Hydrodynamic conditions and sediment release rates
during the Passaic River Dredging Pilot Dec 2005.

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Shipboard and moored data are used to characterized hydrodynamic conditions and sediment release rates during the Passaic River Dredging Pilot that took place Dec 5-10th 2006. A 6 element mooring array was deployed between Dec 1-12 and each mooring contained a bottom mounted profiling Doppler current meter, surface and bottom Conductivity and Temperature (CT) sensors and surface and bottom optical backscatter sensors (OBS). In addition two of the moorings included a Laser In Situ Scattering Transmissometry (LISST-100) that was deployed approximately 1 meter below the surface. Shipboard measurements utilized two vessels and included underway Acoustic Doppler Current Profiling (ADCP) measurements and profiling with a Conductivity, Temperature, Depth (CTD) probe, an OBS and LISST package. Acoustic and optical backscatter measurements were calibrated against Total Suspended Sediment (TSS) measurements.

A high discharge event prior to the dredging pilot coupled with the tidal motion drove the Passaic’s salt wedge and associated turbidity maximum across the study site during each flood and ebb tide. The high suspended load associated with the passage of the turbidity maximum past the study site obscured efforts to estimate sediment release rates from the dredging operation with the moored data. However, the dredge plume was evident in the shipboard ADCP data in the immediate vicinity of the dredging operation. Analysis of the shipboard ADCP data found that daily release rates varied from 1% to 6% of the total sediment dredged. While there is significant scatter in the individual estimates of the release rates, due to both the noisy nature of the “signal” and significant
environmental “noise” associated with the passing turbidity maximum, these numbers are in the expected range. Furthermore, the tendency for shipboard surveys to show an increase in sediment loadings down stream of the dredge strongly supports the contention that this method detected the dredge plume over the environmental noise associated with natural TSS variability. Finally, shipboard Doppler current profile data indicated that the dredge structure significantly modifies the flow field, and thus transport processes, immediately down stream of the dredging operation.
Introduction

This report describes methodology and results of hydrodynamic and suspended sediment observations taken in December 2005 in the Harrison Reach of the Passaic River (Figure 1). The major objective of these measurements were to provide data that allowed an estimate of the quantity of sediment that were released during the Passaic River Pilot Dredging project that took place Dec 5th-10th, 2005. Include in this component of this field effort was the deployment and recovery of moorings in the Harrison reach of the Passaic River and the execution of shipboard surveys. The mooring array consisted of 6 elements with each element containing a Doppler current profiler and surface and bottom Conductivity/Temperature (CT) sensors from which time series of salinity were obtained. Each mooring also included a surface and bottom Optical Backscatter Sensor (OBS). Two of the moorings (M3 & M4) included a Laser In-Situ Scattering and Transmissometry (LISST-100) to provide estimates of the particle size distribution. Both LISST’s collected data every ½ hour over the duration of the deployment and provided estimates of particle size distribution in logarithmically spaced bins ranging from 2-500 μm. Finally moorings M2 and M6 contained bottom mounted paroscientific pressor sensors with sufficient accuracy to measure the time-varying pressure gradient across this array.

Mooring 1 used a 1500 kHz Sontek Acoustic Doppler Profiler, moorings 2-5 contained a 1200 kHz RD Instrument (RDI) Acoustic Doppler Current Profiler (ADCP) and mooring 6 used a 600 kHz ADCP. Moorings 1-5 were programmed to obtained
current measurements with 25 cm resolution in the vertical. Mooring 6, due to the lower
frequency of the Doppler, collected data at 50 cm resolution. Mooring 2 was equipped
with 2 Gigabytes of memory and collected data at nearly 1 Hz throughout the
deployment, while the other current meter were programmed to record the mean velocity
profile every ½ hour based on a 10 minute burst at 1 Hz. The head of the Doppler were
located approximately 50 cm above the bottom. In addition a blanking distance of 15 cm
was used for the higher frequency ADCP’s (the 4 RDI 1200 kHz Dopplers and the
Sontek 1500 kHz Doppler) while the 600 kHz Doppler had a blanking distance of 25 cm.
Thus for the higher frequency Dopplers the first measurement is at 65 cm above the bed,
while for the 600 kHz Doppler the first bin is 75 meter above the bed. Furthermore,
interference of the acoustic signal with the sea surface precludes Dopplers from making
measurements in the upper 10% of the water column. Thus for a nominal depth of 5
meters, velocity measurements are available from 75 cm (for the higher frequency
Dopplers) to 4.5 meters above the bed.

