FINAL REPORT:

Red Tide Disaster Relief Assistance: Bathymetric Surveying of Little Bay, New Hampshire

PRINCIPAL INVESTIGATOR:

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SUMMARY

A bathymetric survey of Little Bay Estuary was conducted on 16 days in the months of February and March of 2013 using a dual-frequency (24 and 200 *khz*) single-beam sonar system. The survey extends from the General Sullivan Bridge to Adam's Point, and spans the width of the estuary to within 20-50 *m* of the high tide shoreline. A total of 360 cross-estuary transects spaced at 20 *m* intervals were transited by the R/V Galen J, a 22 *ft* shallow-draft vessel equipped with the sonar system and differential GPS receiver with accuracy of 1-5 *cm* (based on RTK base corrections transmitted to the vessel from a nearby GPS base station). Sound speed corrections were applied to processed sonar data, and were determined from CTD casts obtained several times during each survey. Full waveform backscatter intensity data from each sonar ping were recorded at about 14 *hz*. Bottom depths below transducer were determined from the 200 *khz* data with estimated accuracy of about 5 *cm*. Sonar depths were combined with GPS positioning to determine bathymetric maps with total uncertainty of about 10 *cm*. Surveys were referenced to the WGS84 ellipsoid, and subsequently converted to elevation relative to the NAVD88 vertical datum using NGS's 2003 Geoid Model. Backscatter data from each sonar frequency were also interrogated to estimate the maximum intensity, total integrated intensity of the bottom return, and width of the bottom return in an effort to begin examination of the acoustic signatures of the Little Bay bottom types (the subject of ongoing research). All data are prepared for distribution to the DES in defined formats.

INTRODUCTION

Seafloor classification and environmental assessment in shallow marine waters is a critical need for establishing marine protected areas (MPA's), essential fish habitat (EFH), coastal management policies, and maintaining navigational waterways. Most commonly these assessments are done using software packages adapted for use with remote acoustic

measurements obtained from various water-borne vessels. Unfortunately, capability to make appropriate measurements in shallow water is limited to highly specialized vehicles, and thus the order one characterization of seafloor environmental properties in shallow marine environments, for example, Little Bay Estuary, is generally lacking. As a consequence, development of shallow marine management practices has virtually no quantifiable data from which to base policies, and guidance from observations is thus limited to anecdotal evidence or historical maps whose relevance to the spatial variability today is not known.

The project performed was aimed at obtaining new bathymetric and seafloor backscatter intensity data for Little Bay Estuary, including the main navigation channel and adjacent shallow flats up to a few 10's of meters from the shoreline. The survey methodologies and results are discussed below. The data are processed and ready for distribution as horizontal coordinates in latitude and longitude in the IGS08 reference frame (equivalent to WGS84 reference frame), and elevations relative to the NAVD88 datum (easily converted to MSL, MLLW, etc., as desired)

METHODS

Survey data were collected onboard the R/V Galen J, a 22 *ft* open-cabin vessel with 75 *hp* outboard motor (Figure 1). Surveys were collected on 16 days in the winter of 2013 (12-15, 20-22, 25-26 February, and 11-15 and 26-27 March). Each survey was conducted about high tide for 1-5 *hrs*, depending on available daylight hours. Prescribed survey lines were determined *a priori* with 20 *m* spacings and oriented across the main channel (Figure 2). A total of 360 survey lines were transited during the 16 survey days, with typical survey speeds of 3-5 *knts*. Transect line length varied with the width of the estuary to within about 20-50 *m* of the high tide shoreline, and a total of 383 *km* of survey lines were obtained. On each day, up to 3 conductivity-temperature-depth (CTD) casts were made with a YSI Cast-a-way CTD to determine actual sound speeds over the water column. Simple, linear sound speed corrections were made by integrating the sound speed profile over various depth ranges and using the nearest CTD cast in time to make the correction. Figure 3 shows a typical sound speed profile obtained during the survey on 13 March indicating a well-mixed water mass with near uniform sound speeds. Occasional gaps in the data were due to GPS drop-outs and acoustic noise from turbulence near the transducer head or within the water column. Data were subsequently smoothed onto 2, 5, and 20 *m* grid spacing for display purposes, and can be distributed in this manner if desired.

