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Spatial Distribution and Thickness of Fine-Grained Sediment along the United States Portion of the Upper Niagara River, New York

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Final report

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Buffalo, NY 14207-3111

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Abstract

Over 220 linear miles of geophysical data, including sidescan sonar and chirp sub-bottom profiles, were collected in 2016 and 2017 by the US Army Corps of Engineers and the US Fish and Wildlife Service in the upper Niagara River. In addition, 36 sediment grab samples were collected to groundtruth the geophysical data. These data were used to map the spatial distribution of fine-grained sediment, including volume data in certain locations, along the shallow shorelines of the upper Niagara River. Overall, the most extensive deposits were spatially associated with either small tributaries or with man-made structures that modified the natural flow of the system. Extensive beds of submerged aquatic vegetation (SAV) were also mapped. Although always associated with a fine-grained matrix, the SAV beds were patchy in distribution, which might reflect subtle differences in the grain size of the sediment matrix or could simply be a function of variations in species or growth. The maps generated from this effort can be used to guide sampling plans for future studies of contamination in fine-grained sediment regions.

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Preface

This study was conducted for the US Army Corps of Engineers, Buffalo District, under MIPR W81EU610087507. The technical monitor was Mr. Gabriel A. Schmidbauer.

The work was performed by the Coastal Observations and Analysis Branch of the Flood and Storm Protection Division, US Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL). At the time of publication of this report, Dr. Jeff Waters was Chief, Coastal Observations and Analysis Branch; Dr. Cary Talbot was Chief, Flood and Storm Protection Division; Mr. Keith Flowers was Deputy Director of CHL; and Dr. Ty V. Wamsley was Director of CHL.

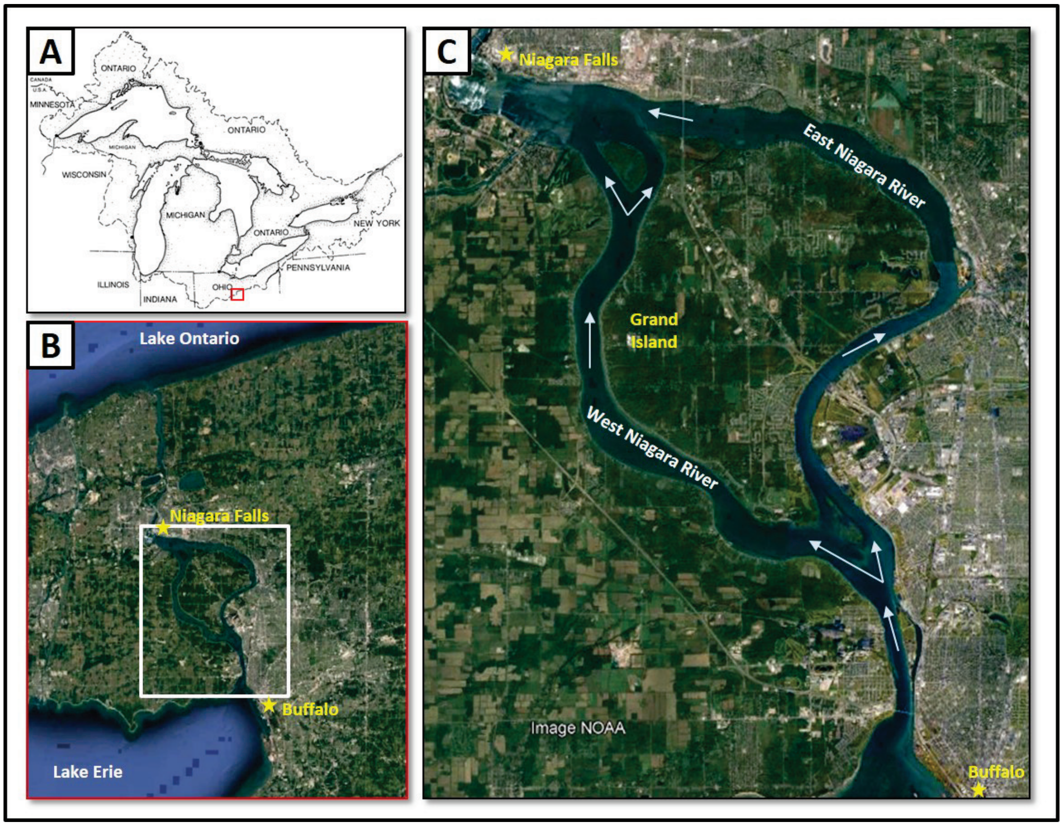
COL Theresa A. Schlosser was the Commander of ERDC, and the Director was Dr. David W. Pittman.

1 Introduction

Quantifying the spatial extent and distribution of contaminated fine-grained sediment in designated Great Lakes Areas of Concern (AOC) is a key mission of the US Army Corps of Engineers (USACE). This includes assessment of potential sediment-associated contaminants in the upper Niagara River system (Figure 1). The Niagara River is a designated Great Lakes AOC due to the identified beneficial use impairments (BUIs) of restrictions on fish and wildlife consumption, fish tumors and other deformities (removed in 2016), degradation of benthos, restrictions on dredging activities, loss of fish and wildlife habitat, degradation of fish and wildlife populations, and bird or animal deformities or reproductive problems. The listed BUIs are generally linked to pollution and physical disturbances, such as filling, bulk-heading, and marina development, associated with the extensive past and present industrial and urban development of the watershed. The Niagara River AOC extends from the southern boundary of the Buffalo Harbor, at the mouth of Smokes Creek, north to the mouth of the Niagara River at Lake Ontario.

The Remedial Action Plan Stage 2 Addendum for the Niagara River AOC (NYSDEC 2012) identifies sediment assessments within depositional zones of the river and certain tributaries as a needed management action with respect to further evaluation of the restrictions on fish and wildlife consumption, degradation of benthos, degradation of fish and wildlife populations and bird or animal deformities or reproductive problems BUIs. Sediment-associated contaminants that may be linked to BUIs include pesticides, polychlorinated biphenyls, dioxin and dibenzofuran, polycyclic aromatic hydrocarbons, and metals (NYSDEC 2012). A previous study examining the ecology of emerald shiners completed in 2016 by the USACE Buffalo District (LRB), in conjunction with SUNY Buffalo, identified multiple regions of potentially contaminated fine-grained sediment in the upper Niagara River and indicated a growing need for a more accurate assessment of contamination in this region. This report details the geophysical and geologic study conducted in 2016 and 2017, which identified the spatial distribution of fine-grained sediment in the upper Niagara River, to allow for more efficient and accurate future sampling.

Figure 1. Niagara River benthos study site, located between Lake Erie and Lake Ontario in upstate New York, USA (A, B). The upper Niagara includes the region between Lake Erie and Niagara Falls (C). White arrows on panel C indicate the general direction of flow (arrow size is not representative of relative velocity).



1.1 Background

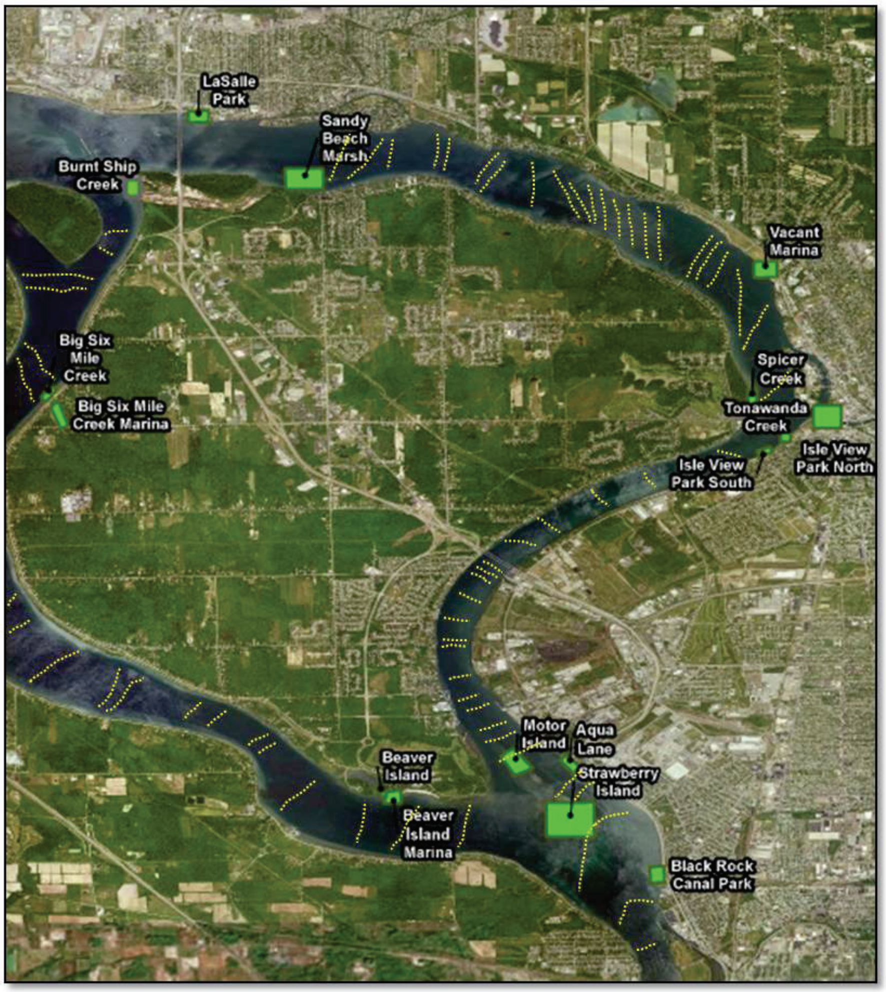
The distribution of surface sediments in the mainstem of the upper Niagara River was mapped by Murdoch and Williams (1989). Overall, they found the river bottom to be dominated by sands and gravels, with occasional deposits of glacial till and outcrops of bedrock, but they did not map the shoals along the riverbanks due to limited vessel draft (Figure 2). More recently, the USACE LRB partnered with SUNY Buffalo to produce high-resolution habitat maps at 16 shallow water sites (<9 ft[1],[2] water depth) for assessment of the ecology of emerald shiners (*Notropis*

[1] For a full list of the spelled-out forms of the units of measure used in this document, please refer to US Government Publishing Office Style Manual, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248-52, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

[2] For a full list of the unit conversions used in this document, please refer to US Government Publishing Office Style Manual, 31st ed. (Washington, DC: US Government Publishing Office 2016), 345-7, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

atherinoides)[1]. Unlike the mainstem of the channel, surface grabs at these shallow water sites indicated at least surficial deposits of silt and clay at most of the sites, though limited sampling efforts and lack of geophysical data precluded extrapolation of these data to the larger system.

Figure 2. Emerald Shiner sampling summary, indicated by green polygons. Survey lines mapped by Murdoch and Williams (1989) are plotted as dashed yellow lines.

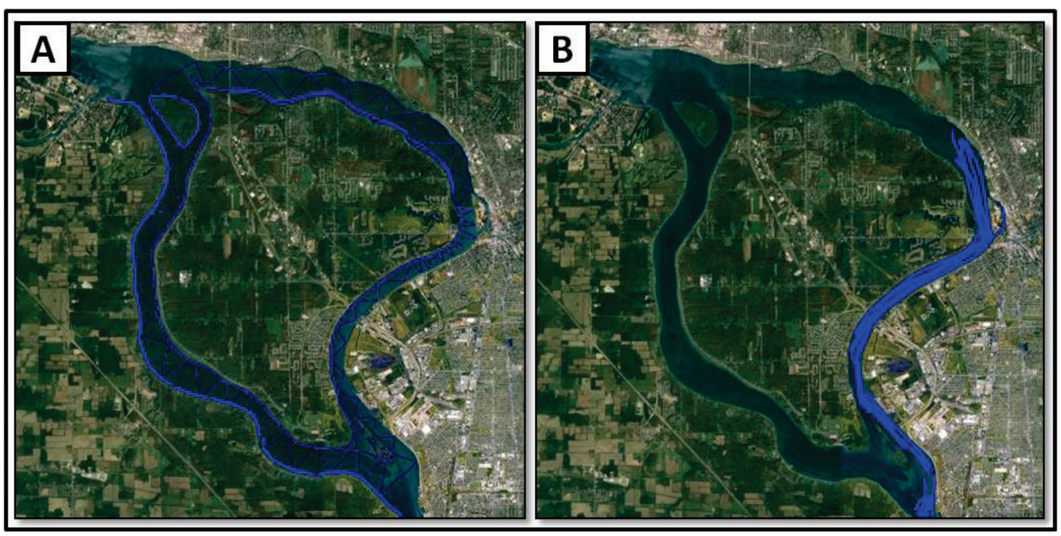


Budget and time constraints preclude collecting samples at a high enough density along the entire upper Niagara shoreline to ensure a full survey of potentially contaminated regions. To maximize the efficiency by which sediments are sampled, and to ensure that potentially contaminated

1 USACE LRB (US Army Corps of Engineers, Buffalo District). 2016. (Unpublished report). *Niagara River Area of Concern Emerald Shiner (Notropis atherinoides) Study, Great Lakes Remedial Action Plans Program, Habitat Characterization*. Figure 2.

regions are not missed which is a risk when areas to be sampled are identified via randomized sampling protocols, surficial maps of surface sediment distribution and layer thickness are considered to be critical components of a sampling protocol. To that effect, in 2016, both LRB and the US Fish and Wildlife Service (USFWS) collected sidescan sonar data over much of the study site to help identify fine-grained regions in order to refine sample locations, the details of which are presented in Section 2.1, below (Figure 3 A,B). Although groundtruthing samples for these data are limited, the variations in sidescan sonar amplitude that were observed along the river's shorelines suggest that fine-grained sediments are preserved in these regions, though the full spatial extent of the fine-grained regions are unclear from these data alone. Also unclear is the thickness of any fine-grained regions mapped. Sidescan data provide an image of only the surficial sediment and do not indicate whether a region of fine-grained sediment represents a shallow, ephemeral deposition (likely not a contaminated region) or a thicker region of long-term deposition (more likely to be a contaminated region).

Figure 3. Sidescan sonar coverage map for survey efforts conducted in 2016. Data were collected using both a (A) Lowrance and (B) EdgeTech sonar.



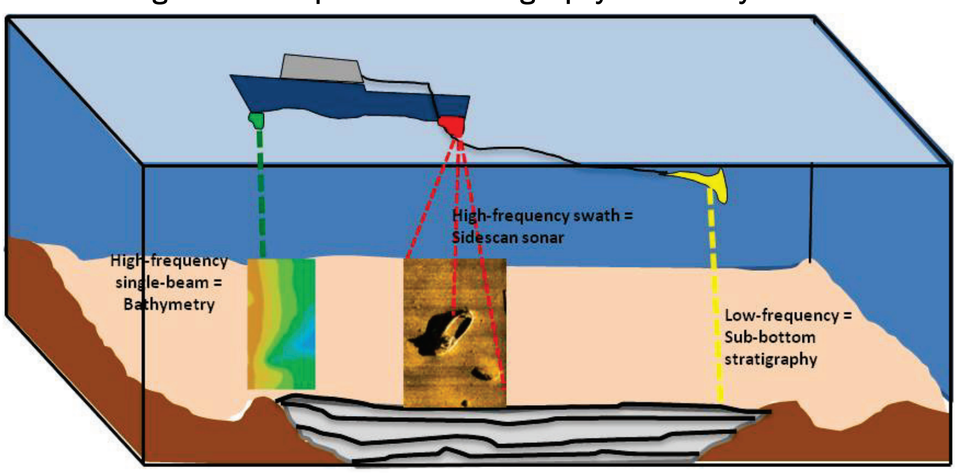
1.2 Objective

The objective of this effort was to identify the spatial extent and thickness of fine-grained regions in the upper Niagara River via geophysical surveying, to include sidescan sonar and shallow reflective (chirp) sub-bottom imagery. These maps will then be used to target future sediment remediation efforts.

1.3 Approach

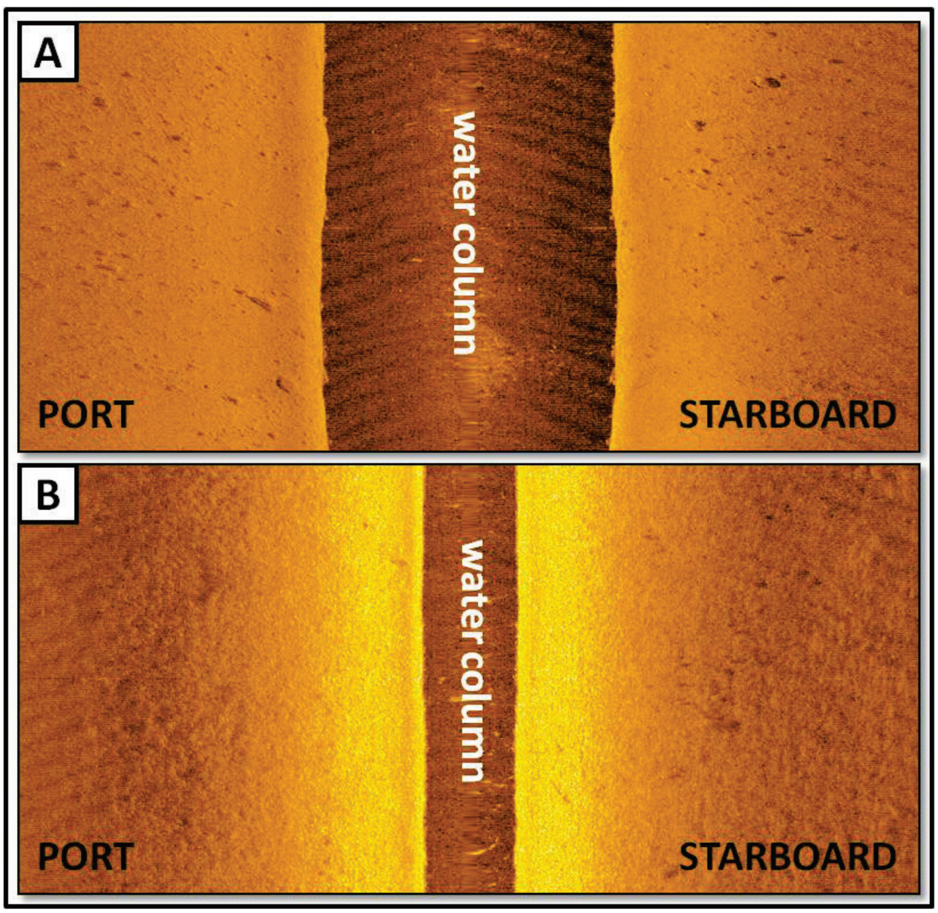
All acoustic geophysical mapping methodologies share the same basic relationship: the geophysical equipment, referred to as a towfish, is towed from a survey vessel, and a sound source is generated from a transducer in the towfish towards the sediment-water interface (referred hereafter as the "riverbed"). The density change at the riverbed reflects the sound back to the surface, where it is detected by receivers either embedded in the towfish or towed behind the towfish or vessel (Figure 4). Since the frequency of the acoustic pulse is known, the two-way travel time provides a measure of the distance, or water depth, between the towfish and the riverbed, and this relationship provides the basis for all bathymetric depth sounders (Figure 4). The acoustic frequency generated by bathymetric towfish is generally of a high-enough frequency (e.g., ~200 kHz or higher) such that all of the generated sound is reflected off of the riverbed, with little or no penetration below the surface.

Figure 4. Examples of common geophysical survey data.



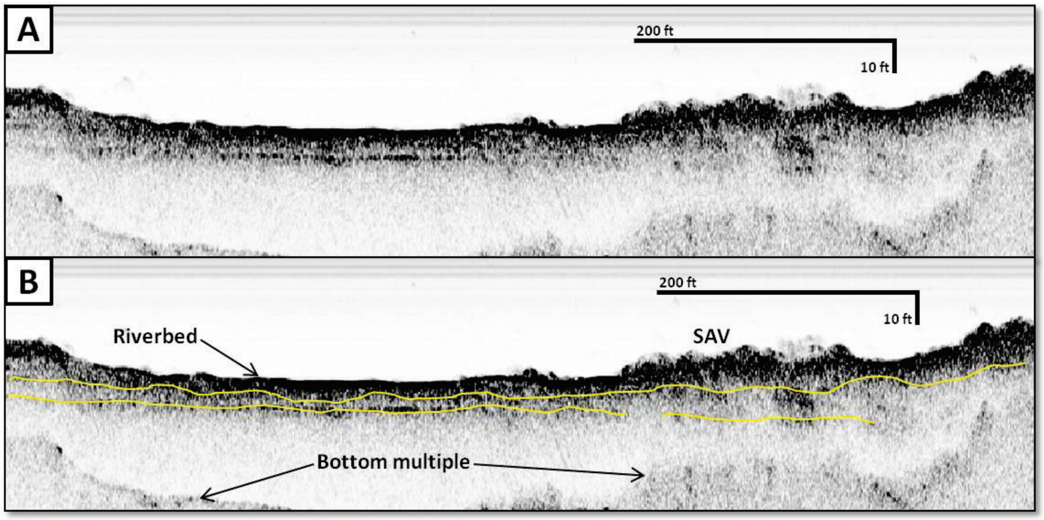
The strength of the returned signal, referred to as the signal's amplitude, is a measure of the acoustic impedance of the geologic unit, which in turn is directly related to the density of the sediment, and thus the amplitude of the acoustic return can be used to delineate the geologic nature of the riverbed. Softer, less dense sediment (e.g., silty-clay) reflects less energy and thus has a lower amplitude return than more dense sediment (e.g., sand). The varying amplitudes require groundtruthing via sediment samples to determine what sediment type they are reflective of in a specific region (Figure 5), but significantly fewer samples are required to groundtruth amplitude data to generate a surface type map than without a survey. The frequency of the acoustic signal generated by the sidescan sonar determines both the size of features that can be resolved — the resolution — as well as the depth under the riverbed — the penetration — to which the signal can penetrate, if at all. Sidescan sonar systems measure a swath of high-frequency amplitude returns from the riverbed, allowing detailed maps of surficial sediment type and features (e.g., ripples) to be generated. However, sidescan sonars cannot penetrate more than the uppermost inch or two at most of the riverbed sediment, precluding their use for mapping subsurface stratigraphy (e.g., Mitchell 1993) and do not measure two-way travel time, which is also required for quantifying the thickness of stratigraphic units.

Figure 5. Examples of sidescan sonar waterfall images showing different sediment reflectivity (hardness). Panel (A) shows hard sediment, characterized by even reflection of the acoustic sonar and features (rocks) standing proud on the riverbed. Panel (B) shows softer sediment, with more variable reflectivity and no proud features. The water column has not been removed in these data.



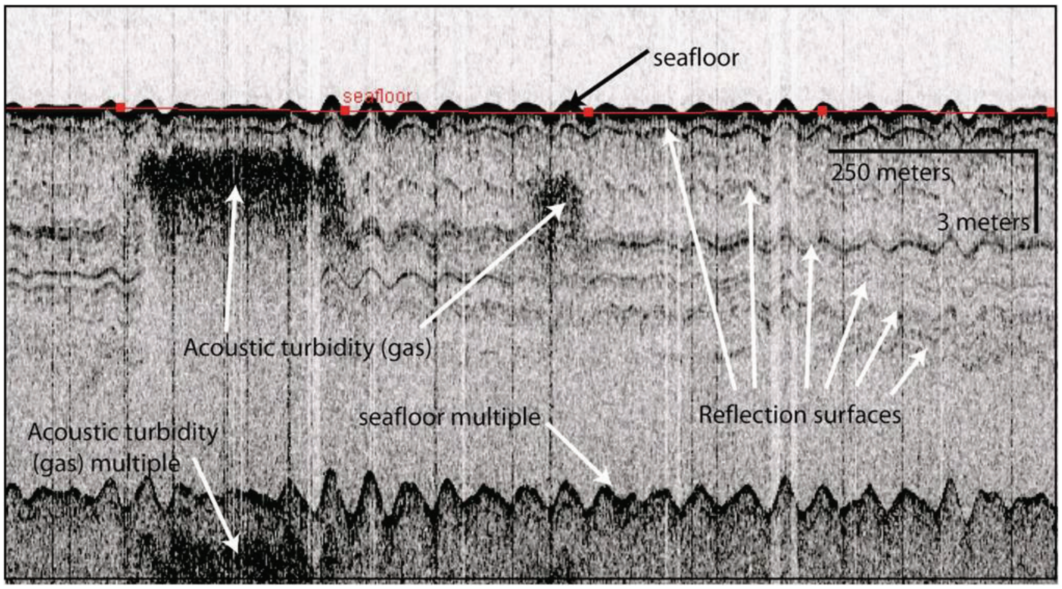
To map the thickness of surface sediments, and the associated stratigraphy below the riverbed, lower acoustic frequencies must be utilized. Although multiple strategies exist for generating these pulses, frequency-modulated, acoustic chirp reflection systems are considered the industry standard for acquiring stratigraphic data in shallow, aqueous environments (e.g., Schock and LeBlanc 1990; LeBlanc et al. 1992; Roberts and Supan 2000; Schock 2004; Lee et al. 2009). Chirp systems produce a frequency-modulated range of acoustic frequencies with each acoustic pulse, similar in audible sound to a bird chirp, and provide a range of lower frequencies than those used for bathymetry or sidescan sonar applications. These lower frequencies are able to penetrate the sediment-water interface and thus are transmitted into the riverbed. Rather than getting a single reflection from the single frequency acoustic pulse, the different frequencies in a chirp pulse are reflected off of changes in density in the subsurface sediment. Since each chirp acoustic pulse is comprised of a range of frequencies, each of the different acoustic frequencies on the same chirp pulse is reflected at different amplitudes and time from different density changes and depths, allowing a detailed map of subsurface stratigraphy to be created (Figure 6). Similar to sidescan sonar data, the amplitude of each return is a function of the different acoustic impedance, or density, of each layer, and sediment sampling via cores can be used to interpret the composition of the mapped layers. Note that frequently, a single acoustic pulse can be reflected off of the seabed and underlying layers and then reflected back down by the towfish after it is first received, where it is then re-reflected back to the towfish receivers. This second reflection is always heard at exactly double the timeframe as the first reflection, resulting in a second “reflection surface” at exactly 2x the distance below the towfish as the original reflection. These artifacts are referred to as “multiples” and are noted when they appear in the acoustic record. Acoustic chirp reflection systems have been utilized to map the shallow stratigraphy of a wide range of aqueous environments (e.g., Schock and LeBlanc 1990; Schock 2004; Roberts and Supan 2000), including rivers and estuaries (e.g., Carbotte et al. 2004; Nitsche et al. 2004; Nitsche et al. 2007; Plets et al. 2009), lacustrine (e.g., Schwamborn et al. 2002; Cukur et al. 2013; Cukur et al. 2015), and shallow coastal (e.g., LeBlanc et al. 1992; Schock 2004; Lee et al. 2009) environments.