The array was deployed on December 1st 2005 and recovered on December 12th
2006. The Doppler current profiler at M3 failed and no data was recovered as did the
CTD at mooring M4. All other instruments where recovered and recorded data for the
entire deployment.

The shipboard surveys included two boats the Caleta and the Julia Miller. The
Caleta was equipped with a 1200 kHZ RDI ADCP that was programmed to collect a
velocity profile at approximately 1 Hz with 25 cm resolution. The Caleta also included an
Ocean Sensor (OS-200) CTD equipped with an OBS and operated at approximately 6 Hz.
The Julia Miller was equipped with a OS-200 CTD and a LISST-100 to provide profiles
collected velocity data, the ADCP’s also record acoustic backscatter intensity that can be correlated with suspended sediment concentration. To calibrate both the OBS and ADCP measurements against total suspended sediment (TSS) approximately 100-0.5 liter pumped water samples were taken during the December experiment. These samples were filtered by USGS (Tim Wilson) and provided the requisite measurements of TSS to calibrate the acoustic and optical sensors.

Figure 3 shows the results of the calibration between the Acoustic Backscatter from the Caleta’s ADCP and the TSS measurements. Note the TSS is plotted logarithmically against the acoustic backscatter. This is done because the backscatter is reported in decibels, which is a logarithmic unit and thus figure 3 is essentially a log-log plot. While there is scatter in the regression, a good correlation was found with a correlation coefficient (r=0.83). With this calibration we then estimated suspended sediment concentration with the shipboard ADCP backscatter as:

$$TSS = 10^{0.0387*\text{abs} - 2.083}$$

(1)

where abs is the acoustic backscatter measurement obtained by the ADCP. The moored ADCP’s were calibrated by obtaining a regression between the shipboard ADCP’s acoustic backscatter and the acoustic backscatter from the moored data. Here data from the moored record were compared to the shipboard acoustic backscatter data when the vessels GPS fix was within 10 meters of the mooring. In general there was excellent correlation between the shipboard and moored ADCP backscatter. Regression coefficients between the vessel and moored Doppler were 0.90, 0.83, 0.95, 0.95 and 0.88.
Based on these regressions TSS at each of the mooring locations was estimated as

\[
\text{TSS}_{\text{site } 1} = 10^{0.0387 \cdot \frac{(\text{abs}-1.3)}{0.7}) - 2.083}
\]

(2a)

\[
\text{TSS}_{\text{site } 2} = 10^{0.0387 \cdot (\text{abs}-0.65)/1.03) - 2.083}
\]

(2b)

\[
\text{TSS}_{\text{site } 4} = 10^{0.0387 \cdot (\text{abs}-3.78)/0.95) - 2.083}
\]

(2c)

\[
\text{TSS}_{\text{site } 5} = 10^{0.0387 \cdot (\text{abs}-9.47)/0.90) - 2.083}
\]

(2d)

\[
\text{TSS}_{\text{site } 6} = 10^{0.0387 \cdot (\text{abs}-16.92)/0.93) - 2.083}
\]

(2e)

The OBS was also calibrated against the TSS measurements and results are shown in figure 3 (R=0.73). During the course of the experiment we calibrated both the OBS sensors that were on the Caleta (red dots on figure 3) and the OBS on the Julia Miller (Blue dots on figure 3). The regression between the OBS and yielded:

\[
\text{TSS} = 2.1 \text{ FTU} - 0.83
\]

(3)

Where FTU is the Formazin Turbidity Unit reported by the OBS. This calibration was then applied to the moored OBS sensors to provide fixed point time series of TSS.

**Estuarine conditions during Dredging operations:**

River discharge measured at the USGS gauge at Little Falls and sea-level measured by the NOAA station at Bergen Point are plotted in figures 4. Also shown in
Prior to the dredging operation Passaic River discharge peaked on Dec 1-2 with discharge of 122 m$^3$/s. Following this peak the flow rate decreased monotonically to 31 m$^3$/s by Dec 14$^{th}$. A rain event on Dec 15$^{th}$ produced another discharge event that peaked on Dec 19$^{th}$ at 127 m$^3$/s (not shown). The sea level record shows both variability associated with the spring/neap cycle and strong variability associated with meteorological forcing. Tidal range peaked just prior to the dredging operation and decreased during the week. A strong wind event on December 9$^{th}$ drove sea-level downward and knocked the top off of the evening high tide producing the lowest sea-level over this record during the following low tide (Figure 4). Later in this report the effects of this event on suspended sediment concentration will be shown.

