in shallow water. Point soundings are extremely accurate unless the morphology becomes rugged between sounding lines. Contemporary, remotely sensed soundings are still recorded in feet (Woodford, 1994).

The American Corps of Topographic Engineers (Corps) conducted the first detailed triangulation and hydrographic surveys of the entire Great Lakes

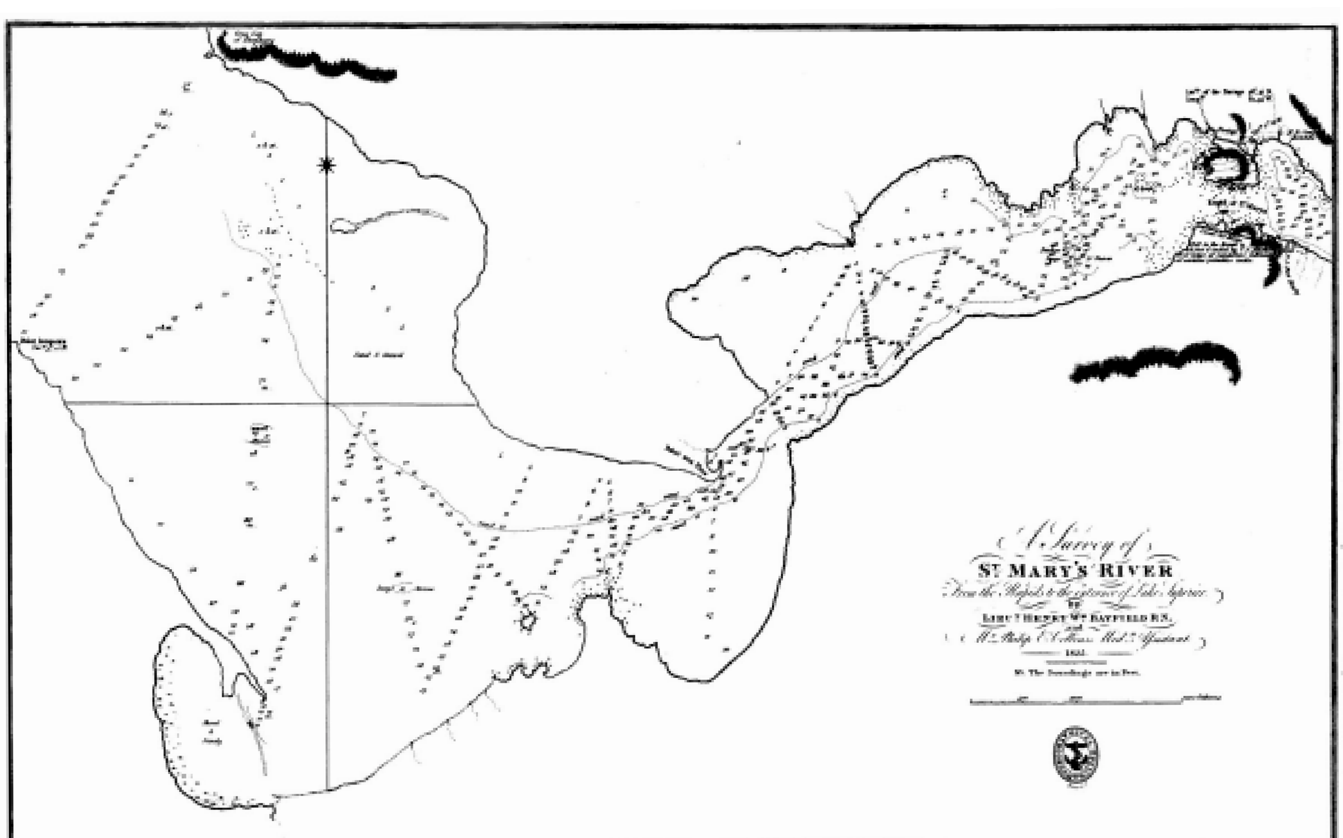

Figure 1. A Survey of St. Mary's River From the Rapids to the entrance of Lake Superior, 1825. The straight lines are survey lines of bathymetric data.