Figure 6. Example of sub-surface stratigraphy as mapped by a chirp sub-bottom profiler. Panel (A) shows an un-interpreted profile; panel (B) includes interpreted reflection surfaces digitized in yellow, which represent changes in sediment density.



A potential concern during chirp mapping is the presence of gas in thick deposits of fine-grained sediments. The gas is usually methane and is formed during methanogenesis of organic material (e.g., Abegg and Anders 1997; Albert et al. 1998; Chanton et al. 1989; Duarte et al. 2007). If the biological activity is extensive, the resulting pockets of methane gas absorb acoustic energy, resulting in a characteristic "smudge" obscuring adjacent reflection surfaces (Anderson and Bryant 1990; Davis 1992; Fader 1997; Silva and Brandes 1998; Kim et al. 2004) (Figure 7). This is most frequently a problem in coastal estuarine or marine environments, as gas pockets formed by methanogensis in thick, muddy layers can be extensive (e.g., Anderson and Bryant 1990; Albert et al. 1998; Hagen and Vogt 1999). In freshwater environments, there is limited bio-available sulphur needed for the relevant metabolic reactions, so the presence and extent of methanogenesis happens near the sediment-water interface. Extensive methanogenesis in freshwater environments is also largely dependent on a sufficient supply of sedimentary organic carbon (OC) that remains in the sediment long enough to be metabolized (e.g., Silva and Brandes 1998; Chanton et al. 1989; Duarte et al. 2007). The upper Niagara River is not known for having abnormally high percentages of OC in its surficial sediments (e.g., Charlton 1983; Durham and Oliver 1983), so the distribution of gas should be limited at best, and the thickness of the fine-grained layer can be estimated under small gas pockets by extending where it is mapped in regions spatially adjacent to the gas. Although mapping the spatial extent of regions characterized by high organic matter in the inorganic sediment is possible, it was beyond the scope of this study. Instead, the presence of gas masking the acoustic record indicates that the chirp is mapping a thick fine-grained layer, which is the objective of this study.

Figure 7. Example of gas in a chirp sub-bottom profile.



2 Methods

To identify regions in need of contaminated sampling, both chirp sub-bottom profiles and sidescan sonar data were collected along all of the US shorelines in the upper Niagara River in July of 2017. In addition, 36 sediment samples were collected to groundtruth the acoustic data. Details on the data collection and processing, including previously collected data, are provided below. Note that in this region, the Niagara River flows around both sides of Grand Island. To better distinguish the shorelines being discussed, the colloquial terms of "East Niagara" and "West Niagara" will be used on the east and west branches of the Niagara, respectively (Figure 1).

2.1 Data collection – summer, Fiscal Year 16 (FY16) sidescan sonar

Multiple data collection surveys were conducted in FY16 by both LRB and USFWS: (1) Approximately 125 linear miles of sidescan sonar data were collected using a Lowrance sidescan sonar with a swath width of ~100 ft; (2) approximately 46 linear miles of data were collected using an EdgeTech sidescan sonar with a swath width of ~325 ft (Figures 3a and 3b, respectively). The Lowrance data were collected from 14 to 16 September 2016, and 28 September 2016, in NY State Plane, West Zone, US feet, but the precision of the Global Positioning System (GPS) used was not provided. In addition, it is unknown whether gains were applied during data collection. The EdgeTech data were collected from 12 to 16 September 2016, in UTM Zone 17N, meters, but the precision of the GPS used was not provided. In addition, it is unknown whether gains were applied during data collection. Despite these limitations, the data are still valuable for assessing general sediment surface distributions in the study region.

2.2 Data collection – FY17 geophysical survey

The FY17 data collection effort represented collaboration between LRB and the US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory (ERDC-CHL). Data were collected 27–30 June 2017, using the LRB research vessel (Figure 9a)[1]. Data collected include sidescan sonar and chirp sub-bottom imagery, and details on each system are provided below. The survey area is shown in Figure 8 and covered the

[1] Crew included Mr. Andrew Hannes, Mr. Jessie Petit, and Mr. Jay Miller from LRB, plus Dr. Heidi Wadman and Dr. Jesse McNinch from CHL.

east and west shorelines of the East Niagara River, the western shoreline of the West Niagara River, as well as the main Niagara River north of Black Rock Lock to Strawberry Island, where the Niagara River bifurcates into the east and west branches. Where possible, survey lines were extended behind small islands and into tributaries, and a survey line was included through the navigable region of the shallow area adjacent to Strawberry Island. A water depth of ~7 ft was used to determine how far offshore of the shoreline the shore-parallel survey lines were tracked, as that had been previously identified as the general limitation of fine-grained sediment by LRB. To help verify this assumption, several short, shore-perpendicular lines were included in regions of fine-grained sediment identified during data collection as having a high likelihood of being significant in overall area and/or volume. These lines extended from as close to the shoreline as navigable, offshore into the main river channel until fine-grained sediment was no longer observed in either the real-time sidescan sonar or sub-bottom data (generally less than 10 ft water depth). The real-time data results were also used to identify sample locations for groundtruthing, and this sediment collection effort is covered in more detail in Section 2.3.3, following. Note that the goal of this effort was to delineate fine-grained, muddy regions from coarser, sandy regions. Accordingly, an assessment of bedforms was not performed; those data are preserved in the sidescan sonar record are available for future analyses.

2.2.1 Data collection – FY17 sidescan sonar

Over 51 linear miles of sidescan sonar data were collected using a Tritech Starfish 990F high-resolution towfish (Figure 9b) and covered the entire, US-owned shallow shoreline of the upper Niagara River, from just north of the confluence with Lake Erie to the south and to as close to Niagara Falls as could be safely navigated to the north. The system has a published maximum range of 115 ft, and maximum feature resolution of ~1/3 in. Data were collected in NY State Plane, West Zone, US feet, using differential GPS, and the layback between the GPS position and the center of the towfish was applied in real time using the data acquisition software. The towfish was mounted on a fixed pole on the bow of the vessel, approximately 1 ft below the water surface. Chesapeake Technology SonarWiz 6 was used for data collection and to tie each acoustic pulse to a horizontal position. A 98 ft range was applied to both the starboard and port transducers. Real-time automatic gain settings were set to a resolution of 17 and an intensity of 30. These settings were maintained on all survey lines. A full table of sidescan line files and settings is provided in Appendix A.

Figure 8. FY17 mapping effort. Dark blue lines represent the actual swath of the sidescan sonar. Chirp sub-bottom data were collected in the center of these lines. Grab samples are plotted as circles, with light blue circles representing dominantly fine-grained sediment and red circles representing dominantly sandy sediment.

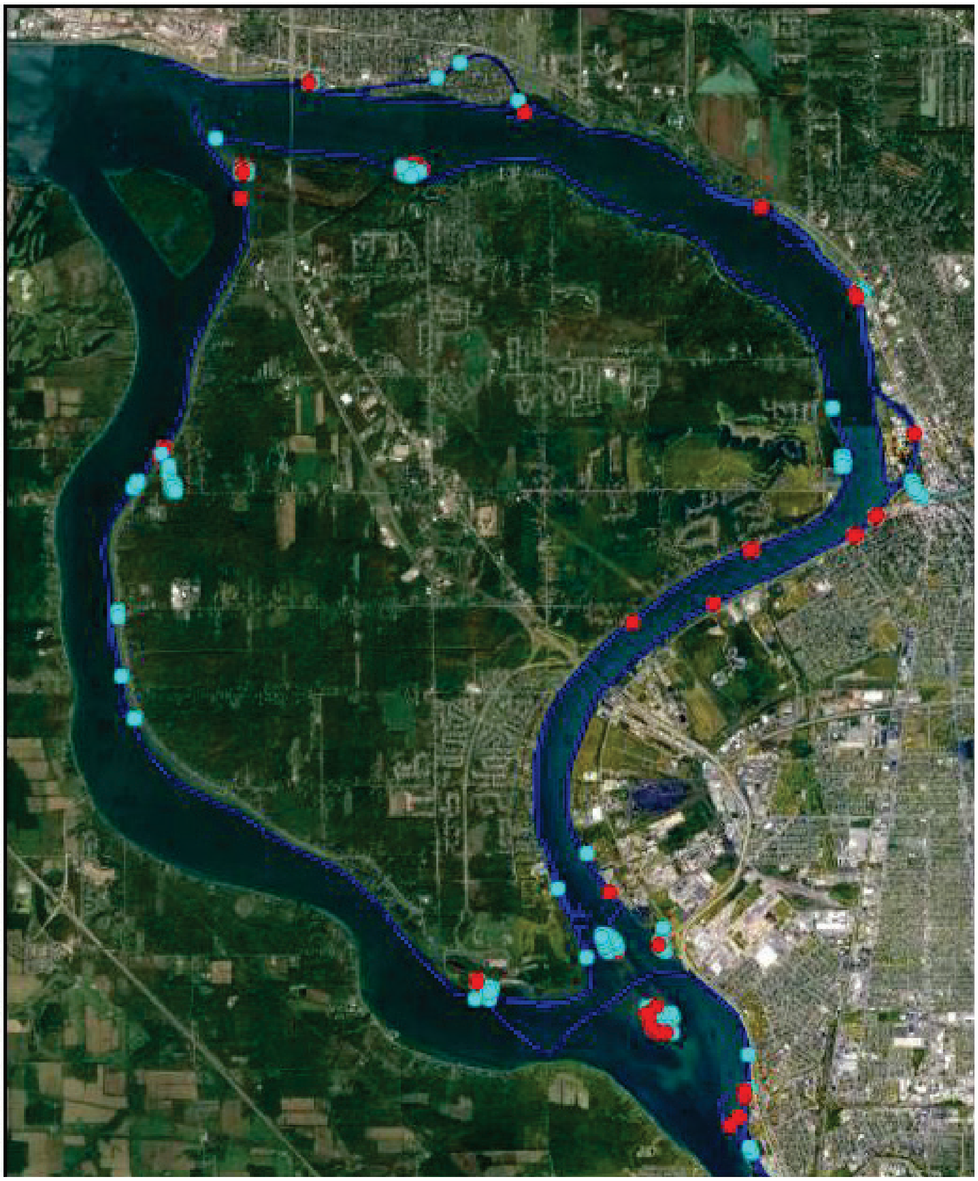
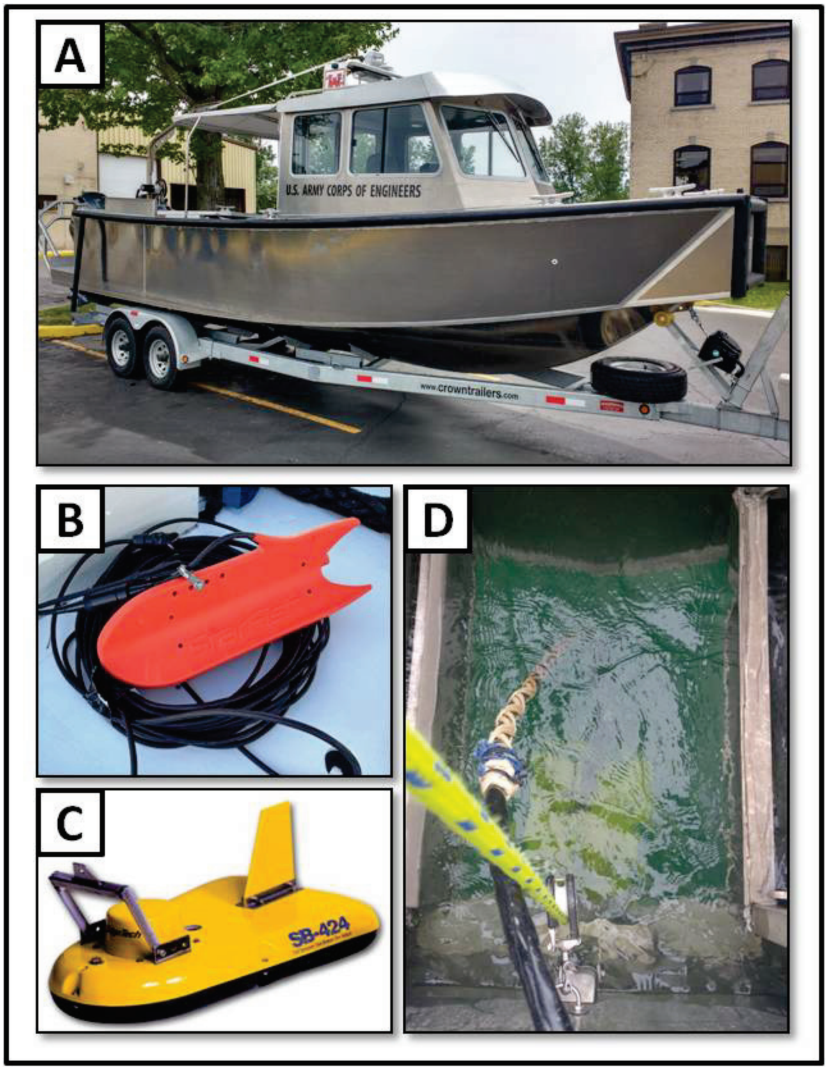


Figure 9. Data collection equipment. (A) survey vessel; (B) Tritech Sidescan Sonar; (C) EdgeTech Chirp 3100p; (D) chirp deployed in the vessel's moon pool.



2.2.2 Data collection – FY17 chirp sub-bottom Imagery

Over 51 linear miles of chirp sub-bottom profiles were collected using an EdgeTech 3100p (SB-424) imaging system (Figure 9c). This system has a user-defined frequency range of 4 – 24 kHz, a published maximum penetration of ~6.6 ft in sand, ~131 ft in clay, and a published stratigraphic layer resolution of ~13 to 26 in. Data were collected in NY State Plane, West Zone, US feet, using differential GPS. The towfish was mounted on a fixed pole and deployed via a moon pool located in the stern of the vessel at approximately 1.5 ft below the water surface (Figure 9d), and the layback between the GPS position and towfish transducer was applied in real-time using the data acquisition software. Chesapeake Technology SonarWiz 6 was used for data collection and to tie each acoustic return to a horizontal position. Chirp sub-bottom data were collected simultaneously with the sidescan sonar data and thus have the same data coverage described in Section 2.2.1, above. All files shared the same acquisition settings: frequency of 4 – 16 kHz, a trigger length of 150 ms, and a record length of 120 ms. Delay was not applied on the return signal.

2.3 Processing and interpretation

2.3.1 Sidescan sonar data processing

All sidescan data, regardless of collection date or method, were imported into Chesapeake Technology Sonar Wiz 6 V6.05.0020 for processing and interpretation. Approximately 60% – 80% of the data files were imported (representing a trim of 20% – 40% of the outer swath) to remove the majority of artifacts found at the far edge of the sonar swath, which allows minimization of edge effects in the mosaic. This also allowed for the removal of bulkheads and creek edges in the narrower creeks to maximize the riverbed data swath. The SonarWiz automated bottom tracking mode was used to identify the sediment/water interface, and each line was visually checked and edited as necessary to ensure proper riverbed identification. On lines that imaged extensive SAV growth extending into the water column, or with large schools of fish, the SonarWiz bottom tracker could not confidently identify the riverbed. The sediment/water interface was identified and digitized on those lines by hand. All line-specific settings are provided in Appendix A. The water column was then removed to allow for identification of the extent of bottom features mapped. Gain was not applied during post-processing; color and contrast were adjusted for individual lines during interpretation but was not permanently applied.

The large number of sidescan sonar files precluded the loading of all files into a single processing project. As a result, a single mosaic of the entire study area could not be generated. Alternatively, the edges of the fine-grained and SAV regions were digitized as data points in SonarWiz and saved as "mud" or "SAV." The x, y positions were subsequently exported as .csv files and imported into GoogleEarth as point data. Polygons were then created in GoogleEarth, and the areas of mud and SAV were calculated for the entire survey area. Details on the data interpretation are provided in Section 2.3.4, following.

2.3.2 Chirp sub-bottom data processing

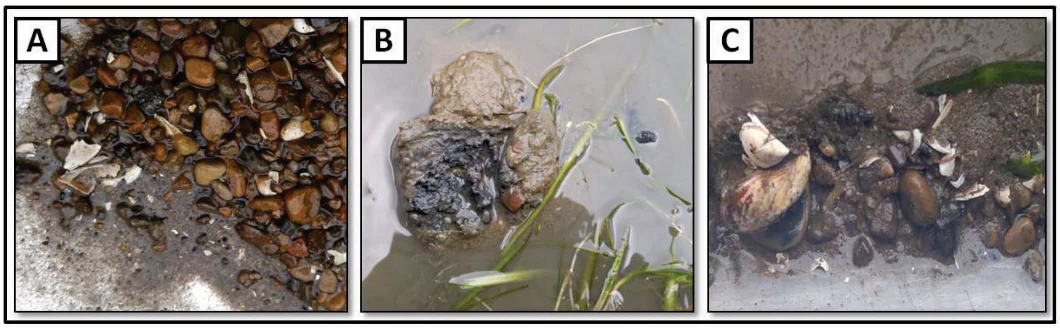
Chirp sub-bottom data were imported into Chesapeake Technology SonarWiz 6 V6.05.0020 for processing and interpretation. During acquisition, the software captures the entire potential length of the acoustic record, generally at depths significantly deeper than the actual data recorded. Accordingly, the lower 25% – 50% of each data file was trimmed to maximize the data returned by the towfish. The SonarWiz automated bottom tracking mode was used to identify the sediment/water interface, and each line was visually checked and edited as necessary to ensure proper riverbed identification. On lines that imaged extensive SAV growth extending into the water column, or with large schools of fish, the SonarWiz bottom tracker could not confidently identify the riverbed. The sediment/water interface was identified and digitized on those lines by hand. Gain was not applied during post-processing; color and contrast were adjusted for individual lines during interpretation but was not permanently applied. A heave filter was not applied, and digitization of all pertinent reflection surfaces was applied through the heave and completed by one individual to eliminate the errors that often result when more than one person participates in data interpretation. Identification of fine-grained sediment layers is explained in Section 2.3.4, following. The difference in elevation between the riverbed and the underlying base of the fine-grained layers was calculated by SonarWiz and exported as .csv files for further analysis using Golden Software Surfer, V15.1.285. All line-specific settings are provided in Appendix B.

Shoreline position data for the Niagara River were imported into Surfer. Because of the highly anisotropic nature of the data coverage in the large study area, it was determined that subdividing the data into spatially adjacent regions would greatly minimize data artifacts that result from gridding over regions with significant data gaps and would allow for easier interpretation of the results. Accordingly, the data were divided into 10 geographic regions, detailed in Section 3.4, following. Within those regions, the thickness data were gridded using Kriging, with a search radius based on the data density in each geographic region. To minimize data artifacts at the far edge of the grid, the grid was blanked to discard data extending (a) farther than 100 ft beyond any data point towards the riverbed and (b) at the actual shoreline. These isopach maps were exported as .kmz file for viewing in GoogleEarth. Gridding details for each geographic region are provided in Appendix C.

2.3.3 Sediment grab samples

A total of 36 surficial sediment samples were collected to groundtruth the data (Figure 8), and details of sample locations and descriptions are provided in Appendix D. Fourteen of the samples were sent for grainsize analysis by LRB, and those samples are identified in Appendix D. Sediments were collected by petite ponar, and all samples were given a field description based on approximately grainsize and the presence/absence of SAV (see Figure 10 for examples and Appendix D for details).

Figure 10. Examples of sediment samples collected to groundtruth the geophysical data. (A) typical coarse-grained sediment; (B) fine-grained (muddy) sediment with SAV; (C) muddy sediment with gravel and minor SAV.



2.3.4 Data interpretation

Fine-grained surficial sediment deposits were identified via (1) low-amplitude (e.g., darker) back-scatter in the sidescan sonar data (Figure 11); (2) the presence of low reflection and high absorption on the chirp sub-bottom profiler data (Figure 11), including occasional signal absorption from gas; and (3) sediment samples, where available (Figure 10).

The presence of SAV was identified via (1) pillow-like features extending into the water column and obscuring the riverbed in both the sidescan sonar and chirp sub-bottom profile data (Figures 11a, 12); (2) low-reflectance (Figure 11); and (3) sediment samples where available (Figures 8 and 10).

Figure 11. Sidescan and chirp data illustrating qualitative differences between (A) coarse-grained sediment with no SAV and (B) fine-grained (muddy) sediment with abundant SAV.

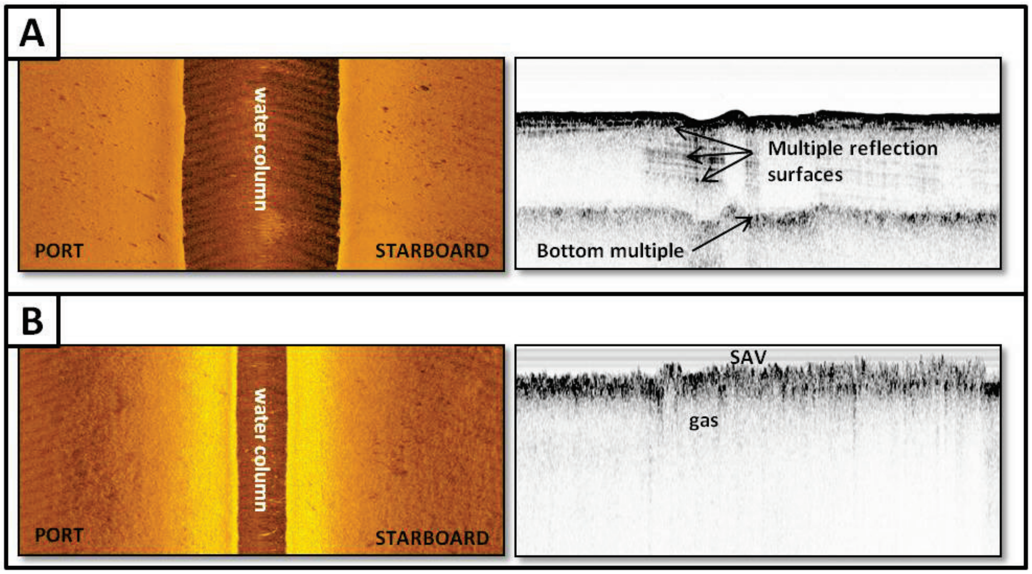
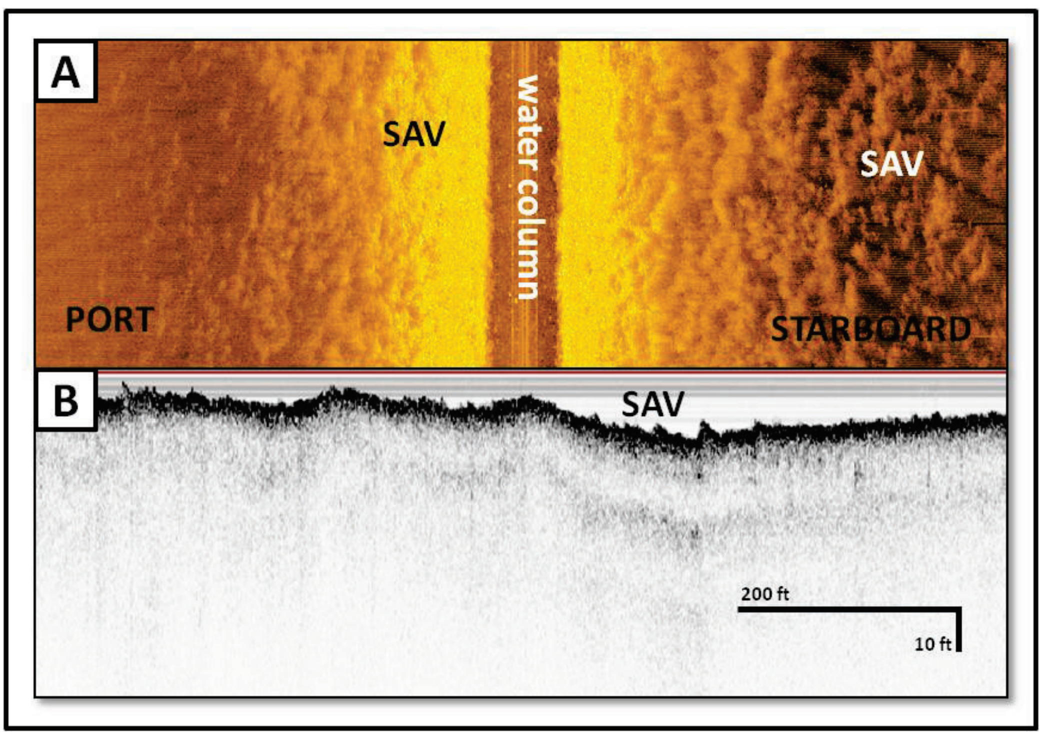


Figure 12. (A) Sidescan and (B) chirp data showing SAV extending into the water column.



3 Results

This section presents the observed distribution of fine-grained sediment and SAV beds, including regions where thickness of fine-grained deposits could be quantified. Validation data, including sediment samples collected specifically for this project as well as previously collected samples, are also included. Finally, a description of potential horizontal and vertical error, and its impacts on the project results, is provided.

3.1 Distribution of riverbed surface sediment

The distribution of fine-grained sediment for the entire region is plotted as light-blue polygons on Figure 13. Overall, on the East Niagara River's eastern shoreline, fine-grained sediment was mapped along most of the shoreline between Gratwick Waterfront Park and Cayuga Island, in a small region near the south entrance to Tonawanda Creek, and close to Black Rock Lock just north of the lock, towards Old Town, NY. On the East Niagara River western shoreline and also the eastern shoreline of Grand Island, fine-grained sediment is limited to small patches near Buckhorn Island State Park, including the breakwaters, across the river fronting Tonawanda Island and the confluence of the East Niagara with Tonawanda Creek, and along the shallow shoreline adjacent to Ferry Village, NY, including between Grand Island and both Pirate's Island and Strawberry Island. On the West Niagara River eastern shoreline as well as the western shoreline of Grand Island, surficial fine-grained deposits are mapped along most of the southern region, south of Sheenwater, including Beaver Island, in the vicinity of the Big Six Marina and Big Six Mile Creek, and along the Grand Island shoreline near Navy Island. In the southern-most region of the study area, near Strawberry Island and where the Niagara River splits into the West and East branches, surficial fine-grained sediments were mapped in all regions near Strawberry Island where the vessel was able to safely navigate. The total area of fine-grained sediment is provided in Table 1.