The high river discharge produced a salt-wedge type estuary that extended only a few miles into the Passaic River (Figure 5). At the end of flood on Dec 6$^{th}$ the head of the salt-wedge was 2 miles upstream of the dredging operation. Tidal currents in the Passaic average around 50 cm/s and thus the tidal excursion (the distance that a parcel of water would travel during the ebb or flood tide) in the Passaic is approximately 6-7 km or about 4 miles. Thus this salt wedge, which lies 2 miles upstream of the Harrison Reach at the end of flood will reside 2 miles south of the Harrison reach at the end of ebb. Suspended sediment loads are low during the transect shown in figure 5, with maximum values of 35 mg/l in the in the lower layer near the Harrison Reach (~river mile 3), because the transect was taken during slack water. Nevertheless, during the dredging operation the salt wedge passed the field site during the ebb and again during the flood. The passage of the front is evident in the moored data (figures 6a-c). For example figure 6b shows
conditions on December 6th when the CTD section shown in figure 5 occurred around noon. During the morning flood (just after 8 EST) frontal passage past the mooring is evident as salinity rises rapidly at both surface and bottom sensors. TSS levels are elevated in the unstratified waters ahead of the front. Later during the flood strong salinity stratification develops and TSS drops dramatically. Note that the CTD section shown in figure 6 was taken around 12 EST when currents and TSS levels were low. The front passes the mooring again during the ebb and TSS levels at the mooring are once again elevated. During the ebb surface and bottom salinities are near zero and TSS level remain high. This pattern is essentially repeated throughout the week, although there is a general rise in salinity due to the declining river discharge. By Dec 10th near bottom salinity is nearly 12 psu at the end of flood. There is also a tendency for TSS levels to decrease from the 5th to the 9th, however the storm event beginning around noon on the 9th appeared to increase TSS loads for the rest of the pilot dredging program. I note that the enhanced TSS levels apparent at the surface on Dec 7th and 8th are artifacts associated with interference of the Doppler’s acoustic beams with the river’s sea-surface.

**Sediment flux estimates from moored data**

With the moored data estimates of the suspended sediment flux were made. The objective of these estimates were to assess if the mooring array could detect increased sediment loadings during the dredging operations. Sediment flux estimates were made using sites 2 and 4. Ideally sites 3 and 4 would have been used as they are the closest moorings to the dredge, however the ADCP at site 3 failed and thus no data was available there. While more detailed estimates of sediment flux could have been make by
combining data from sites 1 and 2, I chose to only use the site 2 because its cross-stream position was similar to site 4 thus making the comparison more meaningful. With the ADCP data sediment flux estimates ($F_{TSS}$) were made as:

$$F_{TSS}(t) = \int_{\eta}^{0} u \ TSS \ w \ dz$$

Where the $u$ is the along channel velocity, TSS is the suspended sediment estimate made with moored ADCP backscatter data, $w$ the depth dependent channel width and $t$ and $z$ are time and the vertical coordinate system. The integral is taken form the surface ($z=\eta$) to the bottom ($z=0$). Near bottom and surface estimates were made by linear extrapolation of the suspended sediment and velocity profiles. While we could have also extrapolated the profiles with a log-layer for velocity and Rouse profile for sediment, the highly stratified conditions that prevailed during this experiment tended to produce near bottom velocity profiles that were more often linear than logarithmic in nature.

Figure 7 shows the results of this calculation, along with estimates of the depth averaged velocity and depth averaged suspended sediment concentration. Depth averaged velocities are maximum during the ebb when tidal currents augments river flows. Depth averaged ebb velocities exceed 75 cm/s prior to the dreding operation and reduce to just above 50 cm/s approaching neap tides on Dec 9th. However, both flood and ebb currents increase in response to the storm event on Dec 9th. Currents during the flood are weaker than those during the ebb with maximum values of exceeding 60 cm /s occurring during the spring tide around Dec 3 and again during the storm event on the 10th while flooding currents are weaker on Dec 7-8.
Depth averaged TSS shows variability consistent with the flow velocities. As expected enhanced TSS levels occur during higher current speeds. In the early part of the record depth averaged TSS levels generally exceeded 100 mg/l throughout much of the ebb. TSS levels drop following the 5th and while they do at time exceed 100 mg/l during peak ebb on the 6th and 7th, levels drop below 50 mg/l throughout the tidal cycle on the 8th and 9th. The storm event on the 9th increases TSS levels to 100-200 mg/l. During the dredging operation on Dec 5th and 6th (shown as grey background on figure 7) enhanced TSS levels at site 4 are apparent during the ebb at site 2 relative to site 4. During the ebb site 4 is downstream of the dredge while site 2 is upstream, and thus the enhanced levels observed at site 4 are suggestive of the release of sediments during the dredging operation. Later in the record, however, there is no evidence of the enhanced sediment concentration associated with dredging operation.