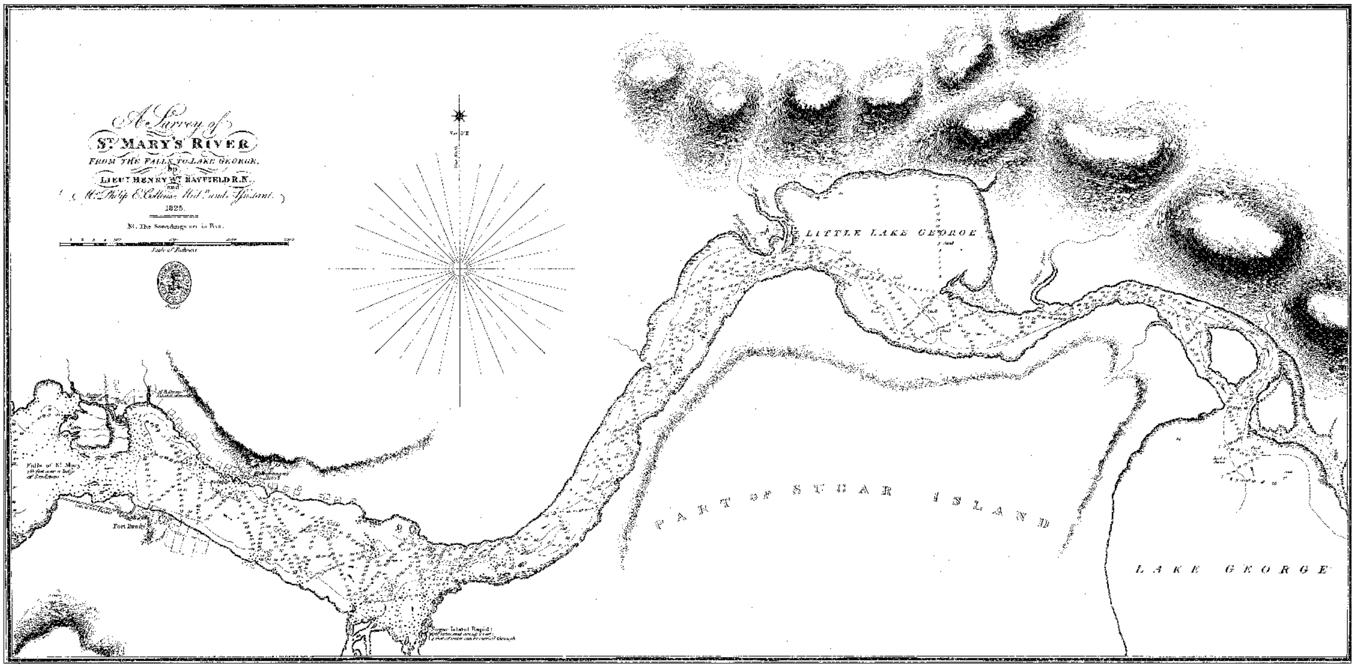

Figure 2. A Survey of St. Mary's River From the Falls to Lake George, 1825.