Figure 13. Google Earth image showing the spatial extent of both fine-grained (mud), and SAV-rich (green) areas in the upper Niagara River. Interpolated regions are shaded in purple. Survey track lines are plotted in dark blue.

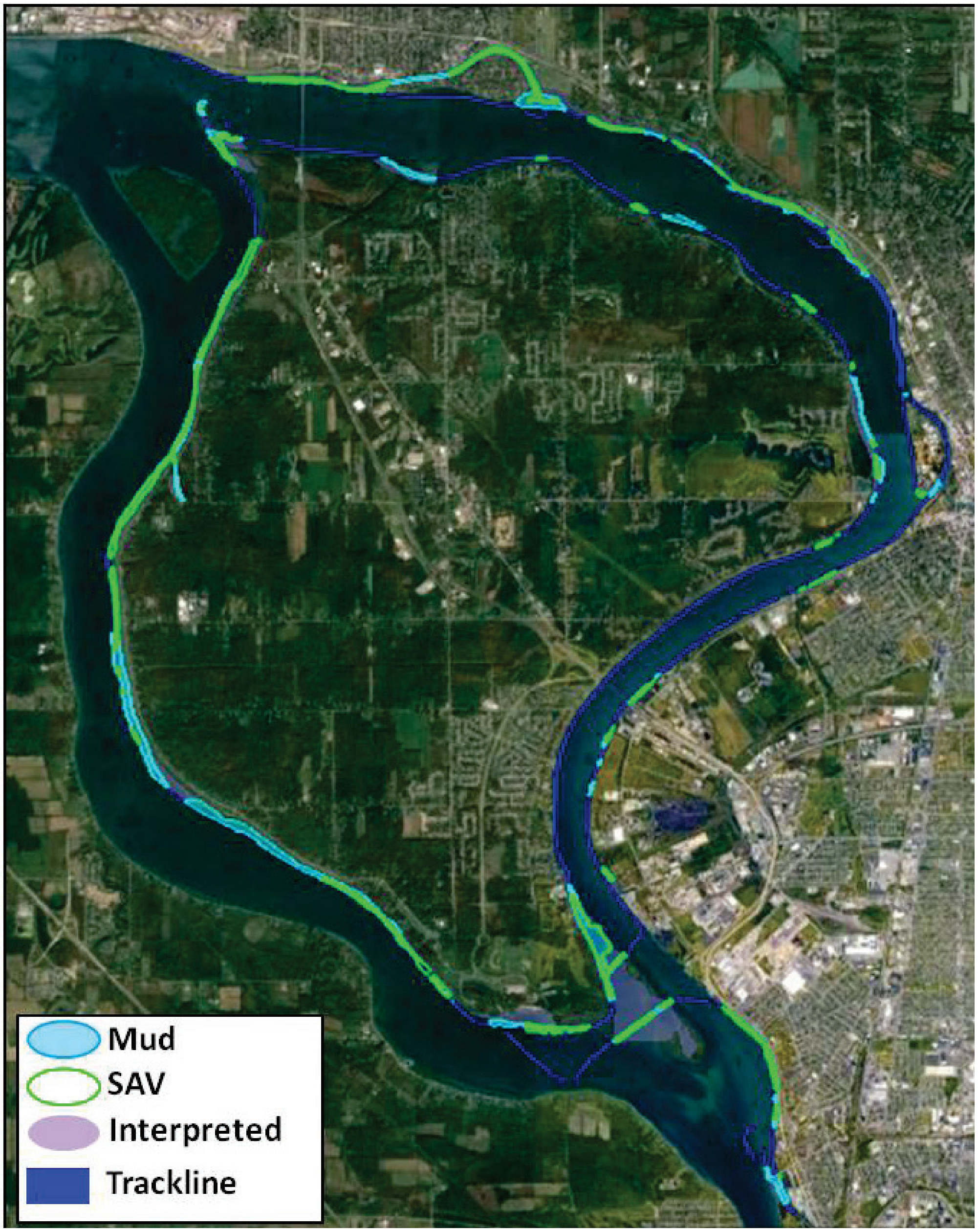


Table 1. Areas of fine-grained regions, SAV-dominated regions, and interpreted fine-grained sediment regions.

	Perimeter (ft)	Area (ft^2)	Area (acres)
Fine-grained	204,895	17,619,114	405
SAV (no sediment characterization)	189,491	11,103,415	255
Interpolation	199,236	23,427,563	538

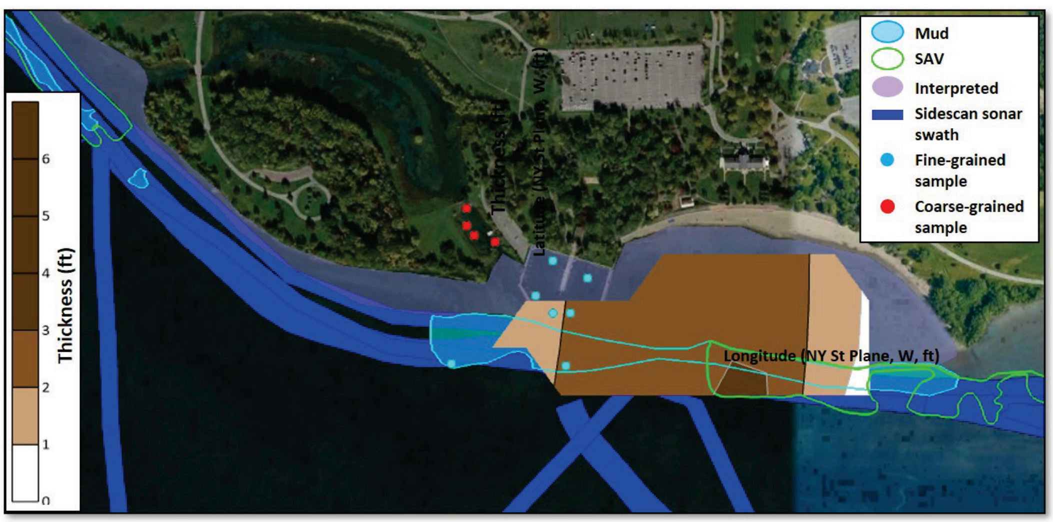
3.2 Distribution of SAV

The distribution of SAV was noted in the same general regions as the fine-grained sediment, as previously described in Section 3.1, above, and plotted as bright green polygons on Figure 13. In many regions, it is mapped as extending farther along the shoreline than the associated fine-grained sediment. This is likely because the SAV growth was frequently thick enough to obscure the seafloor on the sidescan data and scattered enough of the acoustic energy from the chirp to mask the amplitude of the acoustic return on the sub-bottom data (Figures 11, 12). During sediment sampling, SAV was never observed in a sediment matrix that was not dominantly muddy; however, several SAV-rich regions were in a muddy-gravel matrix rather than just a mud-matrix (Figure 10). The geophysical data were not able to discern the subtle differences in amplitude in the two muddy matrices, nor was the sediment sampling sufficient to fully identify muddy regions from muddy-gravel regions. Accordingly, SAV-rich areas are plotted separately from the known fine-grained areas in order not to incorrectly identify muddy-gravels as fine-grained regions, and the total area is provided in Table 1.

3.3 Extrapolation of fine-grained regions

Although data collection covered nearly all of the US-owned shoreline of the upper Niagara River, data collection was occasionally limited by water depth and/or navigation obstructions (e.g., the low railroad bridge spanning the waterway behind Tonawanda Island). In addition, water depths of ~6 ft represent the shallowest safe navigable depth of the survey vessel. Accordingly, fine-grained sediment could not be fully mapped from shallower than ~6 ft of water depth all the way to the river shoreline, though the cross-shore survey lines extended the data coverage as far towards the shoreline as could be safely navigated in specific regions. In addition, digitization of fine-grained and SAV-rich regions was limited to the extent of the sidescan sonar swath in SonarWiz. However, given the results of the previous studies referenced earlier in this report, plus the nature of fine-grained sedimentation, it is likely that fine-grained sediment mapped in water depth of 6 ft or more is also likely present in the adjacent, shallow unmapped regions, and to not include these areas risks underestimating the area and volume of potentially contaminated sediment present along the shoreline in depths too shallow to be safely navigated. Accordingly, these areas were digitized in GoogleEarth (example provided in Figure 14), and the potential area they represent is provided in Table 1.

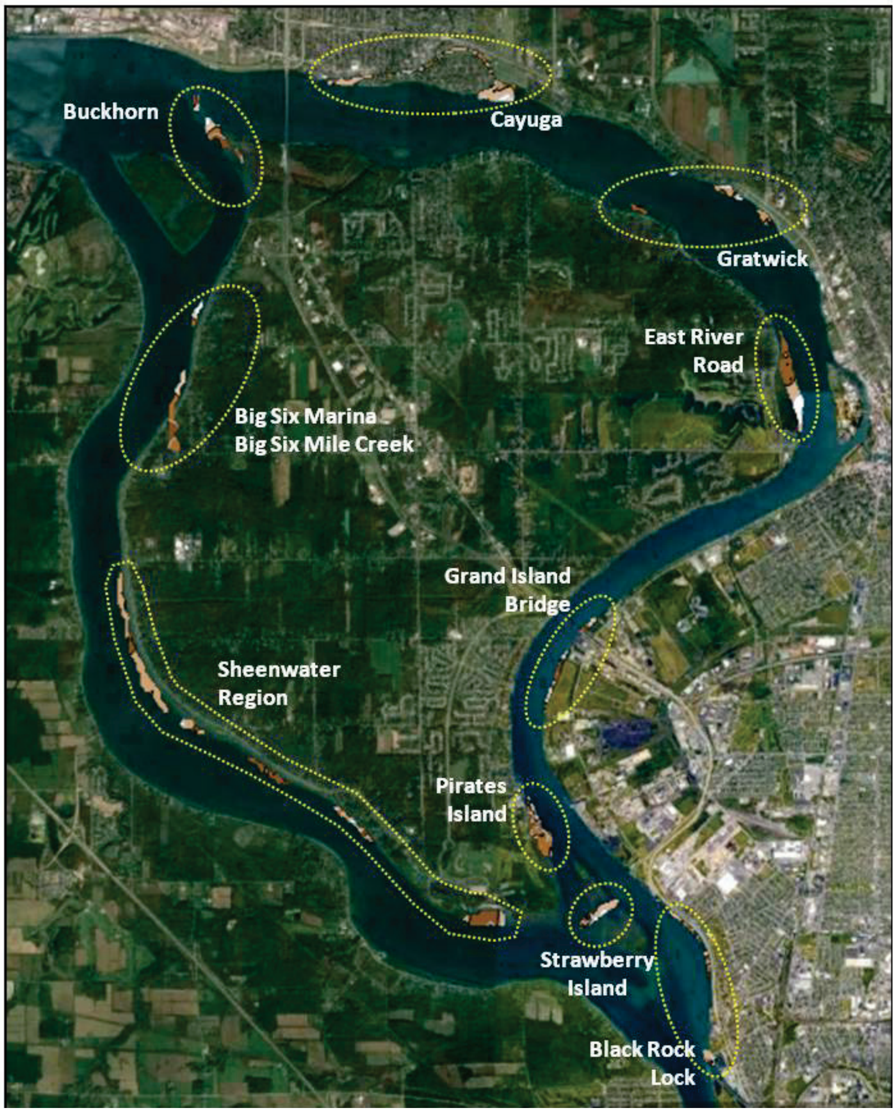
Figure 14. Example of data interpolation. Fine-grained regions and SAV-dominated regions (light blue and green polygons, respectively) were digitized directly on the sidescan sonar swath (dark blue polygon) and imported into Google Earth. Sediment samples are plotted as blue and red circles for dominantly fine- or coarse-grained, respectively. Regions that were not mapped due to limitations in vessel draft but that are interpreted to be fine-grained are plotted as purple polygons. Please note that these color conventions are the same for Figures 16–25, below.



3.4 Isopach maps

Although both fine-grained sediment and SAV surficial deposits were mapped throughout the study area, the base of the fine-grained sediment was only identified in specific locations, and the extent of these data are presented for the entire study region in Figure 15. The paucity of thickness data is due to one of several factors: (1) deposits in excess of 6 ft likely absorbed the bulk of the acoustic signal, resulting in insufficient reflection to generate a reflection surface at the base of the deposit; (2) SAV growth reflected a significant amount of acoustic energy such that there was insufficient signal to reflect off of the base of SAV-rich fine-grained regions; or (3) anaerobic biologic activity in the fine-grained regions generated sufficient gas to absorb all of the acoustic energy, resulting in insufficient energy to penetrate and reflect off of the base of the fine-grained layer. Of the three potential factors, gas is the least likely possibility, as the distinctive acoustic signature of gas (as described in Section 1.2, above) was only rarely noted in the sub-bottom data.

Figure 15. Isopach maps of fine-grained sediment thickness for the upper Niagara River. Details for small sub-regions are identified on the figure and described in more detail in Sections 3.4.1 – 3.4.10, below.

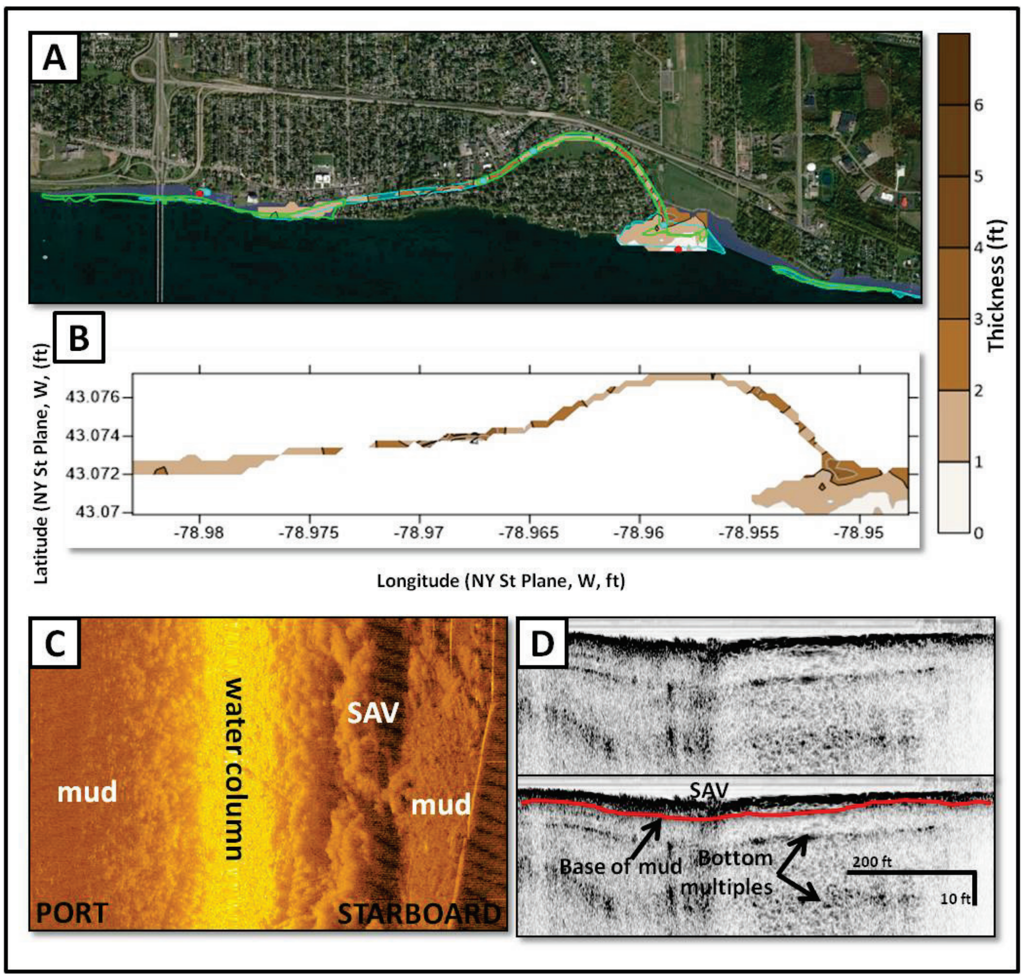


Despite the limitations in acoustic reflection as noted above, there were multiple regions where the base of the fine-grained sediment was clearly mapped. These regions are outlined on Figure 13 and are described in more detail below. Additional gridding and volume details for each sub-region are provided in Appendix C.

3.4.1 Cayuga Island

The region immediately behind Cayuga Island was characterized by a deposit of fine-grained sediment that averaged 1.8 ft thick (Figure 16). Localized patches of > 4 ft of fine-grained sediment were mapped at the northeast entrance to the waterway behind the island, just offshore of the old entrance to Love Canal. Additional localized deposits of > 5 ft of fine-grained sediment were mapped behind the island, particularly with close proximity to the confluence of the back-island waterway to Cayuga Creek. The deposit thins to a surface veneer east and west of the island along the main East Niagara River shoreline, with moderate SAV growth.

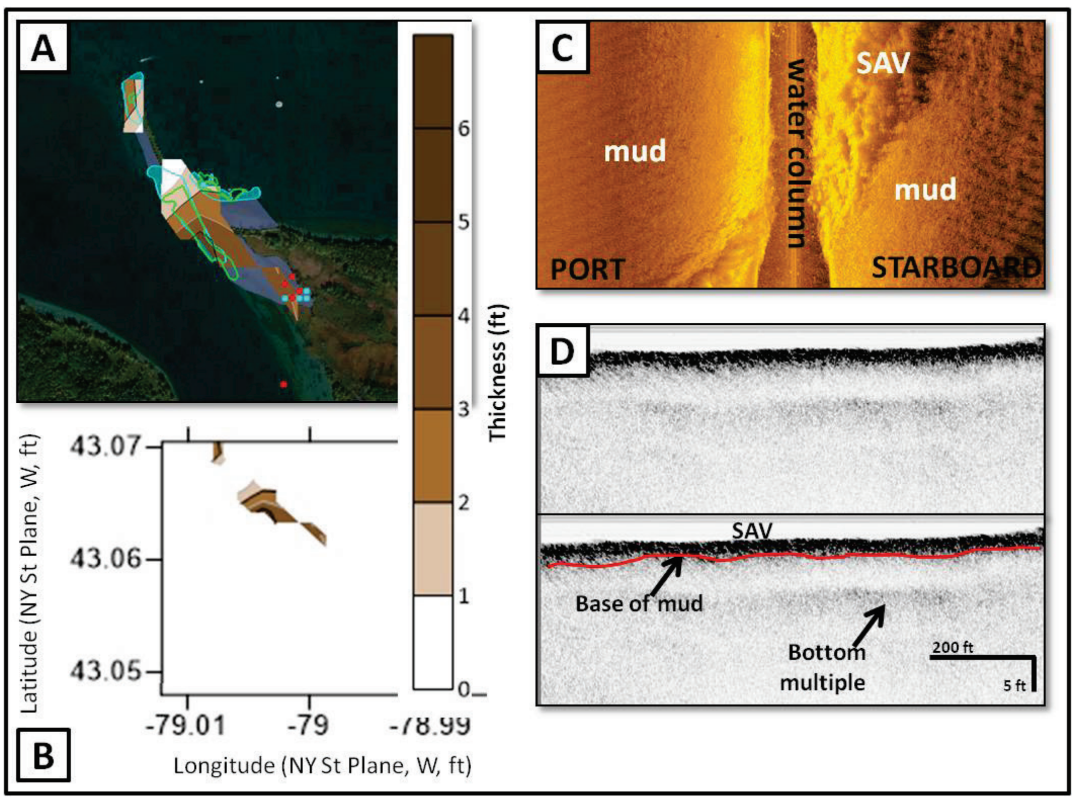
Figure 16. Results for the region near Cayuga Island. (A) Isopach map plotted with digitized regions of fine-grained sediment, SAV, and interpolations, plus sediment samples. (B) Isopach map. Note the isopach map color scale is the same in both panels A and B. (C) Example sidescan sonar image collected behind Cayuga Island. (D) Example un-interpreted (upper) and interpreted (lower) chirp sub-bottom image from the same region.



3.4.2 Buckhorn Island

Located near the far northwestern edge of Grand Island is a small body of land called Buckhorn Island, which is separated from Grand Island by marshes and Burnt Ship Creek. Two breakwaters protect the northwestern most tip of Buckhorn from the East Niagara River, and extensive fine-grained deposits and SAV were mapped on either side of the breakwaters, with an average thickness of 1.9 ft (Figure 17). The thickest deposit in this locality (> 4 ft) was mapped in the southern-most extent of the region, near the confluence of the West Niagara River to Burnt Ship Creek.

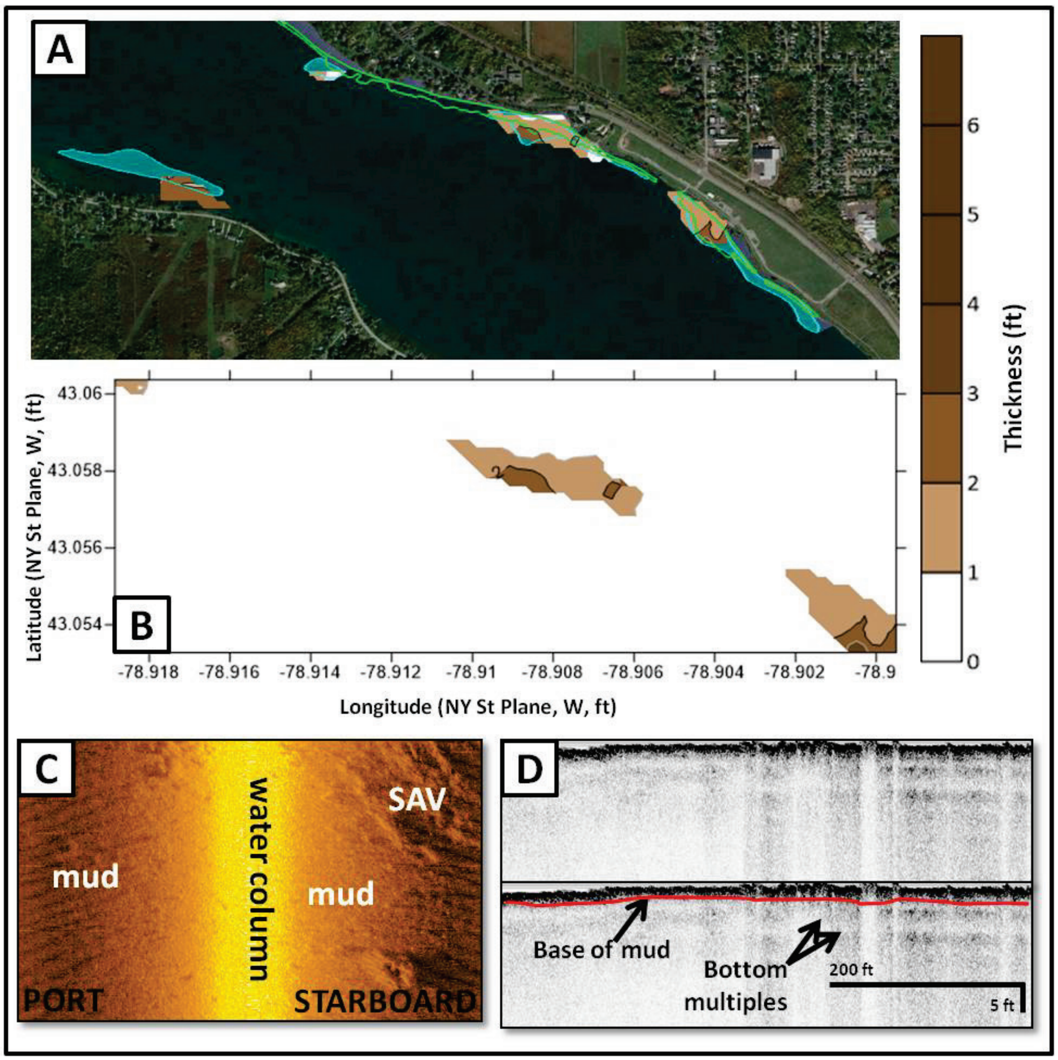
Figure 17. Results for the region near Buckhorn Point. (A) Isopach map plotted with digitized regions of fine-grained sediment, SAV, and interpolations, plus sediment samples. (B) Isopach map. Note the isopach map color scale is the same in both panels A and B. (C) Example sidescan sonar image collected on the south side of the breakwaters. (D) Example un-interpreted (upper) and interpreted (lower) chirp sub-bottom image from the same region.



3.4.3 Gratwick Waterfront Park

Gratwick Waterfront Park runs along the eastern shoreline of the East Niagara River, just north of Tonawanda, between the river and State Route 265. Surficial fine-grained sediments and SAV growth were mapped along almost the entire park shoreline, but the thickness of the fine-grained regions could only be discerned in a few discrete patches (Figure 18). Overall, the fine-grained regions along this shoreline average 2.0 ft thick. Note that a small patch of ~2.5 ft thick fine-grained sediment was mapped on the western East Niagara River shoreline adjacent to the northern-most part of the Gratwick Waterfront.