The lower panel in figure 7 shows estimates of sediment flux as calculated by equation 4. In general these estimates of sediment flux are relatively close, with the mean flux from mooring 2 equal to 1.13 kg/s, while that at site 4 1.26 kg/s. There is evidence of enhanced sediment flux during the ebbs on Dec 5th and 6th at site 4 relative to site 2 during the dredging operation. On Dec 5th the mean flux across section 2 was 3.6 kg/s while it was 5.1 kg/s across section 4. Similarly on the 6th the mean flux past section 2 was 3.0 kg/s and 4.7 kg/s past section 4. While this suggests a release rate of 1.5-1.7 kg/s we note that enhanced sediment fluxes past section 4 are also evident on Dec 3rd and 4th and prior to the dredging operation began. Shipboard surveys (shown next) show significant lateral variability in TSS concentration and current speed and it is likely that this lateral variability confounds short term estimates made with the moored instruments.
Subsequently, results from the moored data are inconclusive in regards to estimating the release rate of sediments from the dredging operation.

LISST data from the moorings also show systematic variability over the tidal cycle, but no discernible signal associated with dredging. Figure 8 shows the particle size distribution (PSD) from the LISST at site 4 as a function of salinity stratification. Here strong stratification is defined as surface to bottom salinity differences greater than 5 psu. Moderate stratification is defined for salinity differences between 3-5 psu, weak stratification 1-3 psu and no stratification defined for surface to bottom salinity differences less than 1 psu. While the river is stratified the LISST shows that the total volume of particles increases with bin size up to the largest bin size reported by the LISST (500 μm). Previously published data with digital floc camera from the Passaic River (Mikkleson et al., 2005) reported that the median particle size observed in the Passaic was greater than 500 μm, and this is consistent with PSD shown during stratified conditions. However, as the river becomes weakly stratified and unstratified there is a clear tendency for the particle size to decrease when the river is unstratified during which time the median particle size around the 100 μm. This suggests that particles primarily travel as flocs during stratified conditions and may be broken into smaller particles during times of weaker stratification and greater turbulence. Alternatively, this may reflect the resuspension of 200-300 size particle during enhanced turbulent events associated with the unstratified conditions.

The analysis of the particle size distribution also utilized the LISST profiling data taken from the Julia Miller. In general there was no clear evidence of a change of particle size distribution in the dredge plume. Like the moored data, I believe the natural
variability in particle size distribution obscured this signal. However, there is one event
that showed a change in PSD upstream and down stream of the dredge. On Dec 6th 14:45
there was a large release of sediments from the dredging operation (this is discussed in
the next section). During this time LISST profiles were taken upstream and down stream
of the dredge (Figure 9) and there is a clear change in the depth averaged particle size
distribution during this time. Upstream of the dredging operation the volume of particles
increases with LISST bin—suggesting that the mean particle size is larger than 500 \( \mu \text{m} \).
In contrast down stream of the dredge there is a clear increase in the volume of particles
in the 200-300 \( \mu \text{m} \) range. While this change in particle size concentration also occurs as
the river destratifies during the ebb (Figure 8), the moored LISST data shows PSD
increasing monotonically with bin number (such as in the upstream sample) during this
time period. Therefore this tentatively suggest that the dredging operation results in the
release of particles in the 200-300 \( \mu \text{m} \) range.