Figure 1. Photograph of the R/V Galen J showing the location of the Odom Echosounder transducer mounted on the starboard side. A GPS receiver antenna is located at the top of the mounting pole. A GPS RTK antenna is located on the port-aft corner of the roof and was used to receive positioning corrections from a nearby base station at 1 *hz*. CTD casts were periodically made over the starboard rail during each survey. Clean power for the sonar system was provided by a portable Honda generator mounted on the aft fantail. Prescribed survey lines were imported into Hypack and transited during each survey at between 3 and 5 *knts*. The boat was launched on each survey from the Great Bay Marina just to the west of the General Sullivan Bridge.

An Odom Echotrac CV2 echosounder with Airmar M108 dual-frequency (24 and 200 *khz*) transducer was used to collect sonar data at about 14 *hz* ping rate. The transducer was attached to a 1.5 *in* diameter pipe and mounted over the starboard side of the vessel (Figure 1). The bottom of the transducer was about 30 *cm* below the waterline. Fore and aft support straps reduced vibrations of the transducer during the surveys. A GPS receiver was mounted at the top of the pipe to best estimate the position of the transducer. A Trimble 5700 GPS base station with RTK transmitter was deployed nearby (at either the Great Bay Marina or near the public boat launch at Adam's Point) and relayed GPS corrections to the vessel at 1 *s* intervals allowing for highly accurate positioning with 1-5 *cm* accuracy. Data were filtered to remove spurious depth soundings and poor GPS data. In total, 2,460,569 depth soundings were retained in the survey. The average spacing between data points along each transect line was 16 *cm* and the average

spacing between transect lines was 20 *m*. Sonar and GPS data were recorded simultaneously in ODOM proprietary format and then converted to universal XTF format for processing. Surveying in this manner allowed for shallow surveys to be referenced to the WGS84 ellipsoid independent of water level. All data were subsequently converted to the NAVD88 vertical datum using the NGS 2003 Geoid model. For reference, mean sea level (MSL) and mean lower low water (MLLW) at Fort Point near the mouth of the Piscataqua river is 9 and 152 *cm*, respectively, below NAVD88.

