SUMMARY

This addendum to the Final Report (submitted to the DES in April 2013) describes comparisons between properties of the acoustic backscatter return pulse waveform and particle grain size fraction from 9 locations within the Little Bay. Waveform properties include the total integrated and maximum backscatter intensity from the 24 and 200 \(khz\) acoustic signals, and the width of bottom return pulse from the 200 \(khz\) signal. Sediment samples were collected between 2000 and 2006 by UNH researchers (PI Dr. Steve Jones) on the mud flats, channel edge, and main channel of the Little Bay. Particle size distribution was characterized by the fraction of silts and clays of the surficial sediments and ranged from 6 – 77% silt/clay, indicating regions of predominantly mud or sand, and areas with a mixture of the two. The 6 samples from the southern half of Little Bay were collected in water depths ranging 1-12 \(m\), and show a strong (logarithmic) relationship with mud fraction with increasing mud content as the depths shallow (with skill of 0.80). This is not surprising considering that the strong currents down the center portion of the deep channel tend to winnow out the fine particles and deposit them on shallower mud flats that border the Bay. Comparisons between sediment mud fraction and the 24 \(khz\) intensities do not show any appreciable correlation, most likely a result of volume scattering effects of the lower frequency acoustic pulses. The 200 \(khz\) signal – with much lower volume scattering – compares more favorably to the sediments, particularly for the maximum intensity return from the bottom. In this case, there is a logarithmic relationship between mud fraction and maximum backscatter intensity (with skill of 0.85).

It should be noted that this logarithmic model (despite its high skill) is likely much too simple for widespread application to the Little Bay. The sediments were sampled from 2000-2006 and are presently limited to six locations, and although the evolution of the Bay during that
time period is not noticeably large, there could have been some recent chances to the surficial sediments (we will be examining more sediment data to be collected in the summer of 2013 to assess more recent and widespread sediment variability). Moreover, there were three additional sediment samples collected near the outflow of the Bellamy River on the north end of Little Bay, and these samples do not follow the same trend as the other data from the southern half of the Bay. These samples are likely influenced by either coarser material emanating from the Bellamy, or that increased flows out of the Bellamy and across the mud flats removes a higher percentage of the fines. It is clear that a more complex model would be needed to accurately represent local variations in sediment distribution (and is being pursued as part of ongoing research). Nevertheless, the logarithmic relationship between maximum 200 kHz backscatter and sediment size fractioning provides a gross, first-order approximation of the mud fraction in surficial sediments in the Little Bay.

**INTRODUCTION**

This Addendum to the final report is to provide field verification of backscatter waveform properties at selected locations and substrate types within Little Bay. This work, although very limited, could be used to make an initial map of mud fraction based on a simple backscatter intensity model and indicates that there is sufficient variation in backscatter intensities to discern different substrate types based on mud fraction. Areas of known substrate type (based on mud fraction) are compared with backscatter properties, and provides an initial interpretation of backscatter variation in the Little Bay.

**METHODS**

Methods that describe the survey data are contained in the initial final report. Herein we briefly describe the historical sediment sampling and comparisons with the backscatter properties. Table 1 summarizes the sediment samples obtained and analyzed between 2000 – 2006. These data were obtained under an EPA Grant to Dr. Steve Jones of UNH under the auspices of the National Coastal Assessment Program. The locations of the samples (indicated in Table 1) are shown on the bathymetry of Little Bay in Figure 1. Samples from Station ID 0051A (Table 1) are located in shallow water at the northern end of Little Bay in a region influenced by effluent from the Bellamy River (indicated with the open circles in Figure 1). Sediment samples were submitted to EPA for analysis. The percentage of sand and silt/clay (mud) mix are indicated in Table 1, as well as any organic carbon that may have been present.
Water depth (relative to NAVD88) and backscatter properties (return pulse width, integrated intensity, and maximum intensity) from our 2013 survey maps with 25 m horizontal resolution were linearly interpolated onto the location of the sediment samples.

<table>
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<th>Station ID</th>
<th>Date</th>
<th>Latitude (N deg)</th>
<th>Longitude (W deg)</th>
<th>Collected By</th>
<th>Organic Carbon (%)</th>
<th>Silt/Clay Mix (%)</th>
<th>Sand (%)</th>
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<td>29.30</td>
<td>70.70</td>
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</table>

**Figure 1.** Bathymetric map of the Little Bay also showing the locations of sediment samples (open circles indicate 3 shallow sites near the Bellamy River; closed circles are 6 sites in the southern portion of the Bay).
RESULTS

Figure 2 shows the comparison between mud fraction and survey variables including water depth, bottom pulse width (200 kHz), integrated backscatter intensity (both 24 and 200 kHz), and maximum backscatter intensity (both 24 and 200 kHz). Data from the three locations near the Bellamy River (station ID 0051A) are indicated with the open circles. The six locations from the southern end of the Bay are shown with solid circles.