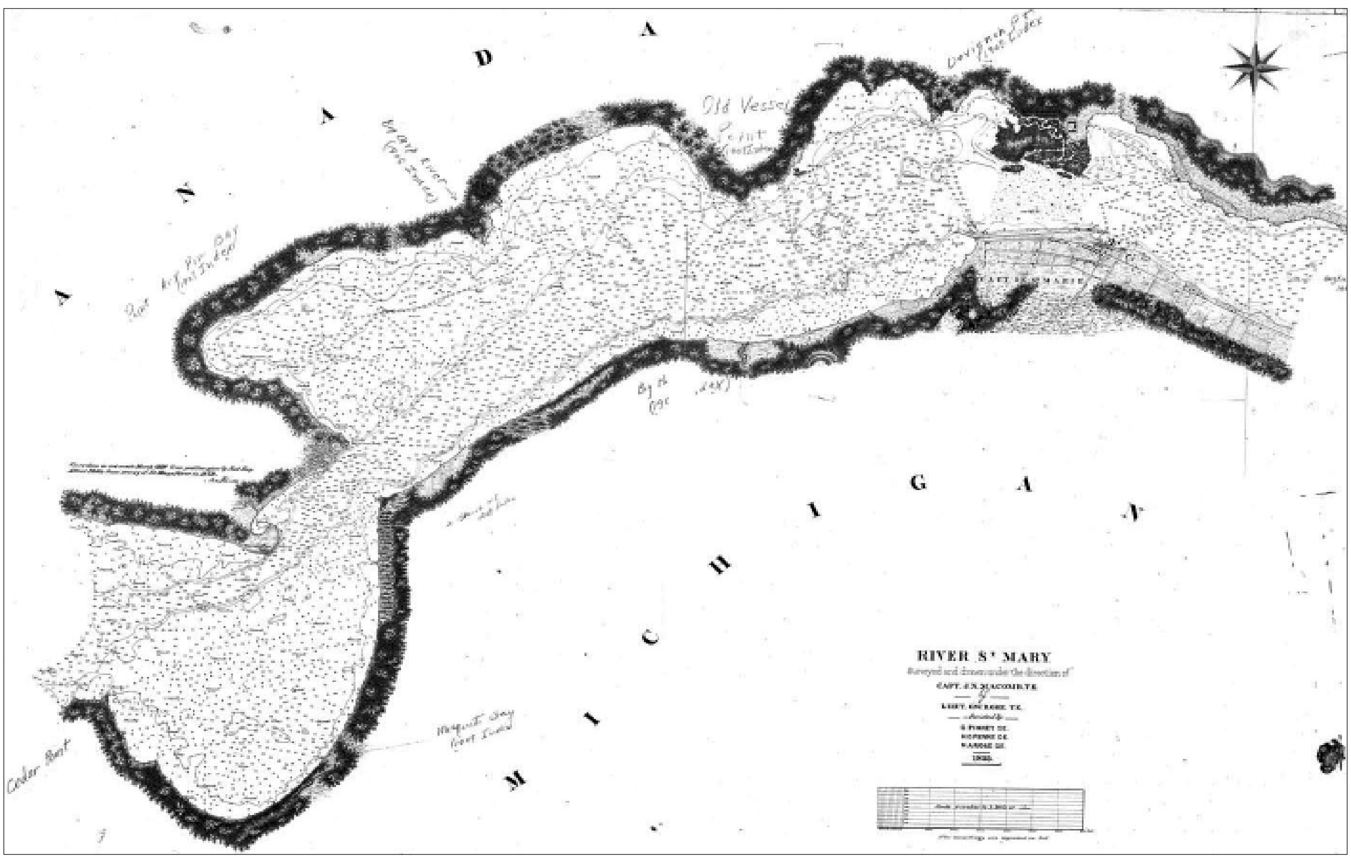

Figure 3. River St. Mary Field Sheet [American Corps of Topographic Engineers], 1855.

region from 1841 to 1882. The Corps completed the St. Marys River channel portion of the survey between 1853 and 1855, just prior to the opening of the Michigan Tandem State Locks (SOO Canal) (Figure 3). The 1908 Boundary Treaty between Great Britain and the United States authorized the accurate re-establishment of the International Boundary through the Great Lakes system. As a result, the St. Marys River channel and BOTH shores were intensively resurveyed in 1913 as a supplement to the surveys of the International Waterways Commission. All hydrographic surveys and navigation charts include shorelines, anthropogenic features, and sounding depths with contour lines shown in fathoms, or six-foot intervals (one fathom is six feet). Nearly 300 years of cartographic detail makes the St. Marys River an excellent area in which to reconstruct the original riverbed morphology using a HGIS database.

Historic GIS

A fundamental step in the visualization of historic documents is the creation of an HGIS database. The 1913 International Waterways Commission map *Sheet No. 25 Saint Marys Falls* provides good intermediate data linking contemporary and historical sources. Because it contains detailed up-to-date (1913) topographic and hydrographic survey data from **both** sides of the international river channel, it was used as the HGIS basemap. The 1913 map was georectified to 1998 ortho-imagery and shape files from Michigan, and 2000 Digital OBM data using ESRI ArcGIS 9® software. Working backwards in time, the 1855 chart was georectified to 1913, and the 1825 charts were georectified to 1855. All were digitized and converted into interpolated raster Digital Elevation (DEM) and Triangulated Irregular Network (TIN) models to create a visual representation of the **first** surveyed bathymetric data. The 1825 charts were merged prior to the modelling process–with excellent registration.

When combining historical artifacts in HGIS one must be aware of the limitations. The accuracy of older maps cannot be improved. Historic maps can be difficult to spatially orient and interpret because the original features and environmental conditions usually have changed. In addition, georeferencing maps changes the original lines, shapes and distances (Knowles, 2002). In order to locate sufficient control points for georectification, the HGIS user must understand the local history and the historical significance of artifacts drawn on the map. Occasionally, the HGIS user must interpolate the location of an artifact using references other than historic maps. If landscape changes have occurred, or names have changed, intermediate maps may have to be used to georectify period maps with contemporary data. In fact, on the 1913 International Waterways Commission map, the streets of Sault Ste. Marie ON were drawn with three lines that include the surveyed street allowance and a 'centre line' that was the streetcar line. The 1998 digital data depicts streets with one