**Sediment release rates from shipboard Surveys**

With the shipboard surveys we resolved lateral variability in both TSS and
velocity structure. Figures 10-1 through 10-42 each show 4 cross-channel sections of
velocity and suspended sediment in the vicinity of the dredging operation. These figures
represent all of the shipboard surveys from which estimates of suspended sediment fluxes
were made. With these sections lateral variability is resolved and the transport of
suspended sediment past each section was calculated as:

\[
\text{TSS}_{\text{flux}} = \int_{a}^{b} \int_{0}^{\eta} (\vec{u} \cdot \vec{n}) \text{TSS} \, dz \, dy. \tag{5}
\]
where the quantity \( \mathbf{u} \cdot \mathbf{n} \) is the velocity normal to the transect \( y \) is the cross-channel coordinate, and \( a \) and \( b \) are the ends of the transects. Other terms are the same as described in equation 4. In these series of figures a map is shown depicting the location of the transects along with vectors showing the current velocity and the location of the dredge. The transects are color coded with transect 1-4 colored black, red green and blue respectively. The second panel in the upper left shows the suspended sediment transport per unit width, which is the result of the vertical integral in equation 5, for each section. The lower 4 panels depict the along-channel velocity and TSS for each section. In the lower left of each panel the total sediment flux (results of equation 5) and the time are reported. For example figure 10-6 shows a series of transects during the ebb on Dec 5th between 13:47-13:57. The panel showing the section across track 2 shows clear evidence of suspended sediment release from the dredge. In contrast to the natural tendency for suspended sediment is to increase towards to bottom, TSS levels are elevated near the surface immediately downstream of the dredge. In addition the flux of suspended sediment in the vicinity of the dredge (between 30-50 meters) is elevated from the upstream section. Sediment flux at section 1 is 5.4 kg/s, while for section 2 immediately down stream of the dredging operation it is 7.8 kg/s. While section 3 shows a reduction in TSS flux note that this section is shorter (less than 100m) and missed sediment fluxes on the flank. Section 4, which ran across the entire channel, TSS flux was back up at 7.0 kg/s.

Also note that the dredge also impacts the flow structure. In section 1, upstream of the dredge, the velocity is strongest on the northern side of the channel and decrease monotonically to the south. In contrast, immediately down stream of the dredging
operation at section 2 there is a minimum in current velocity in the vicinity of the dredge.

During strong currents this pattern was frequently observed, such as in figure 9-3 where currents are greater than 50 cm/s on the flanks of the channel in section 2 but less than 25 cm/s in the vicinity of the dredge. While it is possible for increased turbulence downstream of the dredge to increase backscatter, the fact that there is no increase backscatter in the dredges wake apparent in figure 10-3 suggests that increased turbulence by the dredge does not significantly impact the TSS estimates in the vicinity of the dredge.

Table 1 compiles the estimates of the TSS flux from sections taken immediately upstream and down stream of the dredge (such as the upstream track 1 and the down stream track 2 in figure 10-6). Upstream and down stream are defined by the current flow, so that the upstream estimate is to the east of the dredge during the flood and to the west of the dredge during ebb. During slack water upstream is poorly defined TSS flux estimates are not compared. The 5th column reports the change in TSS flux between these two sections, and a positive number indicates a release of sediments by the dredging operation. Over the course of the weeklong study 29 upstream and down stream pairs of TSS flux estimates were made. In general they show increased TSS loads downstream of the dredging operation indicating the release of sediments. Of the 29 estimates of the change in TSS flux across the upstream and downstream sections 21 are positive, suggestive of release, 3 are zero and 5 are negative. Negative numbers are indicative of the noise in this measurement. Nevertheless, the tendency for an increase in TSS fluxes downstream of the dredging operation suggest that the shipboard measurements did detect the release of sediments from the dredging operation.
A second robust result of this is the day to day variations in the release rate. On Dec 5th the mean release rate was 2.3 kg/s and 1.8 kg/s on Dec 6th. While for Dec 7,8 and 10 the estimated rates of release were 0.3 kg/s, 0.85 kg/s and 0.3 kg/s respectively. While there is significant scatter in the estimates, even for specific days, this trend for reduced release rates on the last 3 days of dredging operation is consistent with the changes in dredging operation over this time period. In particular the dredging operation was altered on 12/7 such that the amount of sediment removed during each bite was significantly reduced. Table 2 relates these release rates to dredge production rates (from Scott Thompson, Malcolm-Pernie). During these 5 days (Dec 5-8, 10) the dredging production was approximately (these numbers taken of bar graph presented by Scott Thompson Aug 2006) were 135 yd$^3$/hour, 215 yd$^3$/hour, 115 yd$^3$/hour, 90yd$^3$/hour, and 100 yd$^3$/hour respectively. Assuming a mean sediment density of 1300 kg/m$^3$ (based on analysis Sediment cores collected by Earth Tech and Malcolm Pirnie collected July 2004) the release rates that we estimate correspond to loss rates of 6. % on Dec 5th, 3 % on Dec 6, 1 % on Dec 7th, 3% on Dec 9th and 1% on Dec 10th. While these numbers are in the range of expected values, I note that significant scatter in individual estimates of the release rate. While much of this scatter is likely due to experimental error and environmental noise, the release rate itself is also likely to be a noisy signal. Subsequently it is difficult to assess what fraction of this “noise” is the actual “signal”, i.e. sediment released from the dredge, and what fraction is true “noise” ,i.e. natural variability of the TSS field. Consequently, it is difficult to place error bars on these estimates of the release rate. As an example of the “noise” associated with the true signal of release consider that the average release rate on Dec 8th was significantly impacted by
TSS flux is 6.0 kg/s compared to 3.8 at track 3 upstream of the dredge. The spatial structure of TSS along this section leaves no doubt that this is in fact a release from the dredge, because TSS levels are elevated high and the water column. However, the fact that this is not observed throughout the day suggests that there is a significant intermittency to the release. A large release also occurred on Dec 10th at 12:50 EST (Figure 9-41). Like the release on the 9th this shows elevated TSS occurring high in the water column immediately down stream of the dredge which is an unambiguous signature of the release of sediments by the dredge. An important unresolved issue is the frequency these intermittent releases occur. Nevertheless, the fact that the estimate of the rate that sediments are released fall in expected the 1-3% range suggests that these estimates of the rate of release are reasonable.