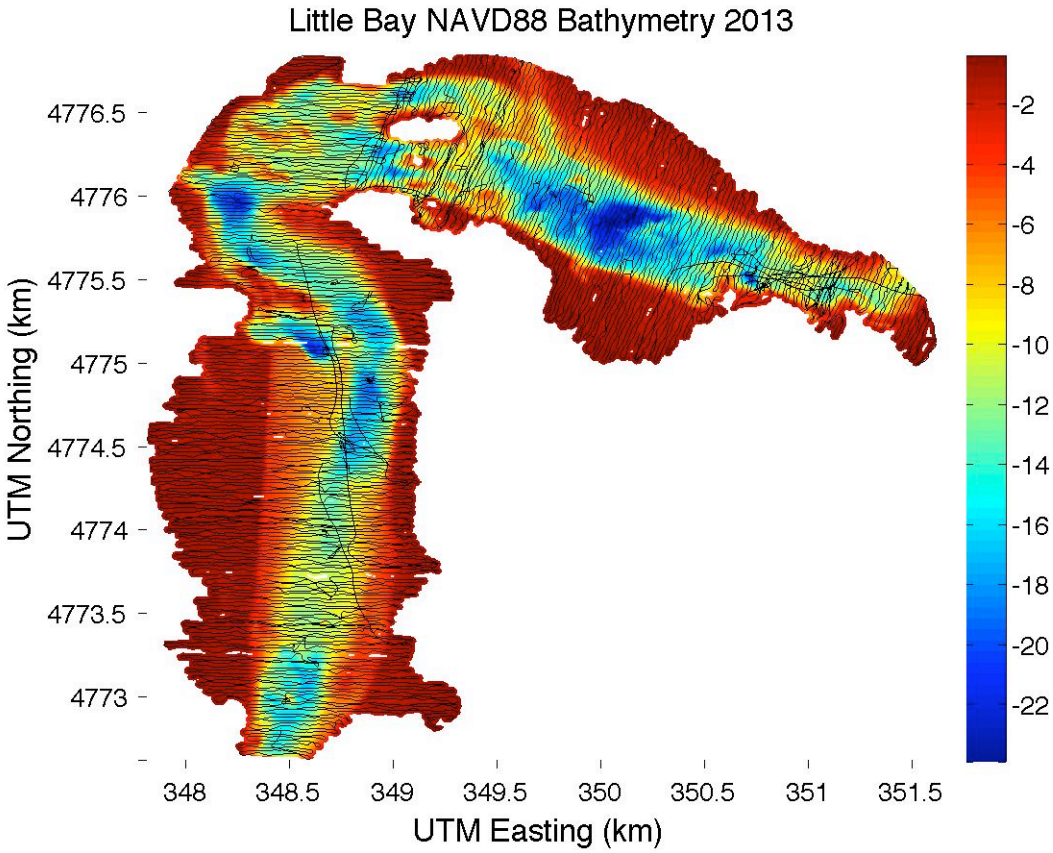

Figure 2. Bathymetric map of Little Bay. Horizontal coordinates are in kilometers as UTM Eastings and Nortings. Elevations as colored contours with scale bar on the right, are in meters relative to the NAVD88 reference datum, about 9 *cm* above MSL. The survey extends from the General Sullivan Bridge at the northeast end of the survey region, to Adam's Point to the south end. Transited transect lines are indicated with the thin solid black lines overlaid on the map.

Full waveform data were recorded for each ping and extended to depths up to 30 *m*, a range based on assumed sound speeds of 1500 *m/s*. Raw waveform data are recorded in intensity as uncalibrated voltage based on amplification to full scale range, and includes both a steady state gain (unchanged throughout the experiment) and time variable gain (based on 20log*R*

adjustments, with *R* the range) that accounts for spherical spreading without accounting for acoustic absorption (assumed small in the Little Bay). Data are initially stored as a function of time and converted to actual distances (*i.e.*, depth) using measured sound speeds from the CTD casts. An example waveform from the 200 *khz* signal is shown in Figure 4. In this example, the bottom depth is about 6.82 *m* below the transducer. The waveform is very clean, and typical of depth soundings collected throughout Little Bay. There is another large return that results from re-reflection off the surface of the water and again off the bottom, and is typical of data collected over hard substrate. Over soft substrate, attenuation of the sonar by the sediments limits the secondary echo's. In any case, secondary echo's are easily avoided in the processing.

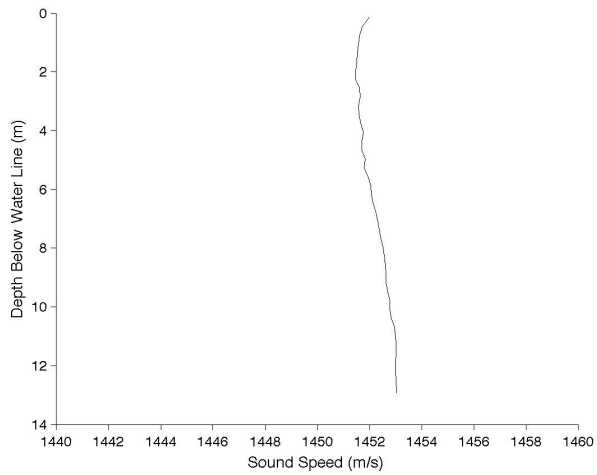

Figure 3. Typical sound speed profile obtained during the survey conducted on 13 March 2013.

Bottom depths were determined from the 200 *khz* sonar because the bottom returns were more consistent over the range of bottom types encountered (ranging from hard substrate to mud). Depths were determined by selecting a threshold level for which the reflected sonar intensity must exceed, and then filtering spurious returns by limiting the search algorithm to within a defined time interval based on previous depth estimates. Accuracies in bottom depths obtained in this manner were estimated to be within about 5 *cm* based on previous comparison with similar systems working in the Great Bay over (assumed) similar seafloor material.

Also shown in Figure 4 is a close-up of the first bottom return showing the variability of the intensity signal as a function of water depth. Indicated in the figure is the intensity maximum, I_{max}, and the width, *Wid*, of the return pulse determined as the distance over which the sonar intensity remains above the median intensity for the entire ping. A third parameter

describing the the bottom return was defined as the total intensity, I_{tot}, of the pulse and determined by integrating the intensity over the width of the pulse.