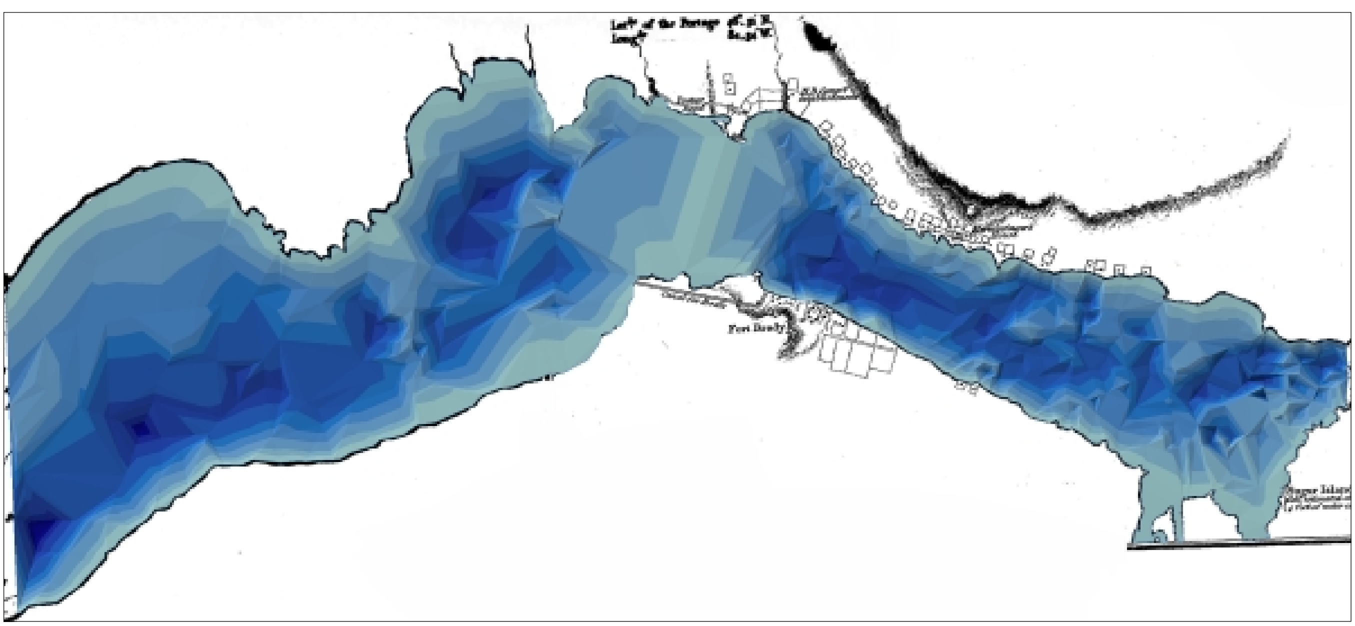

Figure 4. Interpolated TIN of merged 1825 Bayfield charts. There is no sounding data on the rapids.