Conclusions

Analysis of shipboard and moored data have characterized estuarine conditions during the Passaic River Pilot Dredging operation that took place December 5-10, 2005. Prior to the dredging operation a large discharge event exceeding 100 m$^3$/s drove the estuarine salt wedge into the vicinity off the dredging operation. High turbidity associated with this salt wedge obscured efforts to estimate sediment release rates from the dredging operation with the moored data. However, the dredge plume was evident in the shipboard ADCP data from which we estimated daily release rates varied from 1% to 6% of the total sediment dredged. While there is significant scatter in the individual estimates of the release rates, due to both the noisy nature of the “signal” and significant environmental
“noise” associated with the passing turbidity maximum, the estimates of the release rate fall within the expected range of a few percent. Furthermore, the tendency for shipboard surveys to show an increase in sediment loadings down stream of the dredge strongly supports that the shipboard ADCP data detected the dredge plume. Finally, shipboard Doppler current profile data indicated that the dredge structure significantly modifies the flow field, and thus transport processes, immediately down stream of the dredging operation.

References

Table 1: TSS flux estimates from Caleta

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>TSS\text{flux}_upstream</th>
<th>TSS\text{flux}_downstream</th>
<th>Change in TSS\text{flux}</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec 5</td>
<td>9:10-9:38</td>
<td>1.3 kg/s</td>
<td>3.8 kg/s</td>
<td>2.5 kg/s</td>
<td>Not yet dredging. Change in TSS flux likely due to drop in current speed</td>
</tr>
<tr>
<td>Dec 5</td>
<td>10:50-11:15</td>
<td>0.7</td>
<td>0.8</td>
<td>0.1</td>
<td>Weak Current.</td>
</tr>
<tr>
<td>Dec 5</td>
<td>12:13-12:46</td>
<td>1.1</td>
<td>1.5</td>
<td>0.4</td>
<td>High TSS on track 3 but not track 2</td>
</tr>
<tr>
<td>Dec 5</td>
<td>12:49-13:04</td>
<td>1.3</td>
<td>2.5</td>
<td>1.2</td>
<td>Clear evidence of release and reduction of current along track 3</td>
</tr>
<tr>
<td>Dec 5</td>
<td>13:31-13:46</td>
<td>4.2</td>
<td>7.0</td>
<td>2.8</td>
<td>Strong Ebb</td>
</tr>
<tr>
<td>Dec 5</td>
<td>13:47-13:57</td>
<td>5.4</td>
<td>7.8</td>
<td>2.4</td>
<td>Strong Ebb</td>
</tr>
<tr>
<td>Dec 5</td>
<td>14:25-15:02</td>
<td>6.2</td>
<td>13</td>
<td>6.8</td>
<td>Max Ebb</td>
</tr>
<tr>
<td>Dec 6</td>
<td>9:53-10:00</td>
<td>1.3</td>
<td>1.4</td>
<td>0.1</td>
<td>Averaged from two upstream and downstream sections. Weak flood.</td>