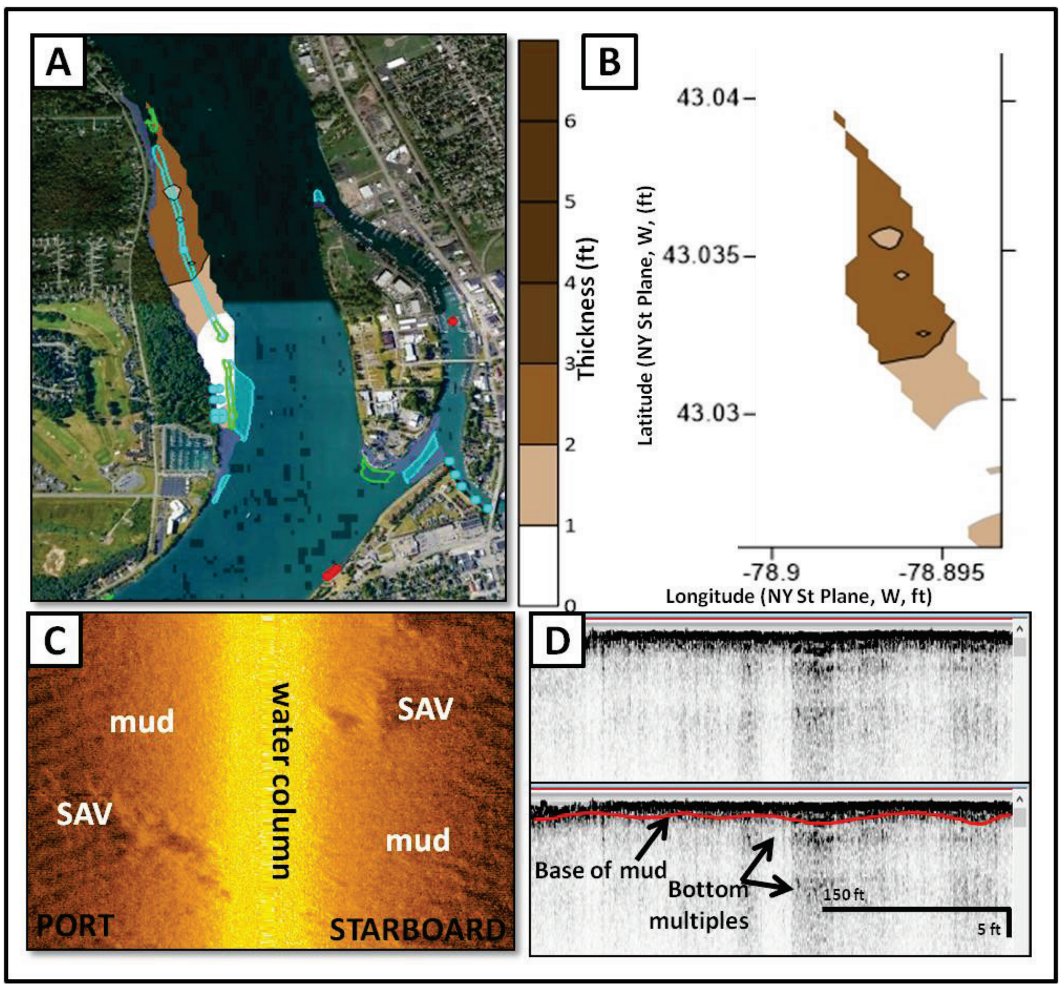
Figure 18. Results for the region near Gratwick Waterfront Park. (A) Isopach map plotted with digitized regions of fine-grained sediment, SAV, and interpolations, plus sediment samples. (B) Isopach map. Note the isopach map color scale is the same in both panels A and B. (C) Example sidescan sonar image collected in ~7 ft water depth along the shoreline. (D) Example un-interpreted (upper) and interpreted (lower) chirp sub-bottom image from the same region.



3.4.4 East River Road

Although neither SAV nor surficial fine-grained sediments were mapped in the vicinity of Tonawanda Island in the East Niagara River, extensive fine-grained sediment was mapped along the shoreline adjacent to the island and the confluence of the East Niagara River and Ellicott Creek. This localized patch averages 2.1 ft in thickness and increases in thickness (up to 3.4 ft) with increasing distance north along the Grand Island shoreline, away from the mouth of Ellicott Creek (Figure 19).

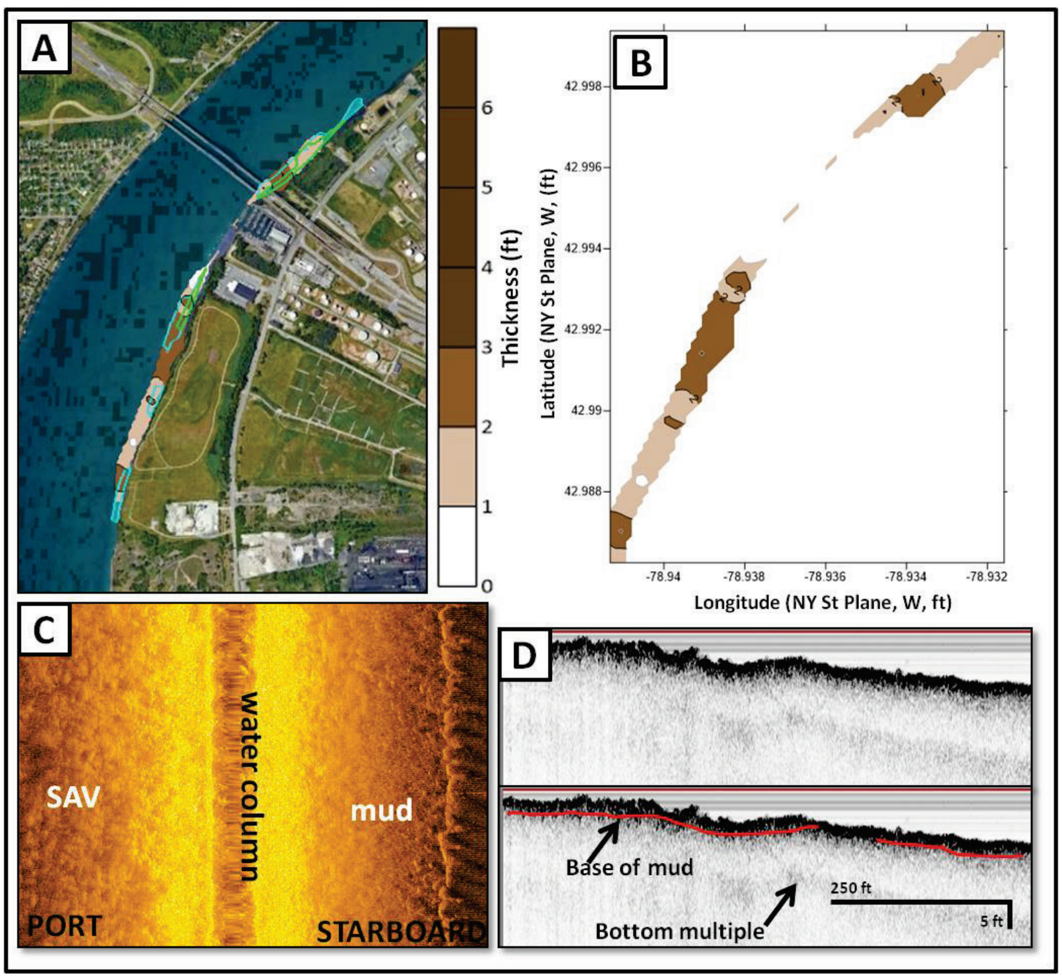
Figure 19. Results for the region near East River Road, Tonawanda Island. (A) Isopach map plotted with digitized regions of fine-grained sediment, SAV, and interpolations, plus sediment samples. (B) Isopach map. Note the isopach map color scale is the same in both panels A and B. (C) Example sidescan sonar image collected in ~7 ft water depth along the shoreline facing Tonawanda Island. (D) Example un-interpreted (upper) and interpreted (lower) chirp sub-bottom image from the same region.



3.4.5 Grand Island Bridge

A region of fine-grained sediment with an average thickness of 1.8 ft was mapped along the eastern shoreline of the East Niagara River, in the vicinity of the South Grand Island Bridge on Interstate 190 (Figure 20). Only a surface veneer of fine-grained sediment was mapped in the immediate vicinity of Collins Marina, but the patch increases in thickness with increasing distance south along the shoreline (maximum thickness of 3.1 ft) and, to a more limited extent, north of the marina, also along the shoreline. Neither fine-grained sediment nor SAV were mapped on the shoreline immediately across the river, along Grand Island.

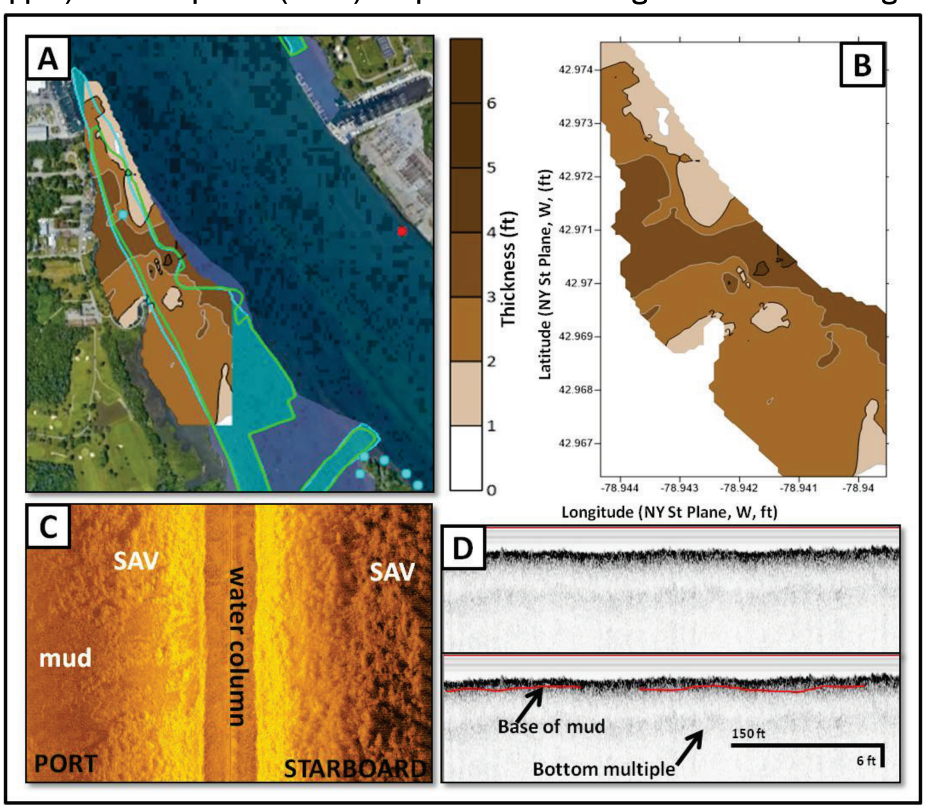
Figure 20. Results for the region near the south bridge to Grand Island. (A) Isopach map plotted with digitized regions of fine-grained sediment, SAV, and interpolations, plus sediment samples. (B) Isopach map. Note the isopach map color scale is the same in both panels A and B. (C) Example sidescan sonar image collected in ~7 ft water depth along the shoreline south of the bridge. (D) Example un-interpreted (upper) and interpreted (lower) chirp sub-bottom image from the same region.



3.4.6 Pirates Island and Ferry Bridge

A small but thick (average thickness of 2.6 ft) deposit of fine-grained sediment was mapped along the southeastern shoreline of the East Niagara River, just upstream from the bifurcation of the Niagara River into the east and west branches, primarily between the shorelines near Ferry Village on Grand Island and Pirates Island, in the East Niagara River (Figure 21). The thickest part of the deposit (4.4 ft) is the center, near Ferry Village, and it thins to an extensive surface veneer to the south and a more limited surface veneer to the north. Note that much of the region between Grand Island and Pirates Island was too shallow to transit, though at least a surface veneer of fine-grained sediment, as well as extensive SAV beds, were mapped around the region. Accordingly, the region is interpreted to likely contain at least a veneer of fine-grained sediment based on the mapped distribution and water depths, but this is speculative at best.

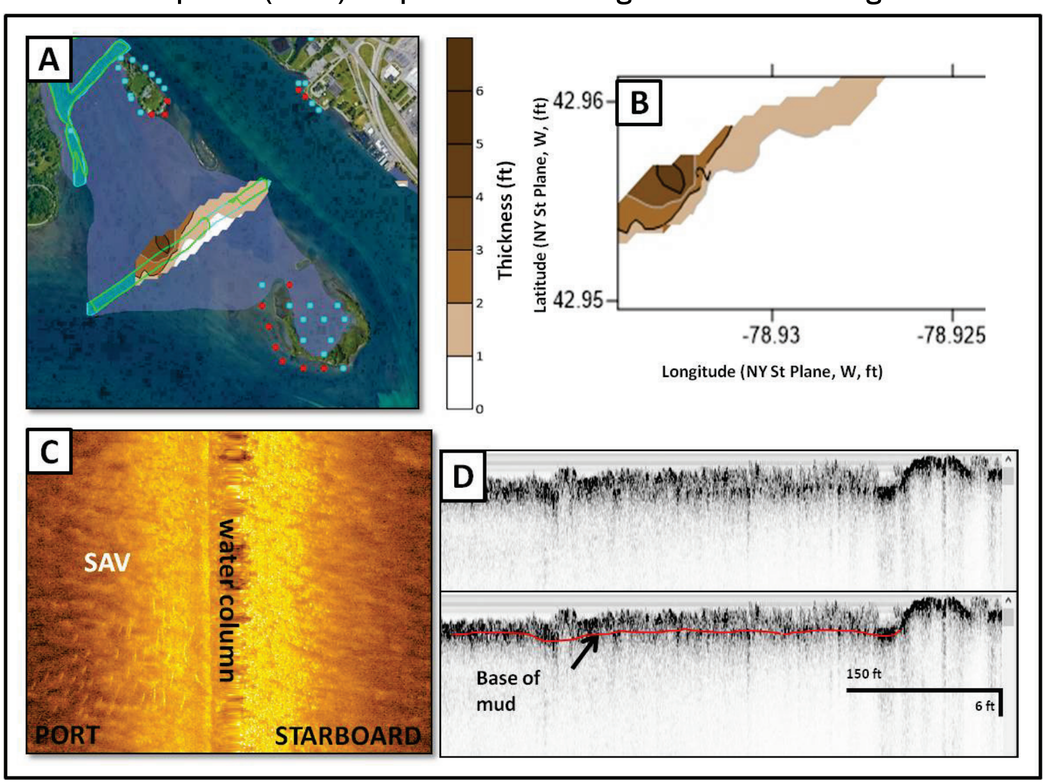
Figure 21. Results for the region north of Pirates Island and near the community of Ferry Bridge. (A) Isopach map plotted with digitized regions of fine-grained sediment, SAV, and interpolations, plus sediment samples. (B) Isopach map. Note the isopach map color scale is the same in both panels A and B. (C) Example sidescan sonar image collected in ~7 ft water depth along the shoreline. (D) Example un-interpreted (upper) and interpreted (lower) chirp sub-bottom image from the same region.



3.4.7 Strawberry Island

A thick wedge of fine-grained sediment was mapped in the only navigable pathway between Pirates Island and Strawberry Island and averaged 2.6 ft in thickness. Overall, the thickest region between the two islands is on the western side, near Grand Island, with mapped thicknesses up to 4.2 ft (Figure 22). The deposit thins to a surface veneer with increasing distance west towards the Niagara River channel and disappears almost immediately west of where the thickness data were obtained. There is, however, an extensive, ~ 2.7 ft thick, fine-grained deposit present along the eastern shoreline of the Niagara River just south of Strawberry Island, extending from Old Town, NY, to just north of Tow Path Park. The thickest deposit is in the middle (~4.6 ft) of the region, and it thins to a surface veneer on both the north and south edges. The region around Strawberry Island is very shallow and not safely navigable. Accordingly, this region has the highest percentage of interpolated data vs. actual mapped extent of SAV and fine-grained sediment.

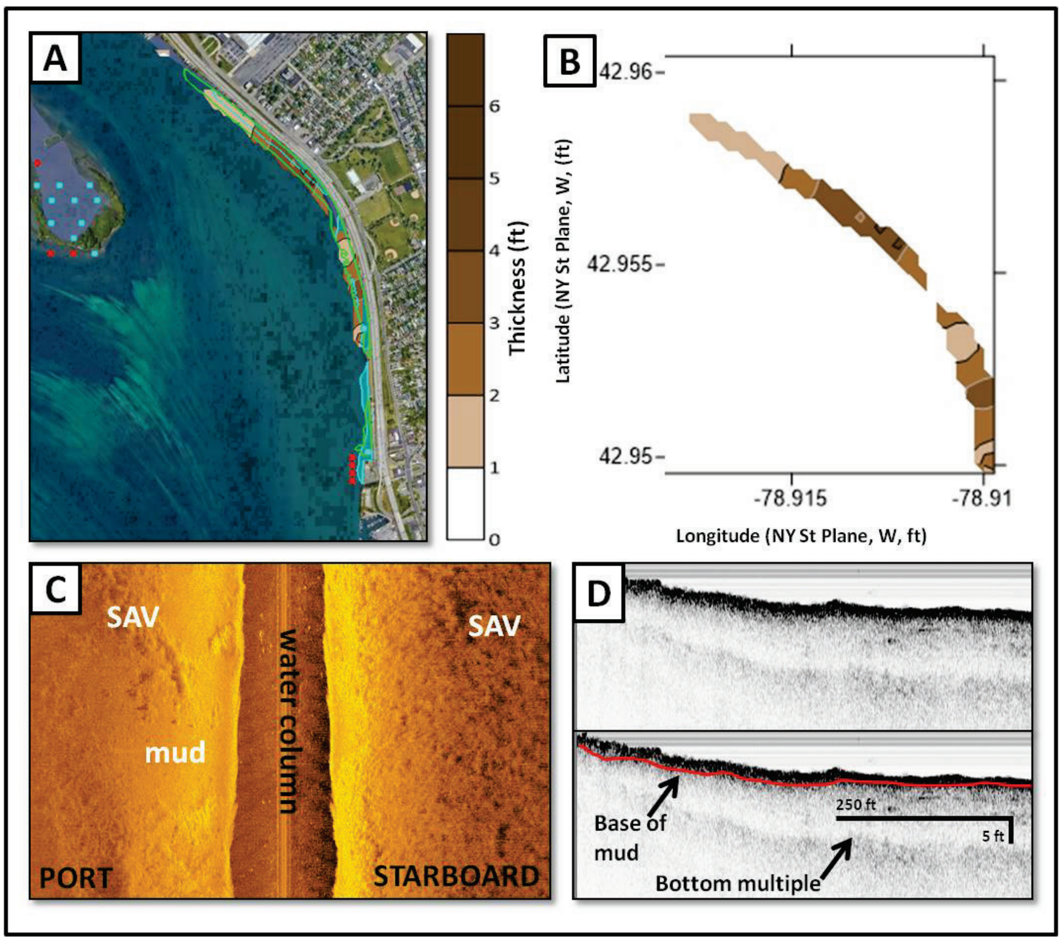
Figure 22. Results for the region around Strawberry Island. (A) Isopach map plotted with digitized regions of fine-grained sediment, SAV, and interpolations, plus sediment samples. (B) Isopach map. Note the isopach map color scale is the same in both panels A and B. (C) Example sidescan sonar image collected in the small navigable region north of Strawberry Island. (D) Example un-interpreted (upper) and interpreted (lower) chirp sub-bottom image from the same region.



3.4.8 Black Rock Lock

A small patch of fine-grained sediment with highly variable thickness is located just north of Black Rock Lock, on the eastern shoreline of the main Niagara River, just offshore of the Rich Marine Sales Marina (Figure 23). Although the deposit averages 1.5 ft in thickness, thicknesses range from a surface veneer to 4.1 ft thick just north of the lock entrance. Overall, this is the smallest region of sediment where thickness could be determined.

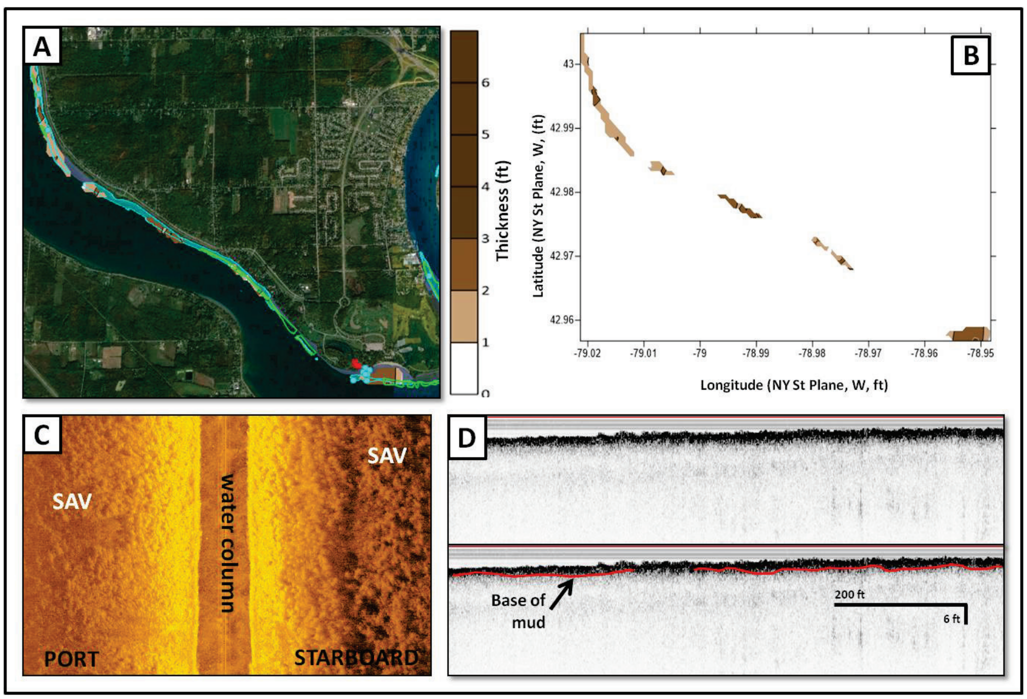
Figure 23. Results for the region just north of Black Rock Lock, including the eastern shoreline near Rich Marine Sales Marina. (A) Isopach map plotted with digitized regions of fine-grained sediment, SAV, and interpolations, plus sediment samples. (B) Isopach map. Note the isopach map color scale is the same in both panels A and B. (C) Example sidescan sonar image collected along the shoreline near the marina. (D) Example un-interpreted (upper) and interpreted (lower) chirp sub-bottom image from the same region.



3.4.9 Sheenwater

The most continuous surface veneer of fine-grained sediment with extensive SAV beds was mapped along nearly the entire southwestern shoreline of Grand Island, along the West Niagara River (Figure 24). This region also yielded the thickest average sediment deposits (3.5 ft). The thickest deposit in this region was mapped just west of Beaver Island, on the small, southern shoreline of Grand Island (4.8 ft thick). The rest of the fine-grained sediments are distributed along the eastern shoreline of the West Niagara River, along Grand Island.

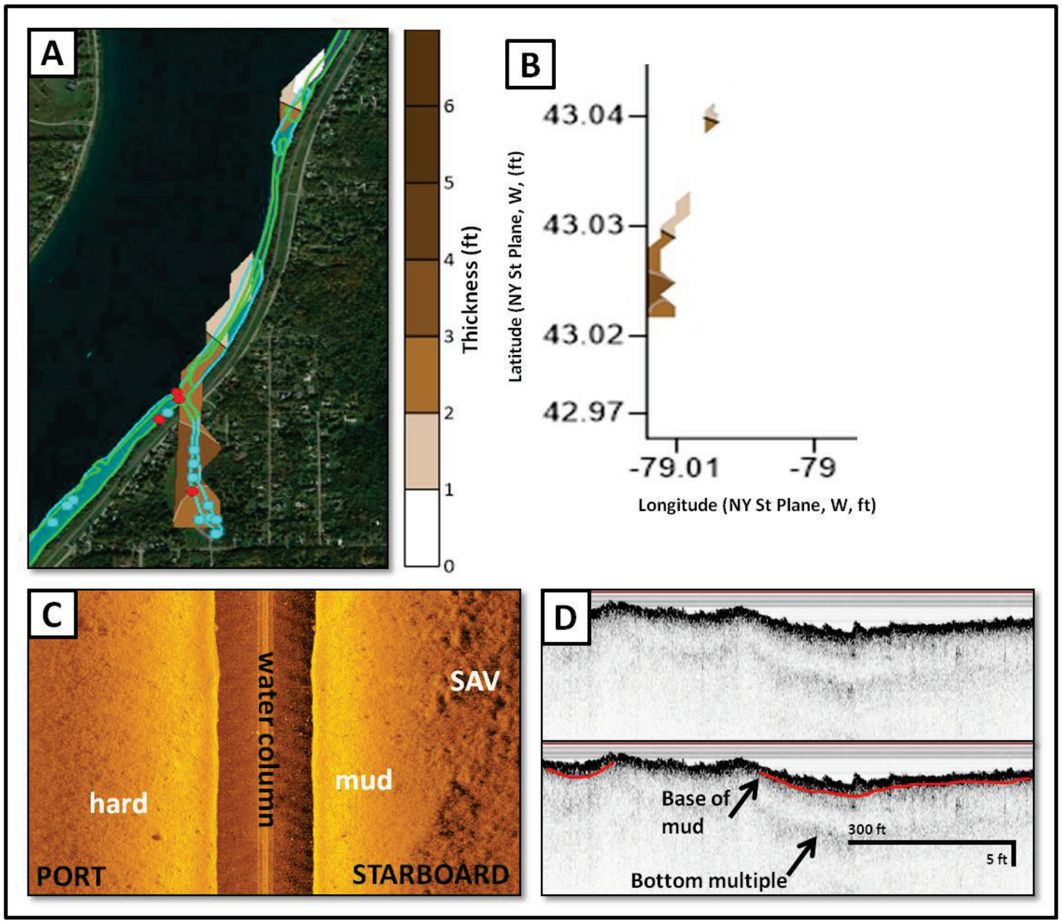
Figure 24. Results for the region along the southern edge of Grand Island, including Beaver Island. (A) Isopach map plotted with digitized regions of fine-grained sediment, SAV, and interpolations, plus sediment samples. (B) Isopach map. Note the isopach map color scale is the same in both panels A and B. (C) Example sidescan sonar image collected just offshore of Beaver Island. (D) Example un-interpreted (upper) and interpreted (lower) chirp sub-bottom image from the same region.



3.4.10 Big Six Marina and Big Six Mile Creek

A thick deposit of fine-grained sediment was mapped within the navigable portion of Big Six Mile Creek (Big Six Marina), as well as to the north, along the eastern shoreline of the West Niagara River (west side of Grand Island). Here, fine-grained sediment averages 2.9 ft thick, with thicknesses in excess of 4.5 ft measured within the Big Six Marina basin itself (Figure 25).

Figure 25. Results for the region including Big Six Mile Creek, Big Six Marina, and the shoreline north of the confluence of the creek with the Western Niagara River. (A) Isopach map plotted with digitized regions of fine-grained sediment, SAV, and interpolations, plus sediment samples. (B) Isopach map. Note the isopach map color scale is the same in both panels A and B. (C) Example sidescan sonar image collected on the shoreline north of the creek entrance. (D) Example un-interpreted (upper) and interpreted (lower) chirp sub-bottom image from the same region.



3.5 Horizontal and vertical error

The geophysical data are subject to both horizontal and vertical error. With respect to horizontal data, the majority of the error is a function of the error inherent in the system used for navigation; in this case, differential GPS, which has a published horizontal error of ~1 ft. There should not be any significant layback error in the data. The offset between the GPS antenna and the two transducers was applied during data acquisition.