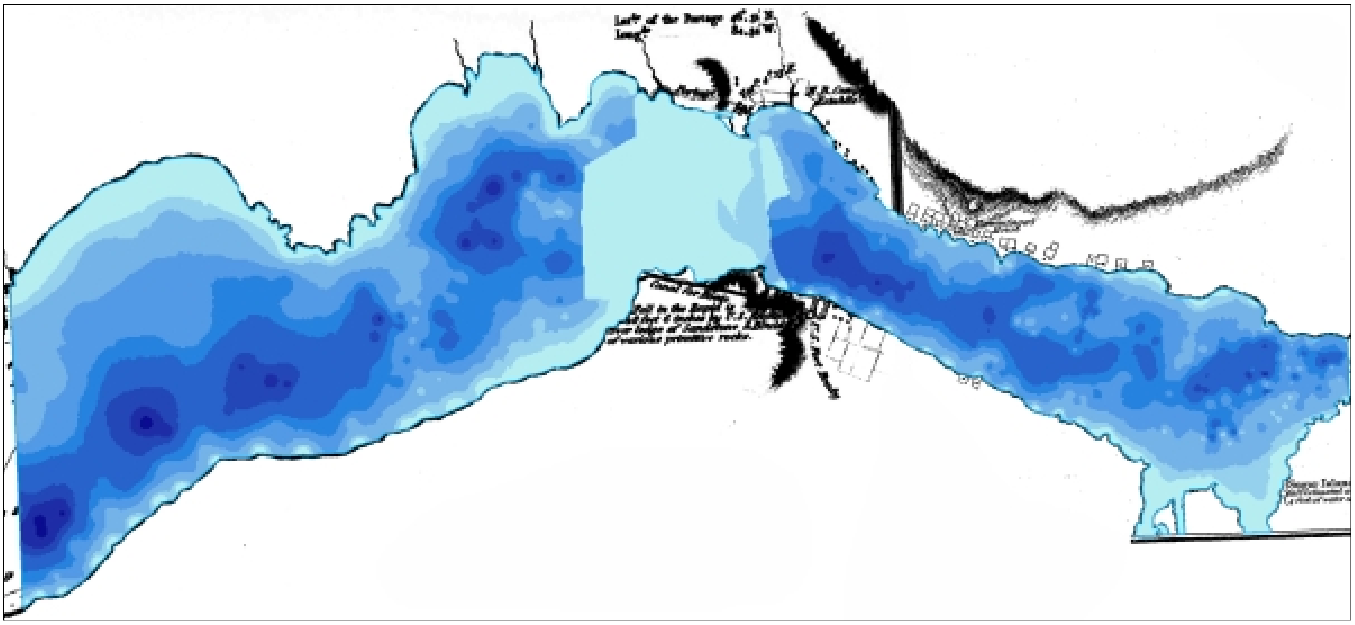

Figure 5. Interpolated DEM of merged 1825 Bayfield charts. There is no sounding data on the rapids.

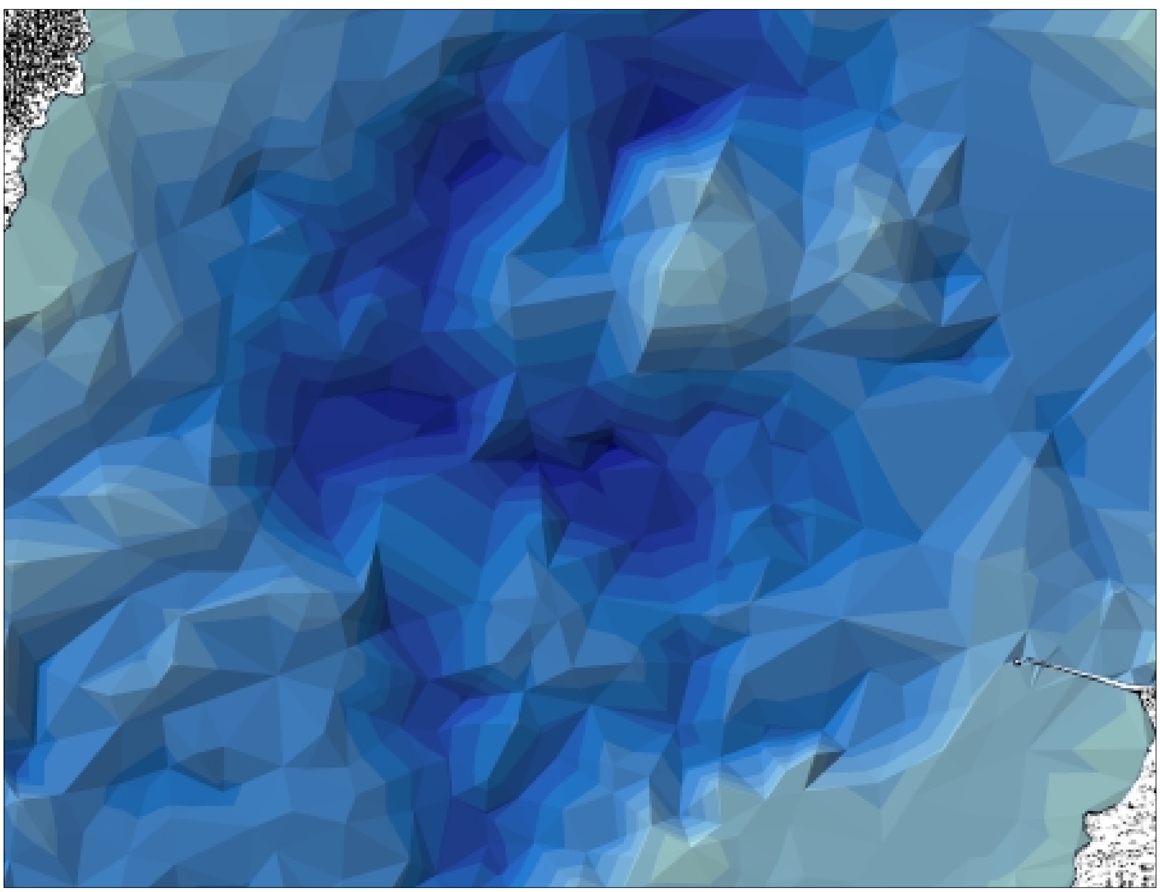

Figure 6. Zoom of 1855 TIN that dramatically depicts the riverbed morphology.

single thin line, and many older maps use very thick street lines—either one or two. Consistent interpolation was required when using intersections as control points.