</tr>
<tr>
<td>Dec 6</td>
<td>13:11-13:25</td>
<td>0.65</td>
<td>1.55</td>
<td>0.9</td>
<td>Averaged from two upstream and downstream sections. Weak Ebb.</td>
</tr>
<tr>
<td>Dec 6</td>
<td>14:02-14:26</td>
<td>1.6</td>
<td>8.2</td>
<td>6.2</td>
<td>Strong Ebb. Large release signal</td>
</tr>
<tr>
<td>Dec 6</td>
<td>14:51-14:53</td>
<td>5.6</td>
<td>5.6</td>
<td>0</td>
<td>Higher TSS flux down stream</td>
</tr>
<tr>
<td>Dec 6</td>
<td>15:31-15:36</td>
<td>7.3</td>
<td>6.6</td>
<td>-7</td>
<td>Strong ebb</td>
</tr>
<tr>
<td>Dec 7</td>
<td>9:08-9:26</td>
<td>1.1</td>
<td>1.3</td>
<td>0.2</td>
<td>Weak Flood</td>
</tr>
<tr>
<td>Dec 7</td>
<td>9:39-10:00</td>
<td>1.5</td>
<td>1.5</td>
<td>0</td>
<td>Flood</td>
</tr>
<tr>
<td>Dec 7</td>
<td>10:33-11:09</td>
<td>1.9</td>
<td>2.3</td>
<td>0.4</td>
<td>Flood</td>
</tr>
<tr>
<td>Dec 7</td>
<td>12:39-13:05</td>
<td>0.6</td>
<td>0.35</td>
<td>-0.25</td>
<td>Weak Ebb</td>
</tr>
<tr>
<td>Dec 7</td>
<td>13:16-13:40</td>
<td>0.7</td>
<td>1.1</td>
<td>0.4</td>
<td>Clear plume in track 1</td>
</tr>
<tr>
<td>Dec 7</td>
<td>14:31-14:50</td>
<td>1.1</td>
<td>1.7</td>
<td>0.6</td>
<td>Average of two tracks for both estimates. Clear plume down stream</td>
</tr>
<tr>
<td>Dec 7</td>
<td>14:31-15:39</td>
<td>1.5</td>
<td>2.3</td>
<td>0.8</td>
<td>Clear plume in track 2 but not in track 3</td>
</tr>
<tr>
<td>Dec 7</td>
<td>15:55-16:01</td>
<td>2.35</td>
<td>2.9</td>
<td>0.55</td>
<td>Average of two upstream and downstream tracks</td>
</tr>
<tr>
<td>Dec 7</td>
<td>16:10-16:17</td>
<td>3.6</td>
<td>3.6</td>
<td>0</td>
<td>Choose tracks 1 &amp; 4 because 2&amp;3 are short</td>
</tr>
<tr>
<td>Dec 8</td>
<td>10:03-10:15</td>
<td>2.1</td>
<td>3.1</td>
<td>1.0</td>
<td>Flood</td>
</tr>
<tr>
<td>Dec 8</td>
<td>11:35-11:53</td>
<td>3.8</td>
<td>6.0</td>
<td>2.2</td>
<td>Large release apparent in track 2</td>
</tr>
<tr>
<td>Dec 8</td>
<td>12:52-13:07</td>
<td>0.2</td>
<td>0.3</td>
<td>0.1</td>
<td>Near Slack</td>
</tr>
<tr>
<td>Dec 8</td>
<td>14:37-14:44</td>
<td>0.7</td>
<td>0.8</td>
<td>0.1</td>
<td>Weak Ebb</td>
</tr>
<tr>
<td>Dec 10</td>
<td>8:43-9:02</td>
<td>3.8</td>
<td>3.3</td>
<td>-5</td>
<td>Strong Ebb</td>
</tr>
<tr>
<td>Dec 10</td>
<td>9:21-9:49</td>
<td>3.5</td>
<td>2.8</td>
<td>-7</td>
<td></td>
</tr>
<tr>
<td>Dec 10</td>
<td>12:47-13:02</td>
<td>5.3</td>
<td>8.2</td>
<td>2.9</td>
<td>GPS error on Caleta. Peak Flood</td>
</tr>
<tr>
<td>Dec 10</td>
<td>13:38-13:55</td>
<td>9.8</td>
<td>9.5</td>
<td>-0.3</td>
<td>Clear plume signal in TSS field in track 2</td>
</tr>
</tbody>
</table>
Table 2: Estimates of Daily Release Rates