Sidescan sonar provide amplitude data, which are not tied to a vertical datum. Vertical error in the thicknesses derived from the chirp seismic profile is dependent on (1) the assumption of a standard speed of sound of

1,485 m/s and (2) errors in digitization by the processor. With respect to speed of sound, the rate at which sound travels through a sedimentary unit is primarily a function of the sediment's density, porosity, and grainsize. Overall, the speed of sound in sediment has been determined to be very similar to the speed of sound in water (usually 1% – 3% less in sediment than in water (e.g., Hamilton 1965; Gorgas et al. 2002) which translates to a potential vertical error of <0.5 ft. Accordingly, many researchers have suggested that the effect is so minimal for stratigraphic purposes that it can be neglected altogether (e.g., Hamilton 1972; Kibblewhite 1989; Gorgas et al. 2002). A greater source of error is in the digitization process. Chesapeake Technology SonarWiz uses sophisticated algorithms to identify the sediment-water interface and digitize the riverbed. The process is not perfect and requires visual inspection to ensure that the software does not erroneously identify water column noise (such as a school of fish) as the riverbed. Subsequent digitization of underlying reflection surfaces is completed by hand, and slight variations in the position of the mouse will also introduce vertical errors. The error in vertical elevation is directly related to subtle variations in each digitized point as entered by the processor and thus is different for every given project. For this project, the difference in elevation between subsequent "horizontal" digitized points was determined on multiple regions for 28 seismic lines and averaged 0.67 ft, with a standard deviation of 0.22 ft. Note that these errors can compound. Consequently, a vertical error of ~0.89 ft should be considered when evaluating these data. This error would persist even if the data were further rectified to known datum (i.e., to a rectified bathymetric survey).

4 Discussion

The distribution of fine-grained sediment, as well as the most extensive SAV beds, is limited to the shorelines (less than ~10 ft water depth) of the Niagara River, with an exception found near Strawberry Island at the southeastern tip of Grand Island (Figures 13 and 22). The only region with extensive coarse-grained sediment at the shoreline is the southeastern shore of Grand Island (southwestern shoreline of the East Niagara River; Figure 13). This could be due to a lack of significant stream drainage near this region but more likely reflects slightly higher current velocities on the cutbank of the East Niagara River.

Of the ten regions where thicknesses of the fine-grained sediments could be quantified, four (Cayuga, Gratwick Waterfront, East River Road, and Big Six Marina) are located spatially adjacent to the mouths of small tributaries (Figures 16, 18, 19, and 25, respectively). Two (Buckhorn and Black Rock Lock) are associated with hardened structures that modify the natural flow of the system (Figures 17 and 23, respectively), and two (Pirates Island and Strawberry Island, Figures 21 and 22, respectively) are associated with marshy areas. With respect to the Pirates Island and Strawberry Island regions, it is likely that the spatial extent and thickness of the deposits have been significantly underestimated as vessel navigability in these regions was greatly limited. Accordingly, the areas and volumes provided here should be considered low-end estimates.

Of particular use for the planning of future sampling efforts is the identification of regions that were mapped successfully but which did not yield any evidence of fine-grained sediment or SAV. Any future sampling in these regions could be minimal or not included altogether.

5 Summary

Geophysical data, including sidescan sonar and chirp sub-bottom profiles were used to map the spatial distribution of fine-grained sediment, including volume data in limited locations, along the shallow shorelines of the upper Niagara River. Overall, the most extensive deposits were spatially associated with small tributaries or man-made structures that modified the natural flow of the system. Extensive SAV beds were also mapped. These beds were patchy in distribution, which might reflect subtle differences in the grainsize of the sediment matrix or simply be a function of variations in species or growth. The maps generated from this effort can be used to guide sampling plans for future studies of contamination in fine-grained sediment regions.

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Appendix A: Sidescan File Index

The following table lists all sidescan files collected in support of this project. Date of collection, equipment used, and percent of the seismic line imported are provided for each survey line. In addition, the bottom tracking method (automatic vs. hand-digitized), the overall bottom tracking offset (used to reduce nadir effects), and any line-specific bottom tracking settings are provided for each line. The abbreviation “BT” refers to the blanking distance in feet between the center of the towfish (the direct return) and the riverbed; the abbreviation “Dr” refers to the duration of consistent pings needed to distinguish between river bottom and acoustic spikes (e.g., fish bladders); and the abbreviation “Td” refers to the threshold in intensity beyond which data are considered spikes. All F settings are the same for the port vs. the starboard receivers and are line-specific.

File Name	Collection Date	Equipment	Import %	BT Offset	BT Mods
ER_ES_09	27-Jun-17	Tritech Starfish	80%	0.2	Bl:5, Dr:4, Td:60
ER_ES_10	27-Jun-17	Tritech Starfish	80%	0.1	hand-digitized
ER_ES_11	27-Jun-17	Tritech Starfish	80%	n/a	Bl:3, Dr:3, Td:60
ER_ES_11x	27-Jun-17	Tritech Starfish	80%	0.1	Bl:3, Dr:3, Td:60
ER_ES_11xx	27-Jun-17	Tritech Starfish	80%	0.1	Bl:3, Dr:3, Td:60
ER_ES_12	28-Jun-17	Tritech Starfish	80%	0.1	Bl:3, Dr:3, Td:60
ER_ES_13	28-Jun-17	Tritech Starfish	80%	0.1	hand-digitized
ER_ES_14	28-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:2, Td:90
ER_ES_14x	28-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:2, Td:90
ER_ES_15	28-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:2, Td:90
ER_ES_15b	28-Jun-17	Tritech Starfish	60%	0.1	Bl:2, Dr:2, Td:90
ER_ES_16	28-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:2, Td:89
ER_ES_17	28-Jun-17	Tritech Starfish	80%	0.1	hand-digitized
ER_WS_06	29-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:2, Td:89
ER_WS_06b	29-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:2, Td:89
ER_WS_06c	29-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:2, Td:89
ER_WS_07	29-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:2, Td:89
ER_ES_15c	28-Jun-17	Tritech Starfish	80%	0.1	Bl:1, Dr:2, Td:89
ER_ES_17b	28-Jun-17	Tritech Starfish	60%	0.1	Bl:1, Dr:2, Td:89

File Name	Collection Date	Equipment	Import %	BT Offset	BT Mods
ER_ES_17c	28-Jun-17	Tritech Starfish	60%	0.1	Bl:1, Dr:2, Td:89
TonwIsl_01	27-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:2, Td:89
TonwIsl_02	27-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:2, Td:89
Transit_TonwIsl_01	28-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:2, Td:89
ER_WS_01	28-Jun-17	Tritech Starfish	80%	0.1	Bl:1, Dr:2, Td:89
ER_WS_01b	28-Jun-17	Tritech Starfish	80%	0.1	Bl:1, Dr:2, Td:89
ER_WS_02	28-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:2, Td:89
ER_WS_03	28-Jun-17	Tritech Starfish	80%	0.1	Bl:1, Dr:2, Td:89
ER_WS_03_tie	28-Jun-17	Tritech Starfish	80%	0.1	Bl:1, Dr:2, Td:89
ER_WS_06b	29-Jun-17	Tritech Starfish	80%	0.1	Bl:1, Dr:2, Td:89
ER_WS_06c	29-Jun-17	Tritech Starfish	80%	0.1	Bl:1, Dr:2, Td:89
ER_WS_05	29-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:9, Td:75
ER_WS_04	29-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:9, Td:75
ER_WS_08	29-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:9, Td:75
ER_WS_08b	29-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:9, Td:75
ER_WS_08c	29-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:9, Td:75
ER_WS_08d	29-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:9, Td:75
ER_ES_07	27-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:9, Td:75
ER_ES_08	27-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:9, Td:75
ER_ES_06	27-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:9, Td:75
ER_ES_05	27-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:9, Td:75
ER_ES_04	27-Jun-17	Tritech Starfish	80%	n/a	hand digitized
ER_ES_03	27-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:9, Td:75
ER_ES_02	27-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:9, Td:75
ER_ES_01	27-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:9, Td:75
SI_transit	27-Jun-17	Tritech Starfish	80%	0.1	Bl:5, Dr:9, Td:75
SI_transit_02	27-Jun-17	Tritech Starfish	80%	0.1	Bl:3, Dr:9, Td:75
SI_transit_03	27-Jun-17	Tritech Starfish	80%	0.1	Bl:3, Dr:9, Td:75
SI_transit_04	27-Jun-17	Tritech Starfish	80%	0.1	Bl:3, Dr:9, Td:75
SI_transit_05	27-Jun-17	Tritech Starfish	80%	0.1	Bl:3, Dr:9, Td:75
SGI_transit	27-Jun-17	Tritech Starfish	80%	0.1	Bl:3, Dr:9, Td:75
SGI_transit_02	27-Jun-17	Tritech Starfish	80%	0.1	Bl:3, Dr:9, Td:75
BISPMar_01	27-Jun-17	Tritech Starfish	80%	0.1	Bl:3, Dr:9, Td:75

File Name	Collection Date	Equipment	Import %	BT Offset	BT Mods
WR_ES_03	30-Jun-17	Tritech Starfish	80%	n/a	hand digitized
marina_out	27-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:9, Td:75
LockRun_sample	27-Jun-17	Tritech Starfish	80%	0.1	Bl:5, Dr:9, Td:75
LockRun_sample_02	27-Jun-17	Tritech Starfish		DELETED - Not used	
LockRun_sample_X	27-Jun-17	Tritech Starfish	80%	0.1	Bl:5, Dr:9, Td:75
LockRun_sample_Xb	27-Jun-17	Tritech Starfish	80%	0.1	Bl:5, Dr:9, Td:75
LockRun_AM	27-Jun-17	Tritech Starfish		DELETED - Not used	
LockRun_AM_02	27-Jun-17	Tritech Starfish		DELETED - Not used	
LockRun_AM_03	27-Jun-17	Tritech Starfish	80%	0.1	Bl:5, Dr:15, Td:65
LockRun_AM_04	27-Jun-17	Tritech Starfish	80%	0.1	Bl:5, Dr:10, Td:65
WR_ES_01	30-Jun-17	Tritech Starfish	80%	0.1	Bl:2, Dr:9, Td:75
WR_ES_01b	30-Jun-17	Tritech Starfish	80%	0.1	Bl:1, Dr:9, Td:75
WR_ES_01c	30-Jun-17	Tritech Starfish	80%	0.1	Bl:1, Dr:9, Td:75
WR_ES_02	30-Jun-17	Tritech Starfish	80%	0.1	Bl:1, Dr:9, Td:75
justSSdrift	29-Jun-17	Tritech Starfish		DELETED - Not used	
WR_ES_04	30-Jun-17	Tritech Starfish	80%	0.1	Bl:1, Dr:9, Td:75
WR_ES_05	30-Jun-17	Tritech Starfish	80%	0.1	Bl:1, Dr:9, Td:75
WR_ES_tie1	30-Jun-17	Tritech Starfish	80%	0.1	Bl:1, Dr:9, Td:75
WR_ES_tie2	30-Jun-17	Tritech Starfish	80%	0.1	Bl:1, Dr:9, Td:75
WR_ES_tie3	30-Jun-17	Tritech Starfish	80%	0.1	Bl:1, Dr:9, Td:75
WR_ES_Stransit	30-Jun-17	Tritech Starfish	80%	0.1	Bl:1, Dr:9, Td:75
WR_ES_Stransit2	30-Jun-17	Tritech Starfish	80%	0.1	Bl:1, Dr:9, Td:75
Sonar0003a	13-Sep-16	Lowrance	50%	0.1	Bl:2, Dr:9, Td:75
Sonar0004a	13-Sep-16	Lowrance	45%	0.1	Bl:2, Dr:9, Td:75
Sonar0005a	13-Sep-16	Lowrance	50%	0.1	Bl:2, Dr:9, Td:75
Sonar0006a	13-Sep-16	Lowrance	50%	n/a	hand digitized
Sonar0007a	13-Sep-16	Lowrance	45%	0.1	Bl:2, Dr:9, Td:75
Sonar0008a	13-Sep-16	Lowrance	40%	0.1	Bl:2, Dr:9, Td:75
Sonar0009a	13-Sep-16	Lowrance	50%	0.1	Bl:2, Dr:9, Td:75
Sonar00010a	13-Sep-16	Lowrance	50%	0.1	Bl:2, Dr:9, Td:75

File Name	Collection Date	Equipment	Import %	BT Offset	BT Mods
Sonar00011a	13-Sep-16	Lowrance	50%	0.1	Bl:2, Dr:9, Td:75
Sonar0003a	13-Sep-16	Lowrance	50%	0.1	Bl:2, Dr:9, Td:75
Sonar0004a	13-Sep-16	Lowrance	50%	0.1	Bl:2, Dr:9, Td:75
Sonar0000b	14-Sep-16	Lowrance	45%	0.1	Bl:2, Dr:9, Td:75
Sonar0001b	14-Sep-16	Lowrance	45%	0.1	Bl:5, Dr:9, Td:75
Sonar0002b	14-Sep-16	Lowrance	45%	0.1	Bl:5, Dr:10, Td:65
Sonar0003b	14-Sep-16	Lowrance	45%	0.1	Bl:2, Dr:9, Td:75
Sonar0004b	14-Sep-16	Lowrance	45%	0.1	Bl:2, Dr:9, Td:75
Sonar0005b	14-Sep-16	Lowrance	50%	n/a	hand digitized
Sonar0006b	14-Sep-16	Lowrance	50%	0.1	Bl:5, Dr:10, Td:65
Sonar0007b	14-Sep-16	Lowrance	50%	0.1	Bl:2, Dr:9, Td:75
Sonar0008b	14-Sep-16	Lowrance	50%	0.1	Bl:2, Dr:9, Td:75
Sonar0009b	14-Sep-16	Lowrance	50%	0.1	Bl:2, Dr:9, Td:75
Sonar0000c	15-Sep-16	Lowrance	50%	0.1	Bl:2, Dr:9, Td:75
Sonar0001c	15-Sep-16	Lowrance	70%	0.1	Bl:2, Dr:9, Td:75
Sonar0002c	15-Sep-16	Lowrance	60%	0.1	Bl:2, Dr:9, Td:75
Sonar0003c	15-Sep-16	Lowrance	60%	0.1	Bl:2, Dr:9, Td:75
Sonar0004c	15-Sep-16	Lowrance	60%	0.1	Bl:2, Dr:9, Td:75
Sonar0005c	15-Sep-16	Lowrance	50%	0.1	Bl:2, Dr:9, Td:75
Sonar0006c	15-Sep-16	Lowrance	50%	0.1	Bl:2, Dr:9, Td:75
Sonar0007c	15-Sep-16	Lowrance	50%	n/a	hand digitized
Sonar0008c	15-Sep-16	Lowrance	50%	n/a	hand digitized
Sonar0009c	15-Sep-16	Lowrance	50%	0.1	Bl:2, Dr:9, Td:75
9162016	16-Sep-16	Lowrance	50%	0.1	Bl:2, Dr:9, Td:75
Sonar0000d	16-Sep-16	Lowrance	60%	0.1	Bl:2, Dr:9, Td:75
Sonar0001d	16-Sep-16	Lowrance	50%	0.1	Bl:2, Dr:9, Td:75
Sonar0002d	16-Sep-16	Lowrance	50%	0.1	Bl:2, Dr:9, Td:75
Sonar0000	28-Sep-16	Lowrance	60%	0.1	Bl:2, Dr:9, Td:75
Sonar0001	28-Sep-16	Lowrance	60%	0.1	Bl:2, Dr:9, Td:75
Sonar0002	28-Sep-16	Lowrance	60%	0.1	Bl:2, Dr:9, Td:75
Sonar0003	28-Sep-16	Lowrance	70%	0.1	Bl:5, Dr:10, Td:65
Sonar0004	28-Sep-16	Lowrance	70%	0.1	Bl:2, Dr:9, Td:75
Sonar0005	28-Sep-16	Lowrance	70%	0.1	Bl:2, Dr:9, Td:75

File Name	Collection Date	Equipment	Import %	BT Offset	BT Mods
Sonar0006	28-Sep-16	Lowrance	80%	0.1	Bl:2, Dr:9, Td:75
Sonar0007	28-Sep-16	Lowrance	70%	0.1	Bl:2, Dr:9, Td:75
Sonar0008	28-Sep-16	Lowrance	70%	0.1	Bl:2, Dr:9, Td:75
Sonar0009	28-Sep-16	Lowrance	80%	0.1	Bl:5, Dr:10, Td:65
Sonar0010	28-Sep-16	Lowrance	80%	0.1	Bl:2, Dr:9, Td:75
Sonar0011	28-Sep-16	Lowrance	70%	0.1	Bl:2, Dr:9, Td:75
UpperNiag-20160913_110917	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_111558	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_112239	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_112920	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_113601	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_114012	13-Sep-16	EdgeTech	85%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_114803	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_115444	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_125437	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_130118	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_130759	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_131646	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_132326	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_140530	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_141040	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_141550	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8

File Name	Collection Date	Equipment	Import %	BT Offset	BT Mods
UpperNiag-20160913_141706	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_142345	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_142855	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_143140	13-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_143821	13-Sep-16	EdgeTech	85%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_144557	13-Sep-16	EdgeTech	85%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160913_145238	13-Sep-16	EdgeTech	85%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_113200	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_115400	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_115800	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_120800	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_123500	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_125800	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_131300	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_131900	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_132500	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_133700	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_132500	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_133700	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_134200	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8

File Name	Collection Date	Equipment	Import %	BT Offset	BT Mods
UpperNiag-20160915_135100	15-Sep-16	EdgeTech	85%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_135600	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_140000	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_142600	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_143000	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_144400	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_150300	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160915_152200	15-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_120936	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_121617	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_122257	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_123059	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_123740	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_124420	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_125255	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_125936	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_130617	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_131258	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_131939	12-Sep-16	EdgeTech	85%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_132620	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8

File Name	Collection Date	Equipment	Import %	BT Offset	BT Mods
UpperNiag-20160912_133301	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_133656	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_134337	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_135018	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_135659	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_141015	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_141656	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_142337	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_143018	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_100043	12-Sep-16	EdgeTech	85%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_100553	12-Sep-16	EdgeTech	85%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_101102	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_103552	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_104812	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160912_110204	12-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160916_104812	16-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8
UpperNiag-20160916_120936	16-Sep-16	EdgeTech	90%	0.1	Bl: 3, Dr:3, Td:8

Appendix B: Sub-bottom File Index

The following table lists all chirp sub-bottom files collected in support of this project. Date of collection, sonar frequency settings, and total data record imported are noted for each line. Bottom tracking all utilized Chesapeake Technology SonarWiz algorithms, modified by hand as necessary to remove artifacts caused by abundant SAV growth on the riverbed or schools of fish in the water column.

File Name	Collection Date	Frequency Range	Trigger Length	Record Length	Import %
ER_ES_09	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_ES_10	27-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_ES_11	27-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_ES_11x	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_ES_11xx	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_ES_12	28-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_ES_13	28-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_ES_14	28-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_ES_14x	28-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_ES_15	28-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_ES_15b	28-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_ES_16	28-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_ES_17	28-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_WS_06	29-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_WS_06b	29-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_WS_06c	29-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_WS_07	29-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_ES_15c	28-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_ES_17b	28-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_ES_17c	28-Jun-17	4-16 kHz	150 ms	120 ms	70%
TonwIsl_01	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
TonwIsl_02	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
Transit_TonwIsl_01	28-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_WS_01	28-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_WS_01b	28-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_WS_02	28-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_WS_03	28-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_WS_03_tie	28-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_WS_06b	29-Jun-17	4-16 kHz	150 ms	120 ms	75%

File Name	Collection Date	Frequency Range	Trigger Length	Record Length	Import %
ER_WS_06c	29-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_WS_05	29-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_WS_04	29-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_WS_08	29-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_WS_08b	29-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_WS_08c	29-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_WS_08d	29-Jun-17	4-16 kHz	150 ms	120 ms	70%
ER_ES_07	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_ES_08	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_ES_06	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_ES_05	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_ES_04	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_ES_03	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_ES_02	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
ER_ES_01	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
SI_transit	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
SI_transit_02	27-Jun-17	4-16 kHz	150 ms	120 ms	70%
SI_transit_03	27-Jun-17	4-16 kHz	150 ms	120 ms	70%
SI_transit_04	27-Jun-17	4-16 kHz	150 ms	120 ms	70%
SI_transit_05	27-Jun-17	4-16 kHz	150 ms	120 ms	70%
SGI_transit	27-Jun-17	4-16 kHz	150 ms	120 ms	70%
SGI_transit_02	27-Jun-17	4-16 kHz	150 ms	120 ms	70%
BISPMar_01	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
WR_ES_03	30-Jun-17	4-16 kHz	150 ms	120 ms	70%
marina_out	27-Jun-17	4-16 kHz	150 ms	120 ms	70%
LockRun_sample	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
LockRun_sample_02	27-Jun-17		DELETED - Not used		70%
LockRun_sample_X	27-Jun-17	4-16 kHz	150 ms	120 ms	70%
LockRun_sample_Xb	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
LockRun_AM	27-Jun-17		DELETED - Not used		75%
LockRun_AM_02	27-Jun-17		DELETED - Not used		70%
LockRun_AM_03	27-Jun-17	4-16 kHz	150 ms	120 ms	75%
LockRun_AM_04	27-Jun-17	4-16 kHz	150 ms	120 ms	70%
WR_ES_01	30-Jun-17	4-16 kHz	150 ms	120 ms	70%
WR_ES_01b	30-Jun-17	4-16 kHz	150 ms	120 ms	75%
WR_ES_01c	30-Jun-17	4-16 kHz	150 ms	120 ms	75%
WR_ES_02	30-Jun-17	4-16 kHz	150 ms	120 ms	75%

File Name	Collection Date	Frequency Range	Trigger Length	Record Length	Import %
justSSdrift	29-Jun-17		DELETED - Not used		70%
WR_ES_04	30-Jun-17	4-16 kHz	150 ms	120 ms	70%
WR_ES_05	30-Jun-17	4-16 kHz	150 ms	120 ms	70%
WR_ES_tie1	30-Jun-17	4-16 kHz	150 ms	120 ms	75%
WR_ES_tie2	30-Jun-17	4-16 kHz	150 ms	120 ms	70%
WR_ES_tie3	30-Jun-17	4-16 kHz	150 ms	120 ms	70%
WR_ES_Stransit	30-Jun-17	4-16 kHz	150 ms	120 ms	70%
WR_ES_Stransit2	30-Jun-17	4-16 kHz	150 ms	120 ms	75%

Appendix C: Sediment Volume Calculations

Golden Software Surfer was used to grid the chirp sub-bottom data to generate isopach maps. To reduce errors associated with gridding spatially variable anisotropic data, the chirp data were divided into the following regions and further delineated as necessary in Section 3.4 of this report:

1. Cayuga (includes 3.4. 1 Cayuga)
2. EastRvRd (includes 3.4.4 East River Road and 3.4.3 Gratwick - western shoreline, only)
3. Gratwick (includes western shoreline of 3.4.3 Gratwick)
4. NWestRvr (includes 3.4.2 Buckhorn and 3.4.10 Big Six Marina and Big Six Mile Creek)
5. Pirates (includes 3.4.6 Pirates Island and Ferry Bridge)
6. SGIBridge (includes 3.4.5 Grand Island Bridge)
7. Sheenwater (includes 3.4.9 Sheenwater)
8. Strawberry (includes 3.4.7 Strawberry Island and 3.4.8 Black Rock Lock).

As noted above, the spatial distribution of data was selected to minimize gridding artifacts that might not be obvious from spatial distribution alone. Accordingly, regions that are presented separately in the report (e.g., section 3.4.2 Buckhorn and section 3.4.10 Big Six Marina) were actually included in one grid during analysis. Likewise, regions that were presented as one data set in the report (e.g., 3.4.3 Gratwick) were calculated as parts of different grids to minimize data aliasing. Accordingly, the list above should be used to guide the reader towards which gridding reports are most appropriate for a specific region.

Gridding Report - Cayuga

Fri Nov 10 11:48:23 2017
Elapsed time for gridding: 1.05 seconds

Data Source

Source Data File Name: C:\Users\Heidi\Documents\LRB Niagara supporting files\Surfer Files\thickness\Grid Groups\Cayuga\Cayuga.CSV
X Column: A
Y Column: B
Z Column: C

Filtered Data Counts

Active Data: 1332

Original Data: 1332
Excluded Data: 0
Deleted Duplicates: 0
Retained Duplicates: 0
Artificial Data: 0
Superseded Data: 0

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep: First
X Duplicate Tolerance: 4.2E-09
Y Duplicate Tolerance: 8.7E-10

No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Z Data Transform

Transformation method: Linear (use Z values directly)

No untransformable data were found.