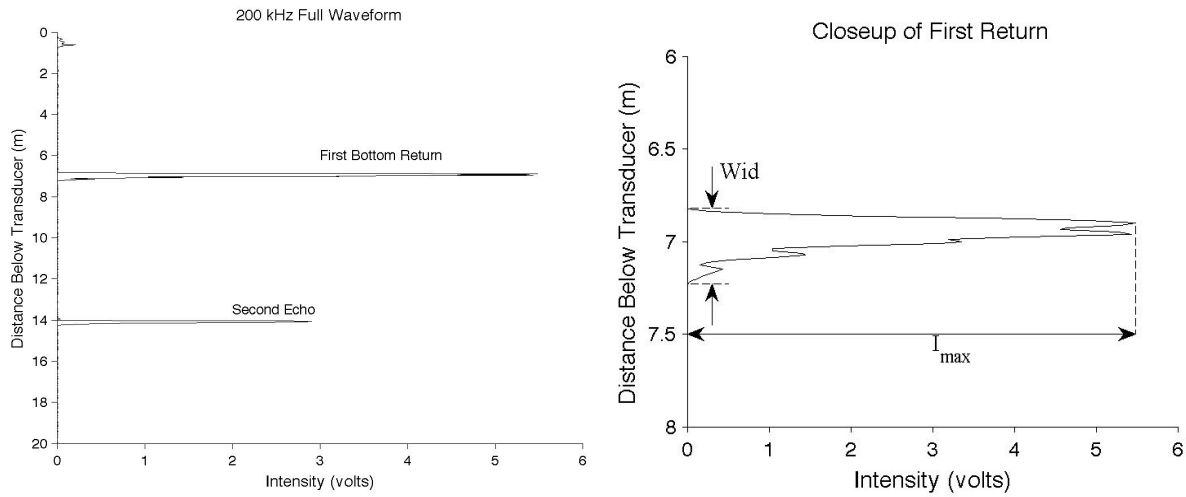

Figure 4. Example waveform from the 200 kHz signal and the defined parameters *Wid* and I_{max} describing the return pulse. The integrated intensity, I_{tot}, is determined by integrating the intensity over the width of the pulse.

RESULTS

Little Bay bathymetry obtained from a composite of the 16 survey days is shown in Figure 2. Observed depths relative to NAVD88 (9 cm above MSL) ranged from about 0.05 *m* close to the high tide shoreline to 24 *m* in the main channels. The grid used in Figure 2 has 5 by 5 *m* resolution.

Backscatter maps of I_{max}, I_{tot}, and *Wid* from the 200 *khz* signal are shown in Figures 5-7, respectively, and for I_{max} and I_{tot} from the 24 *khz* signal in Figures 8-9. The variation in backscatter properties suggests a similar variation in substrate types, however, details of this type of classification require additional examination and is the subject of ongoing research.

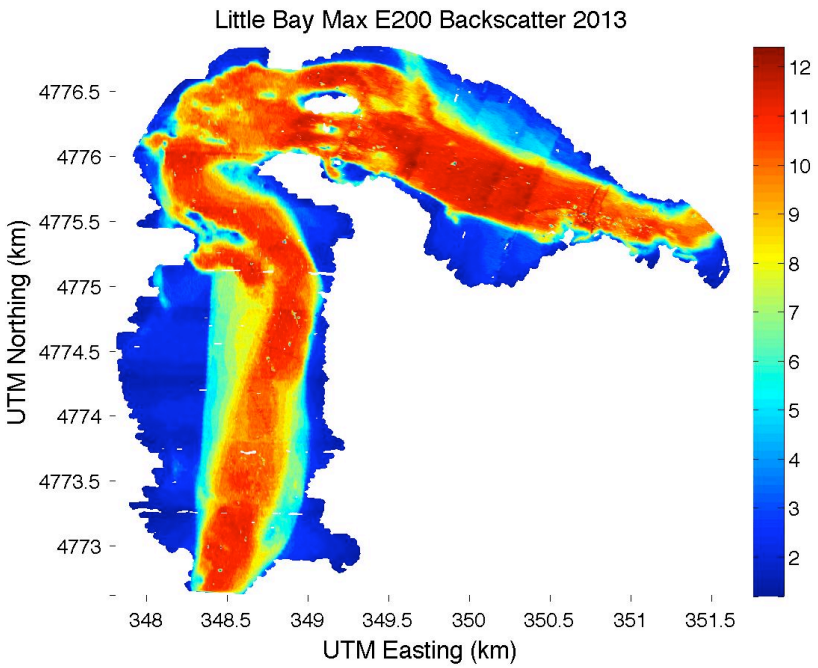

Figure 5. Maximum backscatter intensity, I_{max}, from the 200 *kHz* sonar. Color contours are in uncalibrated voltage. Spatial coordinates are in *km* as UTM Easting sand Northings.