<table>
<thead>
<tr>
<th>Date</th>
<th>Production Rate (yd$^3$/hour)</th>
<th>Production Rate (kg/s)</th>
<th>Release Rate (kg/s)</th>
<th>Release Rate (%)</th>
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</thead>
<tbody>
<tr>
<td>Dec 5</td>
<td>135</td>
<td>37</td>
<td>2.3</td>
<td>6</td>
</tr>
<tr>
<td>Dec 6</td>
<td>215</td>
<td>58</td>
<td>1.8</td>
<td>3</td>
</tr>
<tr>
<td>Dec 7</td>
<td>115</td>
<td>31</td>
<td>0.3</td>
<td>1</td>
</tr>
<tr>
<td>Dec 8</td>
<td>90</td>
<td>25</td>
<td>0.85</td>
<td>3</td>
</tr>
<tr>
<td>Dec 10</td>
<td>100</td>
<td>27</td>
<td>0.3</td>
<td>1</td>
</tr>
</tbody>
</table>
Figure 1 Study site. Insert shows location of dredge (grey box) and 6 mooring sites.
Figure 2. Scatter plot used to calibrate ADCP for TSS estimates. X axis is the acoustic backscatter from the shipboard ADCP, Y axis is total suspended sediment obtained from samples.
Figure 3 Scatter plot showing calibration curve for OBS. Red dots are for OBS that was used on Caleta While blue dots are for OBS used primarily on Juila Miller.
Mean Discharge During Pilot Dredging was 65 m³/s

Figure 4. Upper panel shows river discharge from Little Falls. Lower panel shows sea level from NOAA station at Bergen Point (blue) and pressure sensor at mooring 6. Grey box is time of dredging operation.
Figure 5. Salinity and TSS field on Dec 6th at the end of flood. Dredging operation is around mile 2.8. The Bridge Street Bridge in Newark is at mile 5.
Figure 6a. Moored data from site 2 on Dec 5th and 6th. Along channel velocity is shown in black contours with the zero isopleth drawn as a thick line. Flooding velocities are dotted black contours while ebbing currents are solid black. Red and blue line show bottom and surface salinity respectively (axis to fight). Brown color indicates TSS levels, which are contoured in white.
Figure 6b. Moored data from site 2 on Dec 7th and 8th. Along channel velocity is shown in black contours with the zero isopleth drawn as a thick line. Flooding velocities are dotted black contours while ebbing currents are solid black. Red and blue line show bottom and surface salinity respectively (axis to fight). Brown color indicates TSS levels, which are contoured in white.
Figure 6c. Moored data from site 2 on Dec 9th and 10th. Along channel velocity is shown in black contours with the zero isopleth drawn as a thick line. Flooding velocities are dotted black contours while ebbing currents are solid black. Red and blue line show bottom and surface salinity respectively (axis to fight). Brown color indicates TSS levels, which are contoured in white.
Figure 7 Top panel. Depth averaged current from site 2 (blue) and site 4 (red). Middle panel depth averaged TSS at site 2 and site 4. Lower panel. Estimate of the transport of suspended sediment from site 2 and site 4.
Figure 8. Particle size distribution from LISST at site 4 as a function of stratification. Strong stratification is defined for times when surface and bottom salinity differences ($\Delta S$) are greater than 5. Moderate stratification defined as $3 < \Delta S < 5$, weak stratification as $1 < \Delta S < 3$ and weak stratification for $\Delta S < 1$. 
Figure 9. Depth averaged Particle size distribution from LISST data from Julia Miller from casts taken upstream (1) and downstream of dredge during time of significant release of dredged materials.
Figure 10-1. Panel in upper left shows location of sections (colored lines) and surface currents (blue vectors), dredge location (grey) and mooring location (black dots). Upper right shows estimates of TSS transport per unit width from the four sections. The color of each line is consistent with the colors drawn on maps. Lower four panels show velocity (contours) and TSS (brown) for each of the four transects. Color used for the title of each of these graphs coincides with the color of the track drawn on the map. Estimate of the TSS flux and time are indicated in white in lower left on each of these four panels.
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