For the southern data, there is a strong relationship between water depth and mud fraction (upper left panel of Figure 2). A logarithmic fit to the data (shown in panel) has skill of 0.80 (indicated that 80% of the variance is explained by the model). Despite the limited number of data points and the time between when the sediment samples and the bathymetry was obtained, there is very good agreement. This is, perhaps, not surprising considering that strong tidal currents confined to the deeper channel down the center of the bay (Figure 1) winnow out the fine sediments, resulting in coarser surficial sediments in the channel. Weaker currents on the sides of the channel and toward the banks of the Bay allow finer sediments to be deposited in mud flats that are exposed at spring low tides.

For the northern Bay data (near the Bellamy River mouth), the sediments on the shallow flats are coarser than in other flats of the Bay. This is likely a result of either coarser material being deposited from the Bellamy River or from winnowing of finer material by increased flow from the Bellamy. In any case, it is clear that the logarithmic depth model does not apply to these locations. This indicates that although depth is a good first approximation to the mud fraction of the surficial sediments (to depths up to 11 m), this simple model would not apply to all locations in the Bay.

Also for the southern six data locations, comparison between the backscatter properties from the 24 kHz signal and mud fraction (left middle and lower panels, Figure 2) do not show a clearly strong, predictive relationship that could be used (on its own) to describe the mud fraction in the bay. This result is not necessarily surprising considering that the low frequency (24 kHz) signal penetrates the bottom sediments a distance that is not precisely known. As a consequence, the backscatter from the 24 kHz signal is affected by unquantified volume scattering.

However, comparison with the 200 kHz signals (right panels, Figure 2) shows a more predictive distribution of data, particularly for the maximum backscatter with logarithmic fit to the sampled mud fraction. The high skill (0.85) of the logarithmic fit over the dynamic range of the intensity data and spanning mud fractions from 6 – 77 %, allows a first order estimate of the
mud fraction distribution over the southern portion of the Little Bay where the sediment samples were taken (and even extrapolated to the northern section, but with less confidence). If we use this logarithmic fit and the observed maximum intensities, we obtain a first-order map of the distribution of mud fraction in surficial sediments of the Little Bay (Figure 3).

It should be noted (as before) that the sediment samples near Bellamy River on the northern end of the Bay (open circles in all panels of Figure 2) show lower maximum backscatter intensity than would be predicted by the simple logarithmic model. This suggests that the bottom itself is smoother (less bottom roughness) in this region than in other regions of the Bay with similar material. This assertion, although plausible, is not verified with the available data. In any case, it is clear that these data do not follow a similar pattern as the other data used in this report. This indicates that there is uncertainty in the mud fraction predictions indicated by Figure 3, particularly in regions of the bay influenced by riverine inputs (for example, near the Bellamy and Oyster River mouths).

It should also be noted that there is substantial time span (13 years) between the sediment and backscatter data collection. The changes to the surficial sediments over this time is not known, nor is the evolution of the depths. As well, there is a relatively low sensitivity of backscatter intensity for high mud fractions (greater than about 50 or 60 %) that the logarithmic fit attempts to delineate. Consequently, and despite the high skills between depths and maximum backscatter from the 200 kHz signal, these data may serve only as a gross first-order approximation for mud fraction in the Bay.

As part of ongoing research at UNH, we will be collecting and analyzing new sediment samples from the Little Bay in the summer of 2013. These data will be used to compare with our 2013 backscatter data, and a more complete model developed that utilizes additional factors that describe the backscatter waveform (e.g., nonlinear parameters such as skewness, kurtosis, and asymmetry). We will conduct a principal component analysis that includes all parameters (from both the 24 and 200 kHz signals) to objectively define spatial factors that will be compared with more spatially dense and expansive observations of sediment grain size distribution.
Figure 2. Depth (upper left) and backscatter intensity properties compared with observed mud fraction. Open circles – 3 sites near Bellamy River. Closed circles – 6 sites in the southern portion of the Bay. 200 kHz signals are shown on the right for the width of pulse (upper), total integrated intensity (middle), and maximum intensity (lower); 24 kHz signals are on the left with total integrated (middle) and maximum (lower) intensities. The black lines in three of the panels are log-normal fits to the data. The skill, S, of the logarithmic models are indicated on the panels.
**SUMMARY**

A comparison between sediment samples (collected between 2000-2006) and single-beam echo-sounder bathymetry and backscatter intensities (obtained in 2013) allows a first-order evaluation of the distribution of mud fraction in the Little Bay. Although the skill (0.85) is high of the logarithmic model comparing maximum backscatter intensity from the 200 kHz signal and the mud fraction in six sediment samples, the model does not represent local variation due to other factors (for example, coarsening of surficial material on the mud flats near the mouth of the Bellamy River). Clearly, a more complex model is required, as well as more widespread and more recent sediment samples. As part of ongoing research at UNH by graduate student Joshua Humberston, sediment samples will be obtained in the Little Bay in the summer of 2013, and used to verify a more complex model involving principal component analysis of backscatter waveform properties.