Data Counts

Active Data: 1332

Univariate Statistics

	X	Y	Z
Count:	1332	1332	1332
1%-tile:	-78.98250731	43.07006325	0.6
5%-tile:	-78.98045438	43.07051673	0.86
10%-tile:	-78.97570773	43.0708312	1.08
25%-tile:	-78.96972925	43.07202199	1.42
50%-tile:	-78.95931272	43.07367256	1.84
75%-tile:	-78.95187627	43.07541286	2.22
90%-tile:	-78.95111826	43.07682926	2.96
95%-tile:	-78.94865329	43.07713207	3.31
99%-tile:	-78.94802763	43.07725519	3.82
Minimum:	-78.98305242	43.06989218	0.25
Maximum:	-78.94778683	43.07726186	4.21
Mean:	-78.9613944975	43.073681786	1.90007507508
Median:	-78.959297595	43.073674345	1.84
Geometric Mean:	N/A	43.0736817359	1.76644500744
Harmonic Mean:	N/A	43.0736816857	1.62236259561
Root Mean Square:	78.9613951487	43.0736818362	2.02779229498
Trim Mean (10%):	-78.9610121136	43.073674583	1.87002502085
Interquartile Mean:	-78.9599138703	43.0735266508	1.82851574213
Midrange:	-78.965419625	43.07357702	2.23
Winsorized Mean:	-78.9612148817	43.0736908444	1.88224474474
TriMean:	-78.96005774	43.0736949925	1.83
Variance:	0.000102906787689	4.32680500079e-06	0.502033202474
Standard Deviation:	0.0101442982847	0.00208009735368	0.708543013849
Interquartile Range:	0.01785298	0.00339087	0.8
Range:	0.03526559	0.00736968	3.96
Mean Difference:	0.0114702923564	0.00237213020912	0.784314351918
Median Abs. Deviation:	0.00808709	0.001653865	0.4
Average Abs. Deviation:	0.00882990714715	0.00167371029279	0.545075075075
Quartile Dispersion:	N/A	3.93612416423e-05	0.21978021978

Relative Mean Diff.:	N/A 0.412780717039	5.50714522362e-05	
Standard Error:	0.000277952060821 0.0194139589898	5.6994316407e-05	
Coef. of Variation:	N/A 0.372902641134	4.82916079478e-05	
Skewness:	-0.448924956183 0.656646876913	0.152454741551	
Kurtosis:	1.91704386825 3.32772232642	2.02011934039	
Sum:	-105176.577471	57374.144139	2530.9
Sum Absolute:	105176.577471	57374.144139	2530.9
Sum Squares:	8304889.36253	2471315.63315	5477.1062
Mean Square:	6234.90192382 4.11194159159	1855.34206693	

Inter-Variable Covariance

	X	Y	Z
X:	0.00010290679	-1.6756304e-06	-0.00070549681
Y:	-1.6756304e-06	4.326805e-06	0.00025125256
Z:	-0.00070549681	0.00025125256	0.5020332

Inter-Variable Correlation

	X	Y	Z
X:	1.000	-0.079	-0.098
Y:	-0.079	1.000	0.170
Z:	-0.098	0.170	1.000

Inter-Variable Rank Correlation

	X	Y	Z
X:	1.000	-0.253	-0.163
Y:	-0.253	1.000	0.200
Z:	-0.163	0.200	1.000

Principal Component Analysis

	PC1	PC2	PC3
X:	0.999907462284	0.999907462284	0.0135311218237
Y:	-0.0135304301058	-0.0135304301058	0.99990833429
Z:	0.00141220744607	0.00141220744607	0.99990833429
Lambda:	0.502034319842	0.00010193306174	4.18316239312e-06

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	-5.94765843143	55.7655083355	-2869.76108935
Standard Error:	1.88683404282	9.20178438294	412.208293118

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.079	0.285
B:	0.079	1.000	-0.933
C:	0.285	-0.933	1.000

ANOVA Table

Source	df F	Sum of Squares	Mean Square
Regression:	2 25.0063864568	24.2338905201	12.11694526
Residual:	1329	643.972301972	0.484554027067
Total:	1331	668.206192492	

Coefficient of Multiple Determination (R^2): 0.0362670846101

Nearest Neighbor Statistics

	Separation	|Delta Z|
1%-tile:	6.79411510845e-07	0
5%-tile:	8.15476547672e-06	0
10%-tile:	1.72112637542e-05	0.01
25%-tile:	2.23320084184e-05	0.03
50%-tile:	2.87611491347e-05	0.08
75%-tile:	3.28965910001e-05	0.17
90%-tile:	3.95194243385e-05	0.39
95%-tile:	4.36886632796e-05	0.97
99%-tile:	4.83241813079e-05	1.56
Minimum:	2.50199919182e-07	0
Maximum:	4.89924606434e-05	1.95
Mean:	2.78024387748e-05	0.184429429429
Median:	2.87680847804e-05	0.08
Geometric Mean:	2.46486200874e-05	N/A
Harmonic Mean:	1.31263835751e-05	N/A
Root Mean Square:	2.9416671489e-05	0.361634386403
Trim Mean (10%):	2.80957033796e-05	0.130275229358
Interquartile Mean:	2.88247566902e-05	0.0886656671664

Midrange:	2.46213302813e-05	0.975
Winsorized Mean:	2.82277360312e-05	0.123806306306
TriMean:	2.8187724422e-05	0.09
Variance:	9.2434354821e-11	0.096837916128
Standard Deviation:	9.61427869478e-06	0.311187911282
Interquartile Range:	1.05645825817e-05	0.14
Range:	4.87422607242e-05	1.95
Mean Difference:	1.05119957925e-05	0.239601126295
Median Abs. Deviation:	4.67286648029e-06	0.06
Average Abs. Deviation:	7.2686229317e-06	0.148438438438
Quartile Dispersion:	0.191288258129	N/A
Relative Mean Diff.:	0.378096176296	1.29914801036
Standard Error:	2.63429613516e-07	0.00852649624607
Coef. of Variation:	0.345807026953	1.68730073202
Skewness:	-0.503914938498	3.17293386765
Kurtosis:	3.60161379689	13.269591668
Sum:	0.0370328484481	245.66
Sum Absolute:	0.0370328484481	245.66
Sum Squares:	1.1526336279e-06	174.1982
Mean Square:	8.65340561489e-10	0.130779429429

Complete Spatial Randomness

Lambda:	5125124.73938
Clark and Evans:	0.125882427366
Skellam:	37.1172331003

Gridding Rules

Gridding Method:	Kriging
Kriging Type:	Point
Polynomial Drift Order:	0
Kriging std. deviation grid:	no

Semi-Variogram Model

Component Type:	Linear
Anisotropy Angle:	0
Anisotropy Ratio:	1
Variogram Slope:	1

Search Parameters

Search Ellipse Radius #1:	0.018
Search Ellipse Radius #2:	0.018
Search Ellipse Angle:	0
Number of Search Sectors:	4
Maximum Data Per Sector:	16
Maximum Empty Sectors:	3
Minimum Data:	8
Maximum Data:	64

Output Grid

Grid File Name:	C:\Users\Heidi\Documents\LRB Niagara supporting files\Surfer Files\thickness\Grid Groups\Cayuga\Cayuga_NoS_hullblank5.grd
Grid Size:	22 rows x 100 columns
Total Nodes:	2200
Filled Nodes:	2200
Blanked Nodes:	0
Blank Value:	1.70141E+38

Grid Geometry

X Minimum:	-78.98305243
X Maximum:	-78.94778683
X Spacing:	0.00035621818181821
Y Minimum:	43.06989218
Y Maximum:	43.07726186
Y Spacing:	0.00035093714285731

Univariate Grid Statistics

	Z
Count:	2200
1%-tile:	-0.418349747075
5%-tile:	0.872223790504
10%-tile:	1.12000564775
25%-tile:	1.50993428622
50%-tile:	1.81772225734
75%-tile:	2.05820677001
90%-tile:	2.39219731331
95%-tile:	3.37993332799
99%-tile:	5.10242977553
Minimum:	-3.32542667425
Maximum:	7.93901254848
Mean:	1.85362327148
Median:	1.81773081725
Geometric Mean:	N/A
Harmonic Mean:	N/A
Root Mean Square:	2.0658022198
Trim Mean (10%):	1.79525379511
Interquartile Mean:	1.80455090358
Midrange:	2.30679293711
Winsorized Mean:	1.78202671797
TriMean:	1.80089639273
Variance:	0.831997759551
Standard Deviation:	0.912139111951
Interquartile Range:	0.548272483787
Range:	11.2644392227
Mean Difference:	0.799962531913
Median Abs. Deviation:	0.274953836841

Average Abs. Deviation:	0.502603378676
Quartile Dispersion:	N/A
Relative Mean Diff.:	N/A
Standard Error:	0.0194468712084
Coef. of Variation:	N/A
Skewness:	1.48695995473
Kurtosis:	16.1898369382
Sum:	4077.97119726
Sum Absolute:	4157.74513296
Sum Squares:	9388.58538491
Mean Square:	4.26753881132

Gridding Report - ERiverRd

Fri Nov 10 13:37:42 2017
Elapsed time for gridding: 0.24 seconds

Data Source

Source Data File Name: C:\Users\Heidi\Documents\LRB Niagara supporting files\Surfer Files\thickness\Grid Groups\ERvrRd\ERvrRd.dat

X Column:	A
Y Column:	B
Z Column:	C

Filtered Data Counts

Active Data:	257
Original Data:	257
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep:	First
X Duplicate Tolerance:	3.8E-09
Y Duplicate Tolerance:	3.6E-09

No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Z Data Transform

Transformation method: Linear (use Z values directly)

No untransformable data were found.

Data Counts

Active Data: 257

Univariate Statistics

	X	Y	Z
Count:	257	257	257
1%-tile:	-78.92566769	43.02505808	0.89
5%-tile:	-78.92540786	43.02515808	1.08
10%-tile:	-78.89670649	43.02774155	1.32
25%-tile:	-78.89627401	43.03151667	1.83
50%-tile:	-78.89605095	43.03302545	2.18
75%-tile:	-78.89537633	43.03437337	2.48
90%-tile:	-78.89349616	43.03539717	2.81
95%-tile:	-78.89327044	43.05597084	2.95
99%-tile:	-78.89326856	43.0560305	3.65
Minimum:	-78.92570717	43.02503835	0.4
Maximum:	-78.89326846	43.05604459	4.04
Mean:	-78.89741648	43.0335390195	2.14322957198
Median:	-78.89605095	43.03302545	2.18
Geometric Mean:	N/A	43.0335385341	2.05371425052
Harmonic Mean:	N/A	43.0335380487	1.93848904269
Root Mean Square:	78.8974168194	43.0335395051	2.21830893983
Trim Mean (10%):	-78.8961919021	43.0327164955	2.14120689655
Interquartile Mean:	-78.8959502333	43.0329837298	2.16798449612
Midrange:	-78.909487815	43.04054147	2.22
Winsorized Mean:	-78.8956421113	43.032501906	2.14035019455
TriMean:	-78.89593806	43.032985235	2.1675
Variance:	5.37604759721e-05	4.19544838616e-05	0.328740700997
Standard Deviation:	0.00733215356986	0.00647722810016	

	0.573359137886		
Interquartile Range:	0.000897679999994	0.0028567	0.65
Range:	0.03243871	0.03100624	3.64
Mean Difference:	0.00447511987415	0.00553129061102	
	0.63530520428		
Median Abs. Deviation:	0.000413730000005	0.00143086000001	0.34
Average Abs. Deviation:	0.00251895190661	0.00337346571984	
	0.435525291829		
Quartile Dispersion:	N/A	3.31920113609e-05	
	0.150812064965		
Relative Mean Diff.:	N/A	0.000128534411462	
	0.296424243387		
Standard Error:	0.000457367173515	0.000404038387924	
	0.0357651603727		
Coef. of Variation:	N/A	0.00015051581273	
	0.267521102443		
Skewness:	-3.47434797303	2.33704460677	-
0.0919730905367			
Kurtosis:	13.4710137667	9.32584917375	
	3.60198394718		
Sum:	-20276.6360354	11059.619528	550.81
Sum Absolute:	20276.6360354	11059.619528	550.81
Sum Squares:	1599774.21186	475934.579241	1264.6699
Mean Square:	6224.80238078	1851.88552234	
	4.92089455253		

Inter-Variable Covariance

	X	Y	Z
X:	5.3760476e-05	-4.5061497e-05	-0.0013553565
Y:	-4.5061497e-05	4.1954484e-05	0.0015662888
Z:	-0.0013553565	0.0015662888	0.3287407

Inter-Variable Correlation

	X	Y	Z
X:	1.000	-0.949	-0.322
Y:	-0.949	1.000	0.422
Z:	-0.322	0.422	1.000

Inter-Variable Rank Correlation

	X	Y	Z
X:	1.000	-0.998	-0.315
Y:	-0.998	1.000	0.310
Z:	-0.315	0.310	1.000

Principal Component Analysis

	PC1	PC2	PC3
X:	0.766303364282	0.766303364282	0.642465677586
Y:	-0.642448785865	-0.642448785865	0.766313805497
Z:	0.0062218510396	0.0062218510396	0.766313805497
Lambda:	0.328753754681	8.05343077012e-05	2.12696803034e-06

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	60.9724640293	102.820935157	387.964392798
Standard Error:	13.5576329631	15.3470968433	489.664869427

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.949	0.905
B:	0.949	1.000	0.724
C:	0.905	0.724	1.000

ANOVA Table

Source	df F	Sum of Squares	Mean Square
Regression:	2 39.7782266695	20.0724095076	10.0362047538
Residual:	254	64.0852099477	0.252303976172
Total:	256	84.1576194553	

Coefficient of Multiple Determination (R^2): 0.238509711153

Nearest Neighbor Statistics

	Separation	|Delta Z|
1%-tile:	2.86754250293e-06	0.01
5%-tile:	7.56191113071e-06	0.01
10%-tile:	9.40153711176e-06	0.01
25%-tile:	1.24013063856e-05	0.03
50%-tile:	2.74459997034e-05	0.07
75%-tile:	2.96408788701e-05	0.16

90%-tile:	3.49202247963e-05	0.27
95%-tile:	3.54488589346e-05	0.37
99%-tile:	3.581124125e-05	0.49
Minimum:	6.80073521003e-07	0
Maximum:	3.58606023363e-05	1.17
Mean:	2.29978745911e-05	0.121167315175
Median:	2.74459997034e-05	0.07
Geometric Mean:	1.99771555686e-05	N/A
Harmonic Mean:	1.44459629594e-05	N/A
Root Mean Square:	2.49889244493e-05	0.186340970263
Trim Mean (10%):	2.32271166618e-05	0.10224137931
Interquartile Mean:	2.47235594391e-05	0.0828682170543
Midrange:	1.82703379287e-05	0.585
Winsorized Mean:	2.31999617975e-05	0.104357976654
TriMean:	2.42335461656e-05	0.0825
Variance:	9.5917328602e-11	0.0201197258025
Standard Deviation:	9.79373925536e-06	0.14184401927
Interquartile Range:	1.72395724845e-05	0.13
Range:	3.51805288153e-05	1.17
Mean Difference:	1.09856310098e-05	0.125828064202
Median Abs. Deviation:	7.32309145923e-06	0.05
Average Abs. Deviation:	8.29517845272e-06	0.0845525291829
Quartile Dispersion:	0.4100541487	N/A
Relative Mean Diff.:	0.477680272857	1.0384653982
Standard Error:	6.109166698e-07	0.00884798682339
Coef. of Variation:	0.42585410302	1.170645888
Skewness:	-0.447759862542	3.48669934408
Kurtosis:	1.80415293253	21.8683063533
Sum:	0.00591045376991	31.14
Sum Absolute:	0.00591045376991	31.14
Sum Squares:	1.60482710699e-07	8.9238
Mean Square:	6.24446345132e-10	0.0347229571984

Complete Spatial Randomness

Lambda:	255517.378921
Clark and Evans:	0.0232502656306
Skellam:	0.257649060741

Gridding Rules

Gridding Method:	Kriging
Kriging Type:	Point
Polynomial Drift Order:	0
Kriging std. deviation grid:	no

Semi-Variogram Model

Component Type:	Linear
Anisotropy Angle:	0
Anisotropy Ratio:	1
Variogram Slope:	1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name: C:\Users\Heidi\Documents\LRB Niagara supporting files\Surfer Files\thickness\Grid Groups\ERvrRd\ERvrRd_NoSearch_hull4.grd

Grid Size:	96 rows x 100 columns
Total Nodes:	9600
Filled Nodes:	9600
Blanked Nodes:	0
Blank Value:	1.70141E+38

Grid Geometry

X Minimum:	-78.92570717
X Maximum:	-78.89326846
X Spacing:	0.00032766373737368
Y Minimum:	43.02503835
Y Maximum:	43.05604459
Y Spacing:	0.00032638147368417

Univariate Grid Statistics

	Z
Count:	9600
1%-tile:	1.00694484238
5%-tile:	1.68390549963
10%-tile:	1.91074269615
25%-tile:	2.02912393129
50%-tile:	2.08675463777
75%-tile:	2.15179593491
90%-tile:	2.27020412291
95%-tile:	2.35063739677
99%-tile:	2.47505251749
Minimum:	0.443680014329
Maximum:	3.41999999834
Mean:	2.06542713675
Median:	2.08679642808
Geometric Mean:	2.0489783807
Harmonic Mean:	2.02570507886
Root Mean Square:	2.07784855891
Trim Mean (10%):	2.08793918577
Interquartile Mean:	2.08973739611

Midrange:	1.93184000634
Winsorized Mean:	2.09093277216
TriMean:	2.08860728543
Variance:	0.0514707380743
Standard Deviation:	0.226871633472
Interquartile Range:	0.122672003616
Range:	2.97631998402
Mean Difference:	0.20345494991
Median Abs. Deviation:	0.0614411305796
Average Abs. Deviation:	0.128229066882
Quartile Dispersion:	0.0293409124168
Relative Mean Diff.:	0.0985050241133
Standard Error:	0.00231549891299
Coef. of Variation:	0.109842477343
Skewness:	-2.49483526139
Kurtosis:	13.3231223643
Sum:	19828.1005128
Sum Absolute:	19828.1005128
Sum Squares:	41447.5644843
Mean Square:	4.31745463378

Gridding Report - Gratwick

Fri Nov 10 13:54:24 2017
Elapsed time for gridding: 0.19 seconds

Data Source

Source Data File Name: C:\Users\Heidi\Documents\LRB Niagara supporting files\Surfer Files\thickness\Grid Groups\Gratwick\Gratwick.dat

X Column:	A
Y Column:	B
Z Column:	C

Filtered Data Counts

Active Data:	321
Original Data:	321
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep: First
X Duplicate Tolerance: 2.3E-09
Y Duplicate Tolerance: 8.4E-10

No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Z Data Transform

Transformation method: Linear (use Z values directly)

No untransformable data were found.

Data Counts

Active Data: 321

Univariate Statistics

	X	Y	Z
Count:	321	321	321
1%-tile:	-78.91880861	43.05335936	0.5
5%-tile:	-78.91856786	43.05354629	0.78
10%-tile:	-78.91826429	43.05369176	0.94
25%-tile:	-78.90866394	43.05423923	1.19
50%-tile:	-78.90651643	43.05755912	1.59
75%-tile:	-78.90066969	43.05816708	2.05
90%-tile:	-78.89995092	43.06018628	2.39
95%-tile:	-78.89975149	43.06028799	2.66
99%-tile:	-78.89958282	43.0603558	3.25
Minimum:	-78.91885099	43.05328397	0.31
Maximum:	-78.89951046	43.06037394	3.53
Mean:	-78.9063995489	43.0566964153	
	1.64395638629		
Median:	-78.90651643	43.05755912	1.59
Geometric Mean:	N/A	43.0566963525	
	1.52988412259		
Harmonic Mean:	N/A	43.0566962898	
	1.40602603475		
Root Mean Square:	78.9063997905	43.056696478	

	1.75052221848		
Trim Mean (10%):	-78.9060918064	43.0566759444	
	1.62342560554		
Interquartile Mean:	-78.9053314005	43.0567653332	
	1.58621118012		
Midrange:	-78.909180725	43.056828955	1.92
Winsorized Mean:	-78.9063896509	43.0567024378	
	1.62551401869		
TriMean:	-78.9055916225	43.0568811375	1.605
Variance:	3.82328167075e-05	5.4206503505e-06	
	0.362865860592		
Standard Deviation:	0.00618326909551	0.0023282290159	
	0.602383483001		
Interquartile Range:	0.00799425	0.00392785	0.86
Range:	0.01934053	0.00708997	3.22
Mean Difference:	0.00667300966394	0.00261699698871	
	0.678579439252		
Median Abs. Deviation:	0.00536667	0.00257685	0.42
Average Abs. Deviation:	0.00489984647975	0.0020065323053	
	0.489345794393		
Quartile Dispersion:	N/A	4.56130558686e-05	
	0.265432098765		
Relative Mean Diff.:	N/A	6.07802550262e-05	
	0.412772166531		
Standard Error:	0.000345116426729	0.000129949071626	
	0.0336217673795		
Coef. of Variation:	N/A	5.40735636902e-05	
	0.366423031671		
Skewness:	-0.784013574548	-0.00493124854623	
	0.494507660583		
Kurtosis:	2.58721342187	1.62682857499	
	2.98373872492		
Sum:	-25328.9542552	13821.1995493	527.71
Sum Absolute:	25328.9542552	13821.1995493	527.71
Sum Squares:	1998616.59685	595095.194824	983.6493
Mean Square:	6226.21992789	1853.8791116	
	3.06432803738		

Inter-Variable Covariance

	X	Y	Z
X:	3.8232817e-05	-1.3757784e-05	0.00062723783
Y:	-1.3757784e-05	5.4206504e-06	-0.00034421884
Z:	0.00062723783	-0.00034421884	0.36286586

Inter-Variable Correlation

	X	Y	Z
X:	1.000	-0.956	0.168
Y:	-0.956	1.000	-0.245
Z:	0.168	-0.245	1.000

Inter-Variable Rank Correlation

	X	Y	Z
X:	1.000	-0.961	0.124
Y:	-0.961	1.000	-0.278
Z:	0.124	-0.278	1.000

Principal Component Analysis

—	PC1	PC2	PC3
—			
X:	0.941482416245	0.941482416245	0.337057667527
Y:	-0.33705647543	-0.33705647543	0.941483952261
Z:	-0.00194737551387	-0.00194737551387	0.941483952261
Lambda:	0.362867271503	4.18608001646e-05	3.81755680099e-07

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	-74.3262945457	-252.143906282	4993.30728773
Standard Error:	17.4957215774	46.4648253218	793.367382197

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.956	-0.670
B:	0.956	1.000	-0.859
C:	-0.670	-0.859	1.000

ANOVA Table

Source	df F	Sum of Squares	Mean Square
Regression:	2 19.7940644992	12.8551743938	6.42758719692
Residual:	318	103.261900996	0.324722959106
Total:	320	116.117075389	

Coefficient of Multiple Determination (R^2): 0.110708733842

Nearest Neighbor Statistics

	Separation	|Delta Z|
1%-tile:	5.76132797425e-06	0
5%-tile:	1.92331718607e-05	0
10%-tile:	1.97178725989e-05	0.01
25%-tile:	2.74215991519e-05	0.03
50%-tile:	3.12460125516e-05	0.06
75%-tile:	3.7220343898e-05	0.12
90%-tile:	3.95324183414e-05	0.23
95%-tile:	4.07878229466e-05	0.33
99%-tile:	4.30187145293e-05	0.55
Minimum:	4.19362612773e-06	0
Maximum:	4.37315229614e-05	1.01
Mean:	3.10571360122e-05	0.0992211838006
Median:	3.12460125516e-05	0.06
Geometric Mean:	2.96837320698e-05	N/A
Harmonic Mean:	2.73992315368e-05	N/A
Root Mean Square:	3.20269893874e-05	0.155720614105
Trim Mean (10%):	3.14927350913e-05	0.0829757785467
Interquartile Mean:	3.2289509612e-05	0.066397515528
Midrange:	2.39625745446e-05	0.505
Winsorized Mean:	3.12904526325e-05	0.0845482866044
TriMean:	3.17834920383e-05	0.0675
Variance:	6.13735467867e-11	0.0144490790498
Standard Deviation:	7.83412705965e-06	0.120204322093
Interquartile Range:	9.79874474607e-06	0.09
Range:	3.95378968337e-05	1.01
Mean Difference:	8.58907039564e-06	0.105801401869
Median Abs. Deviation:	5.45520813118e-06	0.04
Average Abs. Deviation:	6.04690182295e-06	0.0695638629283
Quartile Dispersion:	0.151584935164	N/A
Relative Mean Diff.:	0.276557065412	1.06631868132
Standard Error:	4.37258333028e-07	0.00670915101338

Coef. of Variation:	0.252248856963	1.21147841105
Skewness:	-0.868250308371	3.2506457877
Kurtosis:	3.54628381048	18.4774282045
Sum:	0.00996934065993	31.85
Sum Absolute:	0.00996934065993	31.85
Sum Squares:	3.292587038e-07	7.7839
Mean Square:	1.02572804922e-09	0.0242489096573

Complete Spatial Randomness

Lambda:	2340950.67894
Clark and Evans:	0.0950358649126
Skellam:	4.84294343131

Gridding Rules

Gridding Method:	Kriging
Kriging Type:	Point
Polynomial Drift Order:	0
Kriging std. deviation grid:	no

Semi-Variogram Model

Component Type:	Linear
Anisotropy Angle:	0
Anisotropy Ratio:	1
Variogram Slope:	1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name: C:\Users\Heidi\Documents\LRB Niagara supporting files\Surfer Files\thickness\Grid Groups\Gratwick\Gratwick.grd

Grid Size:	37 rows x 100 columns
Total Nodes:	3700
Filled Nodes:	3700
Blanked Nodes:	0
Blank Value:	1.70141E+38

Grid Geometry

X Minimum:	-78.91885099
X Maximum:	-78.89951046
X Spacing:	0.00019535888888883
Y Minimum:	43.05328397
Y Maximum:	43.06037394
Y Spacing:	0.00019694361111099

Univariate Grid Statistics

	Z
Count:	3700
1%-tile:	0.386723509749
5%-tile:	0.47960109494
10%-tile:	0.552675178076
25%-tile:	0.767114938133
50%-tile:	1.3127284137
75%-tile:	1.87582941964
90%-tile:	2.24131152273
95%-tile:	2.3700156645
99%-tile:	2.48267186211
Minimum:	0.314821733736
Maximum:	3.38118904527
Mean:	1.3464675448
Median:	1.31273884912
Geometric Mean:	1.18864861608
Harmonic Mean:	1.03033966299
Root Mean Square:	1.4834327808
Trim Mean (10%):	1.33581477024
Interquartile Mean:	1.31397665872
Midrange:	1.8480053895
Winsorized Mean:	1.34029111324
TriMean:	1.31710029629
Variance:	0.387702750482
Standard Deviation:	0.622657811709
Interquartile Range:	1.10871448151
Range:	3.06636731153
Mean Difference:	0.715982068146
Median Abs. Deviation:	0.556296095911
Average Abs. Deviation:	0.542544996935
Quartile Dispersion:	0.419499744007
Relative Mean Diff.:	0.531748478389
Standard Error:	0.0102364313683
Coef. of Variation:	0.462438039531
Skewness:	0.197669616326
Kurtosis:	1.85806009022
Sum:	4981.92991576
Sum Absolute:	4981.92991576
Sum Squares:	8142.11941606
Mean Square:	2.20057281515

Gridding Report – NwestRvr

Fri Nov 10 12:25:46 2017
Elapsed time for gridding: 2.73 seconds

Data Source

Source Data File Name: C:\Users\Heidi\Documents\LRB Niagara supporting files\Surfer Files\thickness\Grid Groups\NWestRvr\NWestRvr.dat
X Column: A
Y Column: B
Z Column: C

Filtered Data Counts

Active Data: 834

Original Data: 834
Excluded Data: 0
Deleted Duplicates: 0
Retained Duplicates: 0
Artificial Data: 0
Superseded Data: 0

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep: First
X Duplicate Tolerance: 8.6E-09
Y Duplicate Tolerance: 1.2E-08

No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Z Data Transform

Transformation method: Linear (use Z values directly)

No untransformable data were found.