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Interpolated models from 1825 and 1855 provide a visual rendering of the St. Marys River morphology, replacing the numerical representations of depth with colour. Even without a legend, water depth is made apparent by using the conventions of darker blue for deep cold water grading to light blue for shallows. All interpolated models show 'straight lines' of relief along the rapids because surveys were not conducted in the non-navigable area (Figures 4, 5, 7). TIN models are considered to be the most reliable method for representing irregularly spaced point data. The triangular representation of data creates a dramatic 3-D effect (Figures 4, 6). However, TIN exhibits a high inaccuracy in areas of high relief (Rumsey & Williams, 2002)—not a problem in the study area since the river channel has a maximum depth of 61 feet. Map viewers may prefer the look of interpolated DEMs that depict relief in the same manner as topographic maps (Figure 5).

The 1825 charts by Henry Bayfield (Figures 4, 5) provide the first snapshot of an unaltered channel bed. These maps also show the general geographic location of local lots, Fort Brady MI; and the NWC canal and drag road—but not as accurately as earlier maps, which include the 1797 *Plan of the Falls of St. Mary between Lake Huron & Lake Superior, Surveyed by Order of the North West Company*. The 1855 Corps, *River St. Mary Field Sheet* (Figure 3, 7) depicts the altered south shore where the first lock and canal were constructed. The surveyed streets marked with individual buildings in Sault Ste. Marie MI are a contrast to the British side of the river. The poor representation of Sault Ste. Marie ON makes using control points difficult. Only one street is drawn—even though Alexander Vidal, Canada Land Surveyor, had completed a mapped survey of the village in 1845. The Hudson Bay Company post (former NWC) has a skeleton outline.

The interpolated models can be layered over the original map, masking the numerical text with colour (Figure 7). Conversely, the original map can be layered over the model with the transparency adjusted so that the original data can be viewed along with the colour (Figures 6, 8). The numerical and text information enhances the coloured depths. Where the chart has been labelled "Rocky", one sees 'rocks' that rise quickly and steeply from the riverbed—a definite navigation hazard. The bathymetry of the shallows has more meaning with this combination. These methods help the audience to understand the actual morphology of the historic