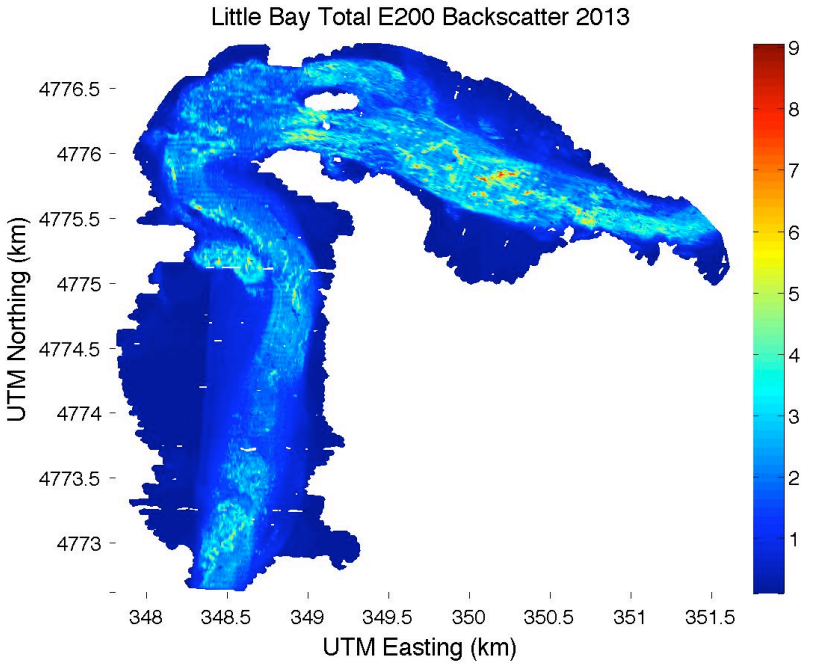

Figure 6. Integrated total backscatter intensity, I_{tot}, from the 200 *kHz* sonar. Color contours are in uncalibrated voltage-meters. Spatial coordinates are in *km* as UTM Easting sand Northings.

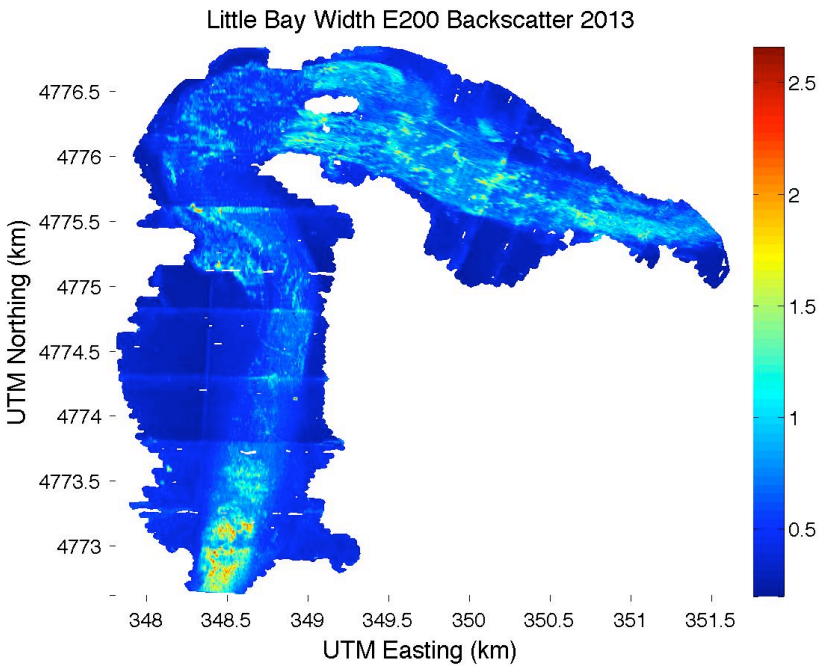

Figure 7. Width of backscatter intensity bottom return, *Wid*, from the 200 *kHz* sonar. Color contours are in meters. Spatial coordinates are in *km* as UTM Easting sand Northings.