Data Counts

Active Data: 834

Univariate Statistics

	X	Y	Z
Count:	834	834	834
1%-tile:	-79.01212205	42.96774756	0.88
5%-tile:	-79.01177258	42.96850932	1.11
10%-tile:	-79.01140725	42.96961252	1.33
25%-tile:	-79.01100052	42.97323557	1.78
50%-tile:	-79.0076933	43.02632654	2.31
75%-tile:	-78.94346295	43.03848402	2.84
90%-tile:	-78.94155453	43.06610345	3.69
95%-tile:	-78.94058554	43.06903245	4.01
99%-tile:	-78.93979393	43.07024154	4.62
Minimum:	-79.01216453	42.96773387	0.54
Maximum:	-78.93953569	43.07046496	4.88
Mean:	-78.9915671567	43.0205392518	2.40628297362
Median:	-79.007689515	43.026335745	2.315
Geometric Mean:	N/A	43.0205263298	2.24818072607
Harmonic Mean:	N/A	43.0205134054	2.08525478235
Root Mean Square:	78.9915726941	43.0205521713	2.55802686437
Trim Mean (10%):	-78.9933311519	43.0206575676	2.37420772304
Interquartile Mean:	-79.0065739957	43.0257465273	2.31544364508
Midrange:	-78.97585011	43.019099415	2.71
Winsorized Mean:	-78.9916276743	43.0204194227	2.38370503597
TriMean:	-78.9924625175	43.0160931675	2.31
Variance:	0.000875867715248	0.00111294721985	0.754208015868
Standard Deviation:	0.0295950623457	0.0333608635957	0.868451504615
Interquartile Range:	0.06753757	0.06524845	1.06
Range:	0.07262884	0.10273109	4.34
Mean Difference:	0.0276019089878	0.0361714463931	0.972583508223
Median Abs. Deviation:	0.003603625	0.012516245	0.53
Average Abs. Deviation:	0.0191234988729	0.024517980012	0.6751558753
Quartile Dispersion:	N/A	0.000758599529355	0.229437229437

Relative Mean Diff.:	N/A	0.000840794816201	0.404185010194
Standard Error:	0.00102479319739	0.00115519223013	0.0300720161964
Coef. of Variation:	N/A	0.000775463631464	0.360909965343
Skewness:	1.07180158666	-0.359656193455	0.546149849555
Kurtosis:	2.17965093405	2.05836958684	2.88612767075
Sum:	-65878.9670087	35879.129736	2006.84
Sum Absolute:	65878.9670087	35879.129736	2006.84
Sum Squares:	5203883.57628	1543540.43621	5457.2802
Mean Square:	6239.6685567	1850.76790913	6.54350143885

Inter-Variable Covariance

	X	Y	Z
X:	0.00087586772	-0.00084730446	-0.0062763652
Y:	-0.00084730446	0.0011129472	0.0050431503
Z:	-0.0062763652	0.0050431503	0.75420802

Inter-Variable Correlation

	X	Y	Z
X:	1.000	-0.858	-0.244
Y:	-0.858	1.000	0.174
Z:	-0.244	0.174	1.000

Inter-Variable Rank Correlation

	X	Y	Z
X:	1.000	-0.286	-0.292
Y:	-0.286	1.000	-0.005
Z:	-0.292	-0.005	1.000

Principal Component Analysis

	PC1	PC2	PC3
X:	-0.64928380406	-0.64928380406	0.760500510524
Y:	0.760473550605	0.760473550605	0.64933429337
Z:	-0.0105128785285	-0.0105128785285	0.64933429337
Lambda:	0.754294163802	0.00176664916299	0.00013601783841

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	-10.5585813959	-3.50706914181	-680.756602764
Standard Error:	1.91808292029	1.70156816976	96.3230318784

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.858	0.921
B:	0.858	1.000	0.590
C:	0.921	0.590	1.000

ANOVA Table

Source	df F	Sum of Squares	Mean Square
Regression:	2 28.607494671	40.4695027908	20.2347513954
Residual:	831	587.785774427	0.707323434931
Total:	833	628.255277218	

Coefficient of Multiple Determination (R^2): 0.0644156989338

Nearest Neighbor Statistics

	Separation	|Delta Z|
1%-tile:	1.10430611707e-05	0
5%-tile:	1.84239436639e-05	0
10%-tile:	2.08138439504e-05	0.01
25%-tile:	2.50920405718e-05	0.03
50%-tile:	3.20588724097e-05	0.08
75%-tile:	3.7427942766e-05	0.14
90%-tile:	4.07092581621e-05	0.23
95%-tile:	4.13411780164e-05	0.31
99%-tile:	4.32298531143e-05	0.53
Minimum:	2.55219513438e-06	0
Maximum:	4.41130604182e-05	0.74
Mean:	3.10391107257e-05	0.103752997602
Median:	3.20627678912e-05	0.08
Geometric Mean:	2.9817874107e-05	N/A
Harmonic Mean:	2.78620276154e-05	N/A
Root Mean Square:	3.19944524531e-05	0.148228144203
Trim Mean (10%):	3.13261843653e-05	0.0912782956059
Interquartile Mean:	3.16588807044e-05	0.0776978417266
Midrange:	2.33326277763e-05	0.37
Winsorized Mean:	3.13269814204e-05	0.0926498800959
TriMean:	3.16594320393e-05	0.0825
Variance:	6.02908843586e-11	0.0112203518818
Standard Deviation:	7.76472049456e-06	0.105926162405
Interquartile Range:	1.23359021942e-05	0.11
Range:	4.15608652838e-05	0.74
Mean Difference:	8.78698315864e-06	0.104742875567
Median Abs. Deviation:	6.05182688682e-06	0.05
Average Abs. Deviation:	6.46883579298e-06	0.0718585131894
Quartile Dispersion:	0.197311348078	N/A
Relative Mean Diff.:	0.283093908079	1.00954071678
Standard Error:	2.68870281451e-07	0.00366792302682
Coef. of Variation:	0.250159244676	1.0209455616
Skewness:	-0.497606963508	2.08202518731
Kurtosis:	2.74108725547	8.95054720757
Sum:	0.0258866183453	86.53
Sum Absolute:	0.0258866183453	86.53
Sum Squares:	8.53719919805e-07	18.3243
Mean Square:	1.02364498778e-09	0.0219715827338

Complete Spatial Randomness

Lambda:	111777.668502
Clark and Evans:	0.0207547157211
Skellam:	0.599584407089

Gridding Rules

Gridding Method:	Kriging
Kriging Type:	Point
Polynomial Drift Order:	0
Kriging std. deviation grid:	no

Semi-Variogram Model

Component Type:	Linear
Anisotropy Angle:	0
Anisotropy Ratio:	1
Variogram Slope:	1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name: C:\Users\Heidi\Documents\LRB Niagara supporting files\Surfer Files\thickness\Grid Groups\NWestRvr\NWestRvr_NoSearch_hull5.grd

Grid Size:	100 rows x 71 columns
Total Nodes:	7100
Filled Nodes:	7100
Blanked Nodes:	0
Blank Value:	1.70141E+38

Grid Geometry

X Minimum:	-79.01216454
X Maximum:	-78.93953569
X Spacing:	0.001037555
Y Minimum:	42.96773387
Y Maximum:	43.07046496
Y Spacing:	0.0010376877777778

Univariate Grid Statistics

	Z
Count:	7100
1%-tile:	1.21568277736
5%-tile:	1.52859822079
10%-tile:	1.59410842333
25%-tile:	1.68537565504
50%-tile:	1.74611562396
75%-tile:	2.00007028938
90%-tile:	2.35337599895
95%-tile:	2.49086434896
99%-tile:	2.95833391288
Minimum:	0.501322801134
Maximum:	4.50779620361

Mean:	1.86661071884
Median:	1.74612430207
Geometric Mean:	1.83854405472
Harmonic Mean:	1.81107315221
Root Mean Square:	1.89708143159
Trim Mean (10%):	1.84457711812
Interquartile Mean:	1.77648842394
Midrange:	2.50455950237
Winsorized Mean:	1.85553234473
TriMean:	1.79441929808
Variance:	0.114698537116
Standard Deviation:	0.338671724708
Interquartile Range:	0.314694634332
Range:	4.00647340247
Mean Difference:	0.338845506388
Median Abs. Deviation:	0.108751202029
Average Abs. Deviation:	0.224739768465
Quartile Dispersion:	0.0853884819038
Relative Mean Diff.:	0.181529819243
Standard Error:	0.00401929391032
Coef. of Variation:	0.181436719123
Skewness:	1.47307002865
Kurtosis:	7.89271877053
Sum:	13252.9361038
Sum Absolute:	13252.9361038
Sum Squares:	25552.3175025
Mean Square:	3.59891795809

Gridding Report – Pirates

Fri Nov 10 14:29:06 2017
Elapsed time for gridding: 1.66 seconds

Data Source

Source Data File Name: C:\Users\Heidi\Documents\LRB Niagara supporting files\Surfer Files\thickness\Grid Groups\Pirates\Pirates.dat

X Column:	A
Y Column:	B
Z Column:	C

Filtered Data Counts

Active Data:	494
Original Data:	494
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep:	First
X Duplicate Tolerance:	5.7E-10
Y Duplicate Tolerance:	9.7E-10

No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Z Data Transform

Transformation method: Linear (use Z values directly)

No untransformable data were found.

Data Counts

Active Data: 494

Univariate Statistics

	X	Y	Z
Count:	494	494	494
1%-tile:	-78.94430248	42.96639001	0.82
5%-tile:	-78.94411571	42.96775995	1.01
10%-tile:	-78.94386586	42.96833593	1.25
25%-tile:	-78.94336911	42.97008418	1.83
50%-tile:	-78.94294009	42.97132684	2.39
75%-tile:	-78.94176794	42.97246336	3.11
90%-tile:	-78.94044785	42.97343039	3.7
95%-tile:	-78.9400622	42.97395168	3.9
99%-tile:	-78.93968122	42.9744239	4.11

Minimum:	-78.94432941	42.96638082	0.44
Maximum:	-78.93953569	42.9745222	4.41
Mean:	-78.9425229833	42.9711043418	2.4582388664
Median:	-78.942937395	42.971328245	2.395
Geometric Mean:	N/A	42.9711043013	2.28317603238
Harmonic Mean:	N/A	42.9711042608	2.07962657134
Root Mean Square:	78.9425229928	42.9711043823	2.60774574187
Trim Mean (10%):	-78.9425810889	42.9711509285	2.45415730337
Interquartile Mean:	-78.9427932465	42.9712281152	2.43299595142
Midrange:	-78.94193255	42.97045151	2.425
Winsorized Mean:	-78.9425420488	42.9711341238	2.46129554656
TriMean:	-78.9427543075	42.971300305	2.43
Variance:	1.48874607103e-06	3.48872433592e-06	0.75893583735
Standard Deviation:	0.00122014182415	0.00186781271436	0.871169235769
Interquartile Range:	0.00160117	0.00237918	1.28
Range:	0.00479372	0.00814138	3.97
Mean Difference:	0.0013481117009	0.00210940854267	1.00051465456
Median Abs. Deviation:	0.000669724999995	0.00121006	0.67
Average Abs. Deviation:	0.000946440587044	0.00147918455466	0.724149797571
Quartile Dispersion:	N/A	2.76833776529e-05	0.259109311741
Relative Mean Diff.:	N/A	4.90890000382e-05	0.407004652084
Standard Error:	5.48967759912e-05	8.4036866981e-05	0.0391957569522
Coef. of Variation:	N/A	4.34667142716e-05	0.354387544546
Skewness:	0.782015873103	-0.432618561723	0.0452325533623
Kurtosis:	2.6358111555	2.74506284895	2.18945314209
Sum:	-38997.6063538	21227.7255448	1214.37
Sum Absolute:	38997.6063538	21227.7255448	1214.37
Sum Squares:	3078569.43661	912178.811047	3359.3669
Mean Square:	6231.92193646	1846.51581184	6.80033785425

Inter-Variable Covariance

	X	Y	Z
X:	1.4887461e-06	-2.1981203e-06	7.1750415e-05
Y:	-2.1981203e-06	3.4887243e-06	-0.00027779277
Z:	7.1750415e-05	-0.00027779277	0.75893584

Inter-Variable Correlation

	X	Y	Z
X:	1.000	-0.965	0.068
Y:	-0.965	1.000	-0.171
Z:	0.068	-0.171	1.000

Inter-Variable Rank Correlation

	X	Y	Z
X:	1.000	-0.975	0.146
Y:	-0.975	1.000	-0.249
Z:	0.146	-0.249	1.000

Principal Component Analysis

	PC1	PC2	PC3
X:	-0.54696826213	-0.54696826213	0.837153337976
Y:	0.837153266709	0.837153266709	0.546968256904
Z:	0.000358135734132	0.000358135734132	0.546968256904
Lambda:	0.758935945815	4.80606315715e-06	6.29429926598e-08

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	-995.063348795	-706.579662889	-48187.8446235
Standard Error:	111.543594282	72.8654449948	5844.30946262

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.965	0.990
B:	0.965	1.000	0.917
C:	0.990	0.917	1.000

ANOVA Table

Source	df F	Sum of Squares	Mean Square
Regression:	2 48.355288937	61.569049798	30.784524899
Residual:	491	312.586318016	0.636632012252
Total:	493	374.155367814	
Coefficient of Multiple Determination (R^2):			0.164554768137

Nearest Neighbor Statistics

	Separation	|Delta Z|
1%-tile:	2.73162955598e-06	0
5%-tile:	6.57450378153e-06	0
10%-tile:	9.26259683056e-06	0.01
25%-tile:	2.41657981464e-05	0.04
50%-tile:	2.84004242876e-05	0.07
75%-tile:	3.38643234139e-05	0.14
90%-tile:	3.50279574084e-05	0.23
95%-tile:	3.62848205168e-05	0.31
99%-tile:	3.81280697237e-05	0.68
Minimum:	2.54943130882e-06	0
Maximum:	3.95027809103e-05	1.25
Mean:	2.62016302569e-05	0.111740890688
Median:	2.84334215454e-05	0.075
Geometric Mean:	2.33848658153e-05	N/A
Harmonic Mean:	1.84902260375e-05	N/A
Root Mean Square:	2.78148184482e-05	0.172841225027
Trim Mean (10%):	2.67441125299e-05	0.0935280898876
Interquartile Mean:	2.84101382076e-05	0.0789473684211
Midrange:	2.10261061096e-05	0.625
Winsorized Mean:	2.63701994604e-05	0.0941700404858
TriMean:	2.87077425338e-05	0.08
Variance:	8.73154491076e-11	0.0174233323205
Standard Deviation:	9.34427359978e-06	0.131997470887
Interquartile Range:	9.6985252675e-06	0.1
Range:	3.69533496015e-05	1.25
Mean Difference:	1.00850073156e-05	0.115577272093
Median Abs. Deviation:	5.01050141425e-06	0.045

Average Abs. Deviation:	7.29849140336e-06	0.0766396761134
Quartile Dispersion:	0.167129156492	N/A
Relative Mean Diff.:	0.384899993501	1.03433283358
Standard Error:	4.20418745146e-07	0.00593884698261
Coef. of Variation:	0.356629473363	1.1812817141
Skewness:	-0.987578526614	3.53842035694
Kurtosis:	2.98854447246	22.0975414498
Sum:	0.0129436053469	55.2
Sum Absolute:	0.0129436053469	55.2
Sum Squares:	3.82190077902e-07	14.7578
Mean Square:	7.73664125307e-10	0.0298740890688

Complete Spatial Randomness

Lambda:	12657742.5902
Clark and Evans:	0.186438860228
Skellam:	30.3959370198

Gridding Rules

Gridding Method: Kriging
Kriging Type: Point

Polynomial Drift Order: 0
Kriging std. deviation grid: no

Semi-Variogram Model
Component Type: Linear
Anisotropy Angle: 0
Anisotropy Ratio: 1
Variogram Slope: 1

Search Parameters
Search Ellipse Radius #1: 0.00472
Search Ellipse Radius #2: 0.0024
Search Ellipse Angle: -55

Number of Search Sectors: 4
Maximum Data Per Sector: 16
Maximum Empty Sectors: 3

Minimum Data: 8
Maximum Data: 64

Output Grid

Grid File Name: C:\Users\Heidi\Documents\LRB Niagara supporting files\Surfer Files\thickness\Grid Groups\Pirates\Pirates_krig_hull3.grd
Grid Size: 100 rows x 59 columns
Total Nodes: 5900
Filled Nodes: 5126
Blanked Nodes: 774
Blank Value: 1.70141E+38

Grid Geometry

X Minimum:	-78.94432941
X Maximum:	-78.93953569
X Spacing:	8.26503448275E-05
Y Minimum:	42.96638082
Y Maximum:	42.9745222
Y Spacing:	8.2236161616212E-05

Univariate Grid Statistics

	Z
Count:	5126
1%-tile:	1.07050076033
5%-tile:	1.27857811987
10%-tile:	1.4708408085
25%-tile:	2.06102544274
50%-tile:	2.56828835929
75%-tile:	3.07902378933
90%-tile:	3.61002425526
95%-tile:	3.89410946701
99%-tile:	4.13260653582
Minimum:	0.456716309741
Maximum:	4.42393828743
Mean:	2.56253737621
Median:	2.56832110853
Geometric Mean:	2.43501566537
Harmonic Mean:	2.29349429033
Root Mean Square:	2.67590158477
Trim Mean (10%):	2.55712048625
Interquartile Mean:	2.56701751027
Midrange:	2.44032729858
Winsorized Mean:	2.55364446623
TriMean:	2.56915648766
Variance:	0.593967360353
Standard Deviation:	0.770692779487
Interquartile Range:	1.01799834659
Range:	3.96722197768
Mean Difference:	0.879077786313
Median Abs. Deviation:	0.509539206838
Average Abs. Deviation:	0.619808672691
Quartile Dispersion:	0.198052256044
Relative Mean Diff.:	0.34304974221
Standard Error:	0.0107644535791
Coef. of Variation:	0.300753771102
Skewness:	0.023884277919
Kurtosis:	2.41331737856
Sum:	13135.5665905

Sum Absolute:	13135.5665905
Sum Squares:	36704.4630676
Mean Square:	7.16044929138

Gridding Report – SGIBridge

Fri Nov 10 14:06:14 2017
Elapsed time for gridding: 0.26 seconds

Data Source

Source Data File Name: C:\Users\Heidi\Documents\LRB Niagara supporting files\Surfer Files\thickness\Grid Groups\SGIBridge\SGIBridge.dat

X Column:	A
Y Column:	B
Z Column:	C

Filtered Data Counts

Active Data:	375
Original Data:	375
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep:	First
X Duplicate Tolerance:	1.1E-09
Y Duplicate Tolerance:	1.5E-09

No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Z Data Transform

Transformation method: Linear (use Z values directly)

No untransformable data were found.

Data Counts

Active Data: 375

Univariate Statistics

	X	Y	Z
Count:	375	375	375
1%-tile:	-78.94130247	42.98634181	0.74
5%-tile:	-78.94114038	42.98683868	1.15
10%-tile:	-78.94045814	42.98841598	1.27
25%-tile:	-78.93973257	42.98982479	1.6
50%-tile:	-78.93881789	42.99196085	2.03
75%-tile:	-78.93398776	42.99758225	2.56
90%-tile:	-78.93241691	42.99869564	2.83
95%-tile:	-78.93199315	42.99904776	2.96
99%-tile:	-78.93167346	42.99930748	3.12
Minimum:	-78.94132524	42.98625305	0.62
Maximum:	-78.93158803	42.9993767	3.2
Mean:	-78.937511959	42.992845317	2.06405333333
Median:	-78.93881789	42.99196085	2.03
Geometric Mean:	N/A	42.9928451335	1.96936928067
Harmonic Mean:	N/A	42.99284495	1.86110019695
Root Mean Square:	78.93751202	42.9928455004	2.14625316929
Trim Mean (10%):	-78.9376353705	42.9928234121	2.07195266272
Interquartile Mean:	-78.9384309177	42.9923171455	2.07606382979
Midrange:	-78.936456635	42.992814875	1.91
Winsorized Mean:	-78.9374912682	42.992960252	2.07104
TriMean:	-78.9378390275	42.992832185	2.055
Variance:	9.65308740359e-06	1.58192701682e-05	0.347011868806
Standard Deviation:	0.00310694180885	0.0039773446127	0.589077133155
Interquartile Range:	0.00574481000001	0.00775746	0.96
Range:	0.00973721	0.01312365	2.58
Mean Difference:	0.00333477546781	0.00448612118702	0.676541604278

Median Abs. Deviation:	0.00112003000001	0.00259391	0.49
Average Abs. Deviation:	0.00236532978667	0.00326323346667	0.49944
Quartile Dispersion:	N/A	9.02162335979e-05	0.230769230769
Relative Mean Diff.:	N/A	0.000104345761578	0.327773315424
Standard Error:	0.000160441785111	0.000205389192628	0.0304198123512
Coef. of Variation:	N/A	9.25117791898e-05	0.285398213138
Skewness:	0.740445205743	0.3034250121	-0.158493587547
Kurtosis:	1.94886857754	1.81693209825	2.1725154342
Sum:	-29601.5669846	16122.3169939	774.02
Sum Absolute:	29601.5669846	16122.3169939	774.02
Sum Squares:	2336674.05146	693144.286584	1727.401
Mean Square:	6231.1308039	1848.38476423	4.60640266667

Inter-Variable Covariance

	X	Y	Z
X:	9.6530874e-06	1.2113042e-05	-0.00030917256
Y:	1.2113042e-05	1.581927e-05	-0.00025017014
Z:	-0.00030917256	-0.00025017014	0.34701187

Inter-Variable Correlation

	X	Y	Z
X:	1.000	0.980	-0.169
Y:	0.980	1.000	-0.107
Z:	-0.169	-0.107	1.000

Inter-Variable Rank Correlation

	X	Y	Z
X:	1.000	1.000	-0.076
Y:	1.000	1.000	-0.076
Z:	-0.076	-0.076	1.000

Principal Component Analysis

	PC1	PC2	PC3
X:	0.610483082786	0.610483082786	0.792028794769
Y:	0.792028511124	0.792028511124	-0.610483675245
Z:	0.0011149882532	0.0011149882532	-0.610483675245
Lambda:	0.34701232465	2.48036319328e-05	2.12881069017e-07

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
—			
Parameter Value:	-311.182803959	222.462876417	-34126.2442902
Standard Error:	46.6865336254	36.4696442867	5231.45856626

Inter-Parameter Correlations

	A	B	C
A:	1.000	-0.980	0.998
B:	-0.980	1.000	-0.990
C:	0.998	-0.990	1.000

ANOVA Table

Source	df F	Sum of Squares	Mean Square
Regression:	2 24.6147511314	15.1678000634	7.58390003171
Residual:	372	114.61463887	0.30810386793
Total:	374	129.782438933	

Coefficient of Multiple Determination (R^2): 0.116870974132

Nearest Neighbor Statistics

	Separation	|Delta Z|
1%-tile:	1.44773478183e-05	0
5%-tile:	2.30708474076e-05	0
10%-tile:	2.36058149653e-05	0.01
25%-tile:	2.48114671098e-05	0.02
50%-tile:	2.79342084145e-05	0.07
75%-tile:	2.90621747249e-05	0.16

90%-tile:	3.15976850388e-05	0.25
95%-tile:	3.39831208126e-05	0.36
99%-tile:	3.51130089838e-05	0.47
Minimum:	6.09476003933e-06	0
Maximum:	3.52284898898e-05	0.68
Mean:	2.750594986e-05	0.107253333333
Median:	2.79342084145e-05	0.07
Geometric Mean:	2.71811392253e-05	N/A
Harmonic Mean:	2.66646842179e-05	N/A
Root Mean Square:	2.77553440379e-05	0.156445517673
Trim Mean (10%):	2.75846457157e-05	0.0942899408284
Interquartile Mean:	2.77999754883e-05	0.0730319148936
Midrange:	2.06616249646e-05	0.34
Winsorized Mean:	2.75477473135e-05	0.0954666666667
TriMean:	2.74355146659e-05	0.08
Variance:	1.38186948157e-11	0.0130066067736
Standard Deviation:	3.7173505102e-06	0.114046511449
Interquartile Range:	4.2507076151e-06	0.14
Range:	2.91337298504e-05	0.68
Mean Difference:	3.83923786214e-06	0.115597860963
Median Abs. Deviation:	1.73797554205e-06	0.05
Average Abs. Deviation:	2.57093232014e-06	0.0802933333333
Quartile Dispersion:	0.0789014343629	N/A
Relative Mean Diff.:	0.139578450542	1.07780203533
Standard Error:	1.91963154907e-07	0.00588933652712
Coef. of Variation:	0.13514714195	1.06333768755
Skewness:	-1.21870320658	1.65604424791
Kurtosis:	8.973593096	5.87587233168
Sum:	0.0103147311975	40.22
Sum Absolute:	0.0103147311975	40.22
Sum Squares:	2.88884670998e-07	9.1782
Mean Square:	7.70359122661e-10	0.0244752

Complete Spatial Randomness

Lambda:	2934553.90705
Clark and Evans:	0.0942383532593
Skellam:	5.32655551562

Gridding Rules

Gridding Method:	Kriging
Kriging Type:	Point
Polynomial Drift Order:	0
Kriging std. deviation grid:	no

Semi-Variogram Model

Component Type:	Linear
Anisotropy Angle:	0

Anisotropy Ratio:	1
Variogram Slope:	1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name: C:\Users\Heidi\Documents\LRB Niagara supporting files\Surfer Files\thickness\Grid Groups\SGIBridge\SGIBridge_NoSearch_Hull3.grd

Grid Size:	100 rows x 74 columns
Total Nodes:	7400
Filled Nodes:	7400
Blanked Nodes:	0
Blank Value:	1.70141E+38

Grid Geometry

X Minimum:	-78.94132524
X Maximum:	-78.93158803
X Spacing:	0.00013338643835613
Y Minimum:	42.98625305
Y Maximum:	42.9993767
Y Spacing:	0.00013256212121209

Univariate Grid Statistics

	Z
Count:	7400
1%-tile:	0.956318694657
5%-tile:	1.24154882978
10%-tile:	1.37984009495
25%-tile:	1.54203524074
50%-tile:	1.70847839744
75%-tile:	1.83595343803
90%-tile:	2.06684295469
95%-tile:	2.2633147474
99%-tile:	2.66434872377
Minimum:	0.652082967743
Maximum:	3.14429936014
Mean:	1.71028391344
Median:	1.70854645864
Geometric Mean:	1.68335264366
Harmonic Mean:	1.65525847183
Root Mean Square:	1.73695641121
Trim Mean (10%):	1.70163058315
Interquartile Mean:	1.69506104366
Midrange:	1.89819116394
Winsorized Mean:	1.70245001002
TriMean:	1.69873636841

Variance:	0.091958936773
Standard Deviation:	0.303247319482
Interquartile Range:	0.29391819729
Range:	2.49221639239
Mean Difference:	0.322714897689
Median Abs. Deviation:	0.149083644363
Average Abs. Deviation:	0.215167249884
Quartile Dispersion:	0.0870098230753
Relative Mean Diff.:	0.188690833817
Standard Error:	0.00352517848452
Coef. of Variation:	0.177308175034
Skewness:	0.552454398573
Kurtosis:	5.00444860971
Sum:	12656.1009594
Sum Absolute:	12656.1009594
Sum Squares:	22325.9300509
Mean Square:	3.01701757445

Gridding Report – Sheenwater

Fri Nov 10 14:53:57 2017
Elapsed time for gridding: 1.70 seconds

Data Source

Source Data File Name: C:\Users\Heidi\Documents\LRB Niagara supporting files\Surfer Files\thickness\Grid Groups\Sheenwater\Sheenwater.dat

X Column:	A
Y Column:	B
Z Column:	C

Filtered Data Counts

Active Data:	1100
Original Data:	1100
Excluded Data:	0
Deleted Duplicates:	0
Retained Duplicates:	0
Artificial Data:	0
Superseded Data:	0

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep:	First
X Duplicate Tolerance:	8.7E-09
Y Duplicate Tolerance:	5.7E-09

No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Z Data Transform

Transformation method: Linear (use Z values directly)

No untransformable data were found.