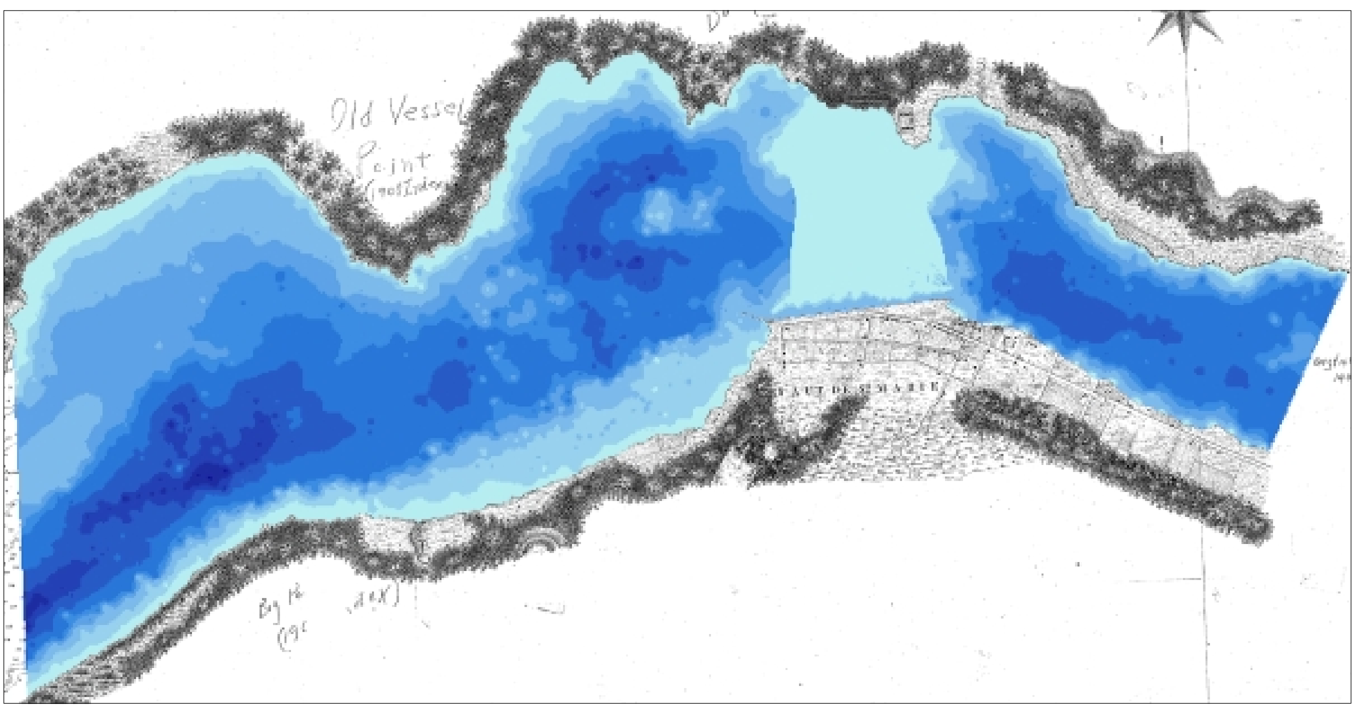

Figure 7. Interpolated DEM of the study area is layered over the 1855 chart.

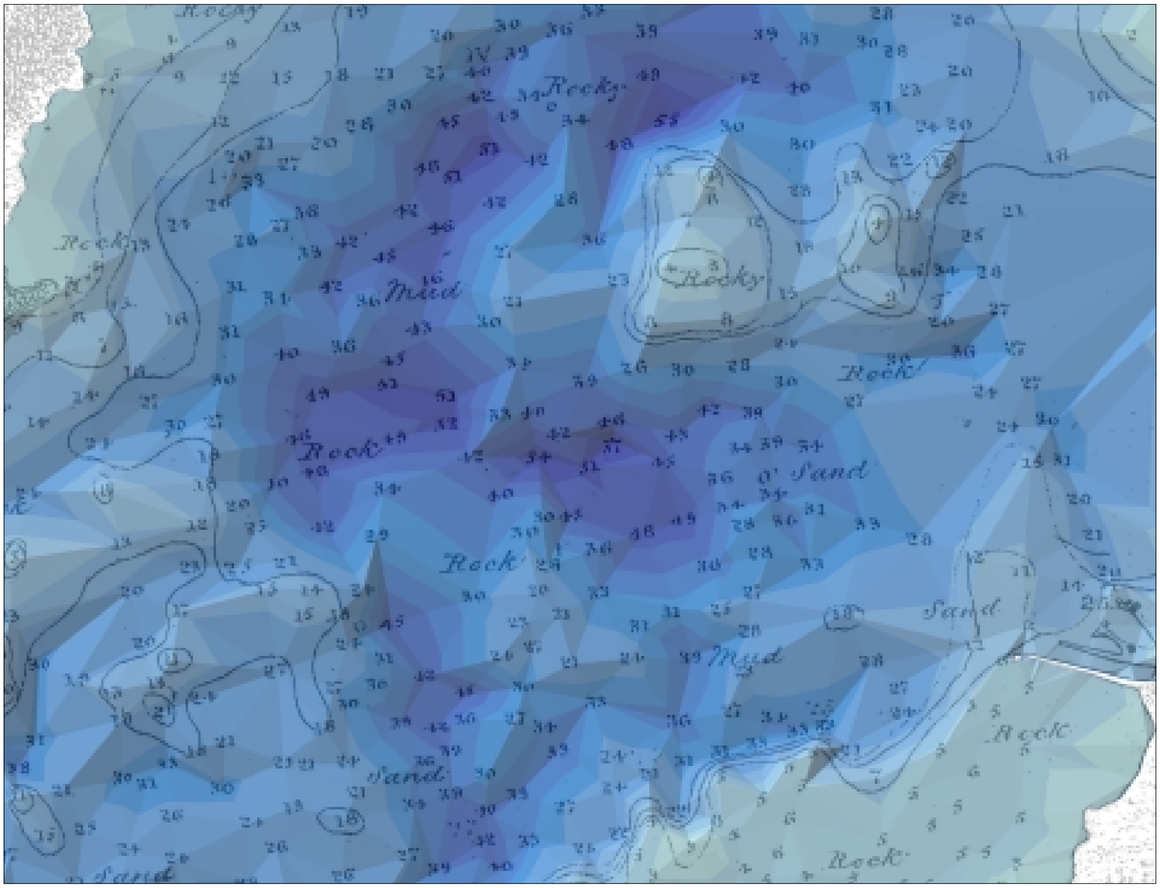

Figure 8. Zoom of 1855 TIN with original chart layered over the model.