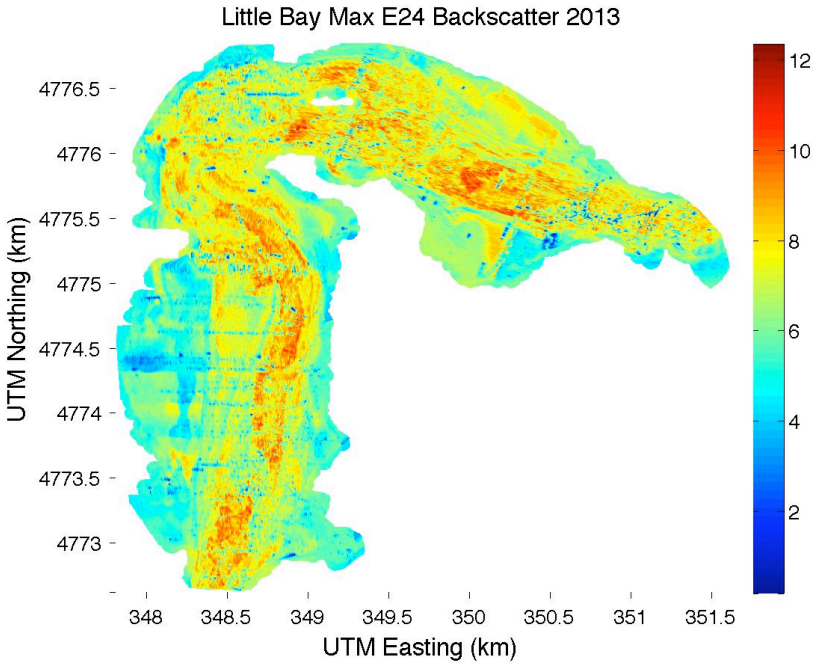

Figure 8. Maximum backscatter intensity, I_{max}, from the 24 *kHz* sonar. Color contours are in uncalibrated voltage. Spatial coordinates are in *km* as UTM Easting sand Northings.

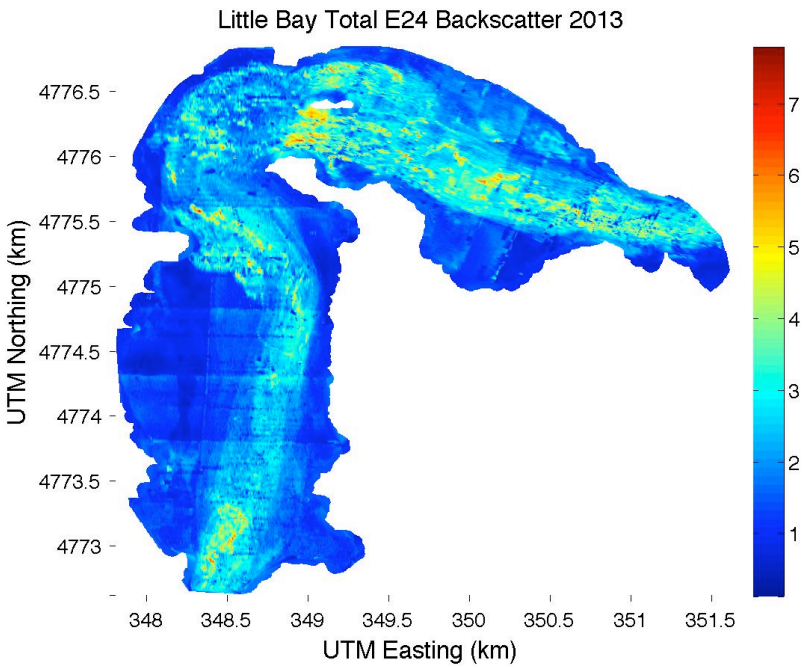

Figure 9. Maximum backscatter intensity, I_{tot}, from the 24 *kHz* sonar. Color contours are in uncalibrated voltage. Spatial coordinates are in *km* as UTM Easting sand Northings.

SUMMARY

A bathymetric survey with full waveform, uncalibrated backscatter intensities were obtained over the Little Bay Estuary in the winter of 2013. Depth soundings were recorded along cross-estuary transect lines spaced 20 *m*, and sampled to within 20-50 *m* of the high-tide shoreline. Positioning was provided by an onboard differential GPS receiver and RTK base station deployed nearby. Surveys were referenced to the WGS84 ellipsoid and subsequently converted to elevations relative to NAVD88, about 9 and 152 *cm* above MSL and MLLW, respectively. Sound speed corrections were determined from CTD casts conducted on each survey day. Overall accuracies of bathymetric depths are estimated to be about 10 *cm*. Uncalibrated backscatter intensity variables were obtained from the full waveforms from both the 200 and 24 *khz* sonar signals, and include the maximum intensity, total integrate intensity, and width of bottom returns. Data can be distributed in a variety of formats determined in conjunction with DES program officers.