Data Counts

Active Data: 1100

Univariate Statistics

	X	Y	Z
Count:	1100	1100	1100
1%-tile:	-79.02125329	42.95680178	0.66
5%-tile:	-79.02081484	42.95695251	1
10%-tile:	-79.01919297	42.95700053	1.18
25%-tile:	-79.01706653	42.96852951	1.54
50%-tile:	-78.9928241	42.97757593	1.92
75%-tile:	-78.97370073	42.99179558	2.18
90%-tile:	-78.95202128	42.99607575	2.67
95%-tile:	-78.95018593	43.00274947	2.92
99%-tile:	-78.94868495	43.00438564	3.42
Minimum:	-79.02133819	42.95675524	0.47
Maximum:	-78.94826303	43.00480955	4.32
Mean:	-78.990350093	42.9778888289	
	1.90659090909		
Median:	-78.992806175	42.97758317	1.92
Geometric Mean:	N/A	42.9778862592	
	1.81634669608		
Harmonic Mean:	N/A	42.9778836894	
	1.71594867737		
Root Mean Square:	78.990354284	42.9778913987	
	1.99009243732		
Trim Mean (10%):	-78.9909571947	42.9775965335	
	1.89180625631		
Interquartile Mean:	-78.9943473422	42.9784252528	

	1.89010889292		
Midrange:	-78.98480061	42.980782395	2.395
Winsorized Mean:	-78.9903865589	42.977298444	
	1.89401818182		
TriMean:	-78.994103865	42.9788692375	1.89
Variance:	0.000662701500186	0.000221085669113	
	0.32567508272		
Standard Deviation:	0.0257429893405	0.0148689498322	
	0.570679492114		
Interquartile Range:	0.0433658	0.02326607	0.64
Range:	0.07307516	0.04805431	3.85
Mean Difference:	0.0290475368208	0.0169878603807	
	0.633310430971		
Median Abs. Deviation:	0.02233681	0.01108735	0.33
Average Abs. Deviation:	0.0224278605	0.0125097998455	
	0.435572727273		
Quartile Dispersion:	N/A	0.00027066056318	
	0.172043010753		
Relative Mean Diff.:	N/A	0.000395269773448	
	0.332169018509		
Standard Error:	0.000776180332951	0.000448315705638	
	0.017206634099		
Coef. of Variation:	N/A	0.00034596743203	
	0.299319318787		
Skewness:	0.333097956668	-0.0151003038622	
	0.393244942405		
Kurtosis:	1.63209800331	1.86994461167	
	3.5902162715		
Sum:	-86889.3851023	47275.6777118	2097.25
Sum Absolute:	86889.3851023	47275.6777118	2097.25
Sum Squares:	6863423.67691	2031809.06398	4356.5147
Mean Square:	6239.47606992	1847.09914908	
	3.96046790909		

Inter-Variable Covariance

	X	Y	Z
X:	0.0006627015	-0.00037513525	0.0039926081
Y:	-0.00037513525	0.00022108567	-0.0024076944
Z:	0.0039926081	-0.0024076944	0.32567508

Inter-Variable Correlation

	X	Y	Z
X:	1.000	-0.980	0.272
Y:	-0.980	1.000	-0.284
Z:	0.272	-0.284	1.000

Inter-Variable Rank Correlation

	X	Y	Z
X:	1.000	-1.000	0.240
Y:	-1.000	1.000	-0.241
Z:	0.240	-0.241	1.000

Principal Component Analysis

	PC1	PC2	PC3
X:	0.868987903854	0.868987903854	0.494680702675
Y:	-0.494625334854	-0.494625334854	0.869074722017
Z:	-0.0143457685742	-0.0143457685742	0.869074722017
Lambda:	0.32574199634	0.00081031502473	6.5585246529e-06

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	-3.54266284116	-16.9014669934	448.45978231
Standard Error:	3.22748487047	5.58782627924	51.5889737743

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.980	0.380
B:	0.980	1.000	0.188
C:	0.380	0.188	1.000

ANOVA Table

Source	df F	Sum of Squares	Mean Square
Regression:	2 48.6824428538	29.1774649668	14.5887324834
Residual:	1097	328.739450942	0.299671331761
Total:	1099	357.916915909	

Coefficient of Multiple Determination (R^2): 0.0815202178771

Nearest Neighbor Statistics

	Separation	|Delta Z|
1%-tile:	7.73493373026e-06	0
5%-tile:	1.43980033432e-05	0
10%-tile:	2.23847738441e-05	0.01
25%-tile:	3.20445502465e-05	0.03
50%-tile:	3.74305343279e-05	0.07
75%-tile:	3.93730326514e-05	0.16
90%-tile:	4.03853847356e-05	0.28
95%-tile:	4.45227234103e-05	0.38
99%-tile:	4.73895347103e-05	0.56
Minimum:	2.94210809006e-06	0
Maximum:	4.79877744827e-05	0.74
Mean:	3.45143051836e-05	0.112918181818
Median:	3.74365364842e-05	0.07
Geometric Mean:	3.29560550788e-05	N/A
Harmonic Mean:	3.0147658325e-05	N/A
Root Mean Square:	3.54810033693e-05	0.164459721513
Trim Mean (10%):	3.52113869542e-05	0.0991725529768
Interquartile Mean:	3.67634257049e-05	0.0792014519056
Midrange:	2.54649412864e-05	0.37
Winsorized Mean:	3.4893859047e-05	0.102263636364
TriMean:	3.65696628885e-05	0.0825
Variance:	6.7725906789e-11	0.0143094928447
Standard Deviation:	8.2295751281e-06	0.119622292424
Interquartile Range:	7.3284824049e-06	0.13
Range:	4.50456663926e-05	0.74
Mean Difference:	8.28619276639e-06	0.119819654231
Median Abs. Deviation:	2.58164459547e-06	0.05
Average Abs. Deviation:	5.55020608333e-06	0.0825727272727
Quartile Dispersion:	0.102614539831	N/A
Relative Mean Diff.:	0.240079953002	1.06111923077
Standard Error:	2.48131026218e-07	0.00360674782302
Coef. of Variation:	0.238439542222	1.05937140058
Skewness:	-1.53619087476	1.82945897506
Kurtosis:	5.31704206287	6.95669654203
Sum:	0.037965735702	124.21
Sum Absolute:	0.037965735702	124.21
Sum Squares:	1.3847917601e-06	29.7517
Mean Square:	1.25890160009e-09	0.027047

Complete Spatial Randomness

Lambda:	313249.628436
Clark and Evans:	0.0386344214295
Skellam:	2.72555470717

Gridding Rules

Gridding Method:	Kriging
Kriging Type:	Point
Polynomial Drift Order:	0
Kriging std. deviation grid:	no

Semi-Variogram Model

Component Type:	Linear
Anisotropy Angle:	0
Anisotropy Ratio:	1
Variogram Slope:	1

Search Parameters

Search Ellipse Radius #1:	0.0437
Search Ellipse Radius #2:	0.0437
Search Ellipse Angle:	0
Number of Search Sectors:	4
Maximum Data Per Sector:	16
Maximum Empty Sectors:	3
Minimum Data:	8
Maximum Data:	64

Output Grid

Grid File Name: C:\Users\Heidi\Documents\LRB Niagara supporting files\Surfer Files\thickness\Grid Groups\Sheenwater\Sheenwater_NoSearch_hull3.grd

Grid Size:	66 rows x 100 columns
Total Nodes:	6600
Filled Nodes:	6598
Blanked Nodes:	2
Blank Value:	1.70141E+38

Grid Geometry

X Minimum:	-79.02133819
X Maximum:	-78.94826303
X Spacing:	0.00073813292929281
Y Minimum:	42.95675524
Y Maximum:	43.00480955
Y Spacing:	0.00073929707692304

Univariate Grid Statistics

	Z
Count:	6598
1%-tile:	0.811021112232
5%-tile:	1.07462095489
10%-tile:	1.2410552939

25%-tile:	1.4621645748
50%-tile:	1.68863200051
75%-tile:	1.9260319141
90%-tile:	2.1809399339
95%-tile:	2.30373440088
99%-tile:	2.71587377263
Minimum:	0.500000000039
Maximum:	3.10498519749
Mean:	1.6967530369
Median:	1.68865774295
Geometric Mean:	1.65354195661
Harmonic Mean:	1.60699877266
Root Mean Square:	1.7374641105
Trim Mean (10%):	1.69397800585
Interquartile Mean:	1.68907689734
Midrange:	1.80249259876
Winsorized Mean:	1.6966784958
TriMean:	1.69136512248
Variance:	0.139831860114
Standard Deviation:	0.373940984801
Interquartile Range:	0.463867339295
Range:	2.60498519745
Mean Difference:	0.417145743356
Median Abs. Deviation:	0.232746670869
Average Abs. Deviation:	0.290146666884
Quartile Dispersion:	0.136906859096
Relative Mean Diff.:	0.245849416082
Standard Error:	0.00460359290267
Coef. of Variation:	0.22038621807
Skewness:	0.175548003209
Kurtosis:	3.40645254618
Sum:	11195.1765374
Sum Absolute:	11195.1765374
Sum Squares:	19917.9205697
Mean Square:	3.01878153527

Gridding Report – Strawberry

Fri Nov 10 14:42:24 2017

Elapsed time for gridding: 1.24 seconds

Data Source

Source Data File Name: C:\Users\Heidi\Documents\LRB Niagara supporting files\Surfer Files\thickness\Grid Groups\Strawberry\Strawberry.dat
X Column: A
Y Column: B
Z Column: C

Filtered Data Counts

Active Data: 592

Original Data: 592
Excluded Data: 0
Deleted Duplicates: 0
Retained Duplicates: 0
Artificial Data: 0
Superseded Data: 0

Exclusion Filtering

Exclusion Filter String: Not In Use

Duplicate Filtering

Duplicate Points to Keep: First
X Duplicate Tolerance: 2.9E-09
Y Duplicate Tolerance: 1.2E-09

No duplicate data were found.

Breakline Filtering

Breakline Filtering: Not In Use

Z Data Transform

Transformation method: Linear (use Z values directly)

No untransformable data were found.

Data Counts

Active Data: 592

Univariate Statistics

	X	Y	Z
Count:	592	592	592
1%-tile:	-78.93417991	42.94990152	0.63
5%-tile:	-78.9336839	42.9503674	0.9
10%-tile:	-78.93308245	42.95263738	1.11
25%-tile:	-78.93183655	42.9565403	1.38
50%-tile:	-78.92808066	42.95765944	1.84
75%-tile:	-78.91336447	42.95855362	2.91
90%-tile:	-78.91041948	42.95984458	3.62
95%-tile:	-78.90978465	42.96018974	3.89
99%-tile:	-78.90972902	42.96061199	4.35
Minimum:	-78.93427449	42.94978921	0.6
Maximum:	-78.90972787	42.96062946	4.54
Mean:	-78.9230237421	42.9570244944	2.13890202703
Median:	-78.928070445	42.95766137	1.84
Geometric Mean:	N/A	42.9570244153	1.92639176253
Harmonic Mean:	N/A	42.9570243362	1.72778535667
Root Mean Square:	78.9230242919	42.9570245735	2.34714025969
Trim Mean (10%):	-78.9231744922	42.9572112062	2.10003752345
Interquartile Mean:	-78.9240989759	42.9576179993	1.95377104377
Midrange:	-78.92200118	42.955209335	2.57
Winsorized Mean:	-78.9230079762	42.9571431049	2.12731418919
TriMean:	-78.925340585	42.9576032	1.9925
Variance:	8.69417118128e-05	6.80749607671e-06	0.935746169742
Standard Deviation:	0.00932425395475	0.00260911787329	0.967339738531
Interquartile Range:	0.01847208	0.00201332	1.53
Range:	0.02454662	0.01084025	3.94
Mean Difference:	0.010276688817	0.00271312639691	1.08848464581
Median Abs. Deviation:	0.00560328	0.000954194999998	0.615
Average Abs. Deviation:	0.00850254663851	0.00178253086149	0.796638513514
Quartile Dispersion:	N/A	2.34338334295e-05	0.356643356643
Relative Mean Diff.:	N/A	6.31590858269e-05	0.508898786414
Standard Error:	0.000383224476885	0.000107234084032	0.0397574183487
Coef. of Variation:	N/A	6.07378631085e-05	

	0.452259956888		
Skewness:	0.234861207531	-1.24334770957	
	0.584722368868		
Kurtosis:	1.25726053599	3.91346007611	
	2.24482648589		
Sum:	-46722.4300553	25430.5585007	1266.23
Sum Absolute:	46722.4300553	25430.5585007	1266.23
Sum Squares:	3687475.50793	1092421.12844	3261.3679
Mean Square:	6228.84376339	1845.30596021	
	5.50906739865		

Inter-Variable Covariance

	X	Y	Z
X:	8.6941712e-05	-1.5983587e-05	0.00208763
Y:	-1.5983587e-05	6.8074961e-06	-0.00069337755
Z:	0.00208763	-0.00069337755	0.93574617

Inter-Variable Correlation

	X	Y	Z
X:	1.000	-0.657	0.231
Y:	-0.657	1.000	-0.275
Z:	0.231	-0.275	1.000

Inter-Variable Rank Correlation

	X	Y	Z
X:	1.000	-0.453	0.103
Y:	-0.453	1.000	-0.574
Z:	0.103	-0.574	1.000

Principal Component Analysis

	PC1	PC2	PC3
X:	0.983561418922	0.983561418922	0.1805601203
Y:	-0.180558893963	-0.180558893963	0.983563895581
Z:	-0.00232830824285	-0.00232830824285	0.983563895581
Lambda:	0.935751341446	8.4934041262e-05	3.64346237922e-06

Planar Regression: Z = AX+BY+C

Fitted Parameters

	A	B	C
Parameter Value:	9.30159213176	-80.0154330915	4173.47359792
Standard Error:	5.43855776205	19.4358768686	640.635318717

Inter-Parameter Correlations

	A	B	C
A:	1.000	0.657	-0.186
B:	0.657	1.000	-0.863
C:	-0.186	-0.863	1.000

ANOVA Table

Source	df F	Sum of Squares	Mean Square
Regression:	2 25.623381583	44.2654197973	22.1327098987
Residual:	589	508.76056652	0.863770062004
Total:	591	553.025986318	

Coefficient of Multiple Determination (R^2): 0.0800422057779

Nearest Neighbor Statistics

	Separation	|Delta Z|
1%-tile:	4.55816849384e-06	0
5%-tile:	1.28880603638e-05	0
10%-tile:	1.82016070749e-05	0.01
25%-tile:	2.0898846851e-05	0.03
50%-tile:	2.33409597156e-05	0.05
75%-tile:	3.15661226689e-05	0.12
90%-tile:	3.9870359911e-05	0.2
95%-tile:	4.23294814486e-05	0.31
99%-tile:	4.53966562588e-05	0.46
Minimum:	2.52982213074e-06	0
Maximum:	4.61725816932e-05	0.76
Mean:	2.57570849183e-05	0.0906925675676

Median:	2.33458984755e-05	0.05
Geometric Mean:	2.40432480656e-05	N/A
Harmonic Mean:	2.16106816252e-05	N/A
Root Mean Square:	2.72481224032e-05	0.141314413679
Trim Mean (10%):	2.56941940474e-05	0.0754971857411
Interquartile Mean:	2.34606379708e-05	0.0610101010101
Midrange:	2.43512019119e-05	0.38
Winsorized Mean:	2.60961038966e-05	0.0763006756757
TriMean:	2.47867222378e-05	0.0625
Variance:	7.91664781695e-11	0.0117644941579
Standard Deviation:	8.89755461739e-06	0.108464252903
Interquartile Range:	1.06672758178e-05	0.09
Range:	4.36427595624e-05	0.76
Mean Difference:	9.45511453014e-06	0.0975110326063
Median Abs. Deviation:	2.5921384156e-06	0.04
Average Abs. Deviation:	6.25812789755e-06	0.0648817567568
Quartile Dispersion:	0.203321872012	N/A
Relative Mean Diff.:	0.367087912322	1.07518218109
Standard Error:	3.65687242148e-07	0.00445785333403
Coef. of Variation:	0.345441056145	1.19595525645
Skewness:	0.468676946827	2.93904068338
Kurtosis:	2.94507765823	14.8718135053
Sum:	0.0152481942716	53.69
Sum Absolute:	0.0152481942716	53.69
Sum Squares:	4.39536423303e-07	11.8221
Mean Square:	7.42460174499e-10	0.0199697635135

Complete Spatial Randomness

Lambda:	2224798.63379
Clark and Evans:	0.0768372936898
Skellam:	6.14420146221

Gridding Rules

Gridding Method:	Kriging
Kriging Type:	Point
Polynomial Drift Order:	0
Kriging std. deviation grid:	no

Semi-Variogram Model

Component Type:	Linear
Anisotropy Angle:	0
Anisotropy Ratio:	1
Variogram Slope:	1

Search Parameters

No Search (use all data):	true

Output Grid

Grid File Name:	C:\Users\Heidi\Documents\LRB Niagara supporting files\Surfer Files\thickness\Grid Groups\Strawberry\Strawberry_NoSearch_hull3.grd
Grid Size:	45 rows x 100 columns
Total Nodes:	4500
Filled Nodes:	4500
Blanked Nodes:	0
Blank Value:	1.70141E+38

Grid Geometry

X Minimum:	-78.9342745
X Maximum:	-78.90972787
X Spacing:	0.00024794575757579
Y Minimum:	42.94978921
Y Maximum:	42.96062946
Y Spacing:	0.00024636931818184

Univariate Grid Statistics

	Z
Count:	4500
1%-tile:	-0.019869835796
5%-tile:	0.0216694280932
10%-tile:	0.0779017530582
25%-tile:	0.359568194305
50%-tile:	0.905180321565
75%-tile:	1.87081578532
90%-tile:	2.8815271761
95%-tile:	3.16058709568
99%-tile:	3.6978175385
Minimum:	-0.0327105911983
Maximum:	4.41829549912
Mean:	1.19504391743
Median:	0.905473312495
Geometric Mean:	N/A
Harmonic Mean:	N/A
Root Mean Square:	1.56821232667
Trim Mean (10%):	1.13317860335
Interquartile Mean:	0.972660219002
Midrange:	2.19279245396
Winsorized Mean:	1.16333082008
TriMean:	1.01018615569
Variance:	1.03138913452
Standard Deviation:	1.01557330337
Interquartile Range:	1.51124759102
Range:	4.45100609032
Mean Difference:	1.12479839894

Median Abs. Deviation:	0.663414663817
Average Abs. Deviation:	0.811182819931
Quartile Dispersion:	N/A
Relative Mean Diff.:	N/A
Standard Error:	0.0151392729498
Coef. of Variation:	N/A
Skewness:	0.805735131856
Kurtosis:	2.63247439185
Sum:	5377.69762845
Sum Absolute:	5381.68561005
Sum Squares:	11066.8045569
Mean Square:	2.45928990153

Appendix D: Sediment Grab Samples

The following table provides data associated with sediment samples collected in 2017 to groundtruth the geophysical data. In addition to the position of the grab sample, the closest survey line is noted for reference. Field descriptions and how the samples were plotted in GoogleEarth (coarse vs. mud) are also provided. Samples selected for additional grainsize analysis by LRB are shaded in gray, and those data can be provided by LRB upon request.

Sample ID	Survey Line	Date	Lat	Lon	Plot	Notes
NR_01	lock_sample	27-Jun-17	42 56.27650	78 54.53650	FINE	Muddy sample taken from within the lock
NR_02	LockRun_sample_02	27-Jun-17	42 56.54916	54.674	COARSE	Poorly sorted coarse gravel and shell with minor fine-coarse sand; needed multiple grabs
NN_001	LockRun_sample_X	27-Jun-17	42 56.48483	78 54.76650	COARSE	Very coarse sample; collected to groundtruth geophysical data
NR_03	LockRun_sample_Xb	27-Jun-17	42 56.32183	78 54.56550	FINE	Muddy sample taken drifting just outside of marina
NR_04	SI_transit	27-Jun-17	42 57.02700	78 54.58166	FINE	Fine sandy-silt with abundant SAV
NR_05	SI_transit_03	27-Jun-17	42 57.45051	78 55.95483	FINE	Fine sandy-silt with abundant SAV; in shoaled area between Strawberry Island and US shoreline
NR_06	SGI_transit	27-Jun-17	42 57.75883	78 56.27866	FINE	Sandy silt with gravel-cobble and abundant SAV
NR_07	ER_ES_01	27-Jun-17	42 58.25766	78 56.04316	COARSE	Poorly sorted coarse gravel and shell with minor fine-coarse sand; two grabs
NR_08a	ER_ES_03	27-Jun-17	42 58.55233	78 56.28333	FINE	Poorly sorted coarse gravel and shell with minor fine-coarse sandy silt

Sample ID	Survey Line	Date	Lat	Lon	Plot	Notes
NR_08b	ER_ES_03	27-Jun-17	42 58.55233	78 56.28333	COARSE	Poorly sorted coarse gravel and shell with minor fine-coarse sandy silt and SAV
NR_09	ER_ES_07	27-Jun-17	43 00.46866	78 54.98116	COARSE	Poorly sorted coarse gravel and shell with minor fine-coarse sand;
NR_10	TonwIsl_01	27-Jun-17	43 01.77566	78 52.90485	COARSE	Poorly sorted coarse gravel and shell with minor fine-coarse sand;
NN_002	ER_ES_12	28-Jun-17	43 03.48983	78 54.52583	COARSE	Multiple grabs, hard with rock/gravel; no sample
NR_11	ER_ES_15	28-Jun-17	43 04.20000	78 57.00183	COARSE	Poorly sorted coarse gravel and shell with minor fine-coarse sand;
NR_12	ER_ES_15b	28-Jun-17	43 04.29200	78 57.07003	FINE	Silty-fine sand
NR_13	ER_ES_15c	28-Jun-17	43 04.57616	78 57.684500	FINE	Sandy silt with SAV
NR_14	ER_ES_15c	28-Jun-17	43 04.46150	78 57.92083	FINE	Sandy silt with SAV; very fine and strongly sulfate reducing
NR_15	ER_WS_03	28-Jun-17	43 03.98051	79 00.22366	FINE	Sandy silt with SAV
NR_16	ER_WS_04	29-Jun-17	42 58.28116	78 56.58516	FINE	Soupy mud with very minor sand. Giant crawdad.
NN_003a	ER_WS_05	29-Jun-17	43 00.31583	78 55.82933	COARSE	Sand & gravel while drifting
NN_003b	ER_WS_05	29-Jun-17	43 00.87583	78 54.60566	COARSE	Sand & gravel while drifting; large rocks.
NN_003c	ER_WS_05	29-Jun-17	43 00.88350	78 54.57533	COARSE	Sand & gravel while drifting, also some finer sand and SAV
NR_17	ER_WS_07	29-Jun-17	43 01.96663	78 53.76016	FINE	Sandy silt with SAV. Drifting east of line during the grab
NN_004a	WR_ES_01	29-Jun-17	43 01.31050	79 01.05016	FINE	Very coarse sand and gravel with abundant SAV
NN_004b	WR_ES_01	29-Jun-17	43 01.34953	79 01.01521	FINE	Very coarse sand and gravel with abundant SAV

Sample ID	Survey Line	Date	Lat	Lon	Plot	Notes
NN_004c	WR_ES_02	29-Jun-17	43 01.36266	79 01.00066	FINE	Very coarse sand and gravel with abundant SAV
NR_18	WR_ES_01c	29-Jun-17	43 01.32150	79 00.63116	FINE	Soupy mud with minor sand and giant crawdad
NN_005	WR_ES_02	29-Jun-17	43 03.52683	79 59.96383	COARSE	Gravel and rock, clean
NN_006a	WR_ES_03	30-Jun-17	42 57.43268	78 57.28716	FINE	Sandy silt with gravel-cobble and abundant SAV
NN_006b	WR_ES_03	30-Jun-17	42 57.43466	78 57.43466	FINE	Sandy silt with gravel-cobble and abundant SAV
NN_006c	WR_ES_03	30-Jun-17	42 57.43833	78 57.31283	FINE	Sandy silt with gravel-cobble and abundant SAV
NR_19a	WR_ES_tie1	30-Jun-17	43 00.3200	79 01.19550	FINE	Sandy silt with SAV
NR_19b	WR_ES_tie1	30-Jun-17	43 00.36683	79 01.19850	FINE	Sandy silt with SAV; sandier than first grab
NR_20	WR_ES_tie2	30-Jun-17	42 59.87216	79 01.15516	FINE	Mud with SAV
NR_21a	WR_ES_tie3	30-Jun-17	42 59.54900	79 01.01560	FINE	Sandy silt with SAV
NR_21b	WR_ES_tie3	30-Jun-17	42 59.55000	79 01.00783	FINE	Sandy silt with SAV

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14. ABSTRACT
Over 220 linear miles of geophysical data, including sidescan sonar and chirp sub-bottom profiles, were collected in 2016 and 2017 by the US Army Corps of Engineers and the US Fish and Wildlife Service in the upper Niagara River. In addition, 36 sediment grab samples were collected to groundtruth the geophysical data. These data were used to map the spatial distribution of fine-grained sediment, including volume data in certain locations, along the shallow shorelines of the upper Niagara River. Overall, the most extensive deposits were spatially associated with either small tributaries or with man-made structures that modified the natural flow of the system. Extensive beds of submerged aquatic vegetation (SAV) were also mapped. Although always associated with a fine-grained matrix, the SAV beds were patchy in distribution, which might reflect subtle differences in the grain size of the sediment matrix or could simply be a function of variations in species or growth. The maps generated from this effort can be used to guide sampling plans for future studies of contamination in fine-grained sediment regions.

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