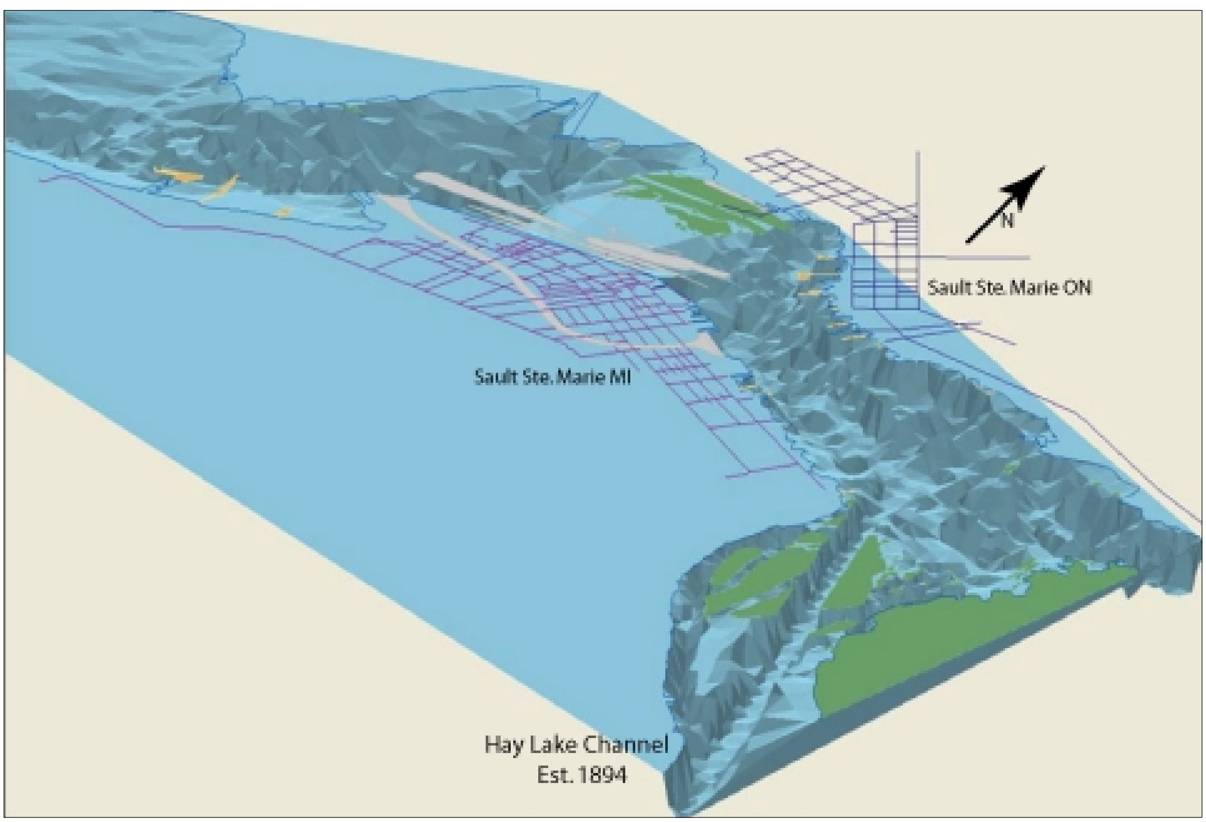

Figure 9. 3-D interpolated TIN of the International Waterways Commission map, Sheet No. 25 Saint Marys Falls, 1913.

channel. Taking into consideration that the 1855 *Field Sheet* has more sounding lines, one can observe qualitatively how the channel bed may have altered between 1825 and 1855.

Finally, virtual reality and 3-D representations that can be viewed from any angle enhance the underwater topography. Inputting the 1913 interpolated TIN at 10 times exaggeration into ArcScene software (sub-extension of ArcGIS 3D-Analyst) turns the 2-D bathymetry of the dredged Hay Lake Channel into a 3-D engineering marvel (7m deep, 183m wide) (Figure 9). Fun, fly-through software sends the viewer back in time. Imagine cruising along the bed of St. Marys River in 1825 and negotiating all those rocks! Combining historical cartography with GIS software can make history and geography an enjoyable contemporary reality.

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Notes

Portions of this article appear in *Proceedings of the ASPRS 2007 Annual Conference, Identifying Geospatial Solutions*, May 7-11, 2007. Tampa, Florida.

All maps are available at the Serge A. Sauer Map Library, University of Western Ontario. This article is part of a larger thesis that would not have been possible without the catalogued resources (including books) and fantastic personnel of the Serge A. Sauer Map Library.

This paper is based on a Masters of Science thesis in progress, ***GIS and Historic Maps: Modelling the St. Marys River Channel Topography****, to be submitted to the Department of Geography, University of Western Ontario, anticipated date June 2009.*