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Coastal and Hydraulics Laboratory

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Regional Sediment Management and Dredging Operation

Field Measurement and Monitoring of Hydrodynamic and Suspended Sediment within the Seven Mile Island Innovation Laboratory, New Jersey

Kelsey A. Fall, David W. Perkey, Zachary J. Tyler, and Timothy L. Welp

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Abstract

The Seven Mile Island Innovation Laboratory (SMIIL) was launched in 2019 to evaluate beneficial use of dredge material management practices in coastal New Jersey. As part of that effort, the Philadelphia District requested that the US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, collect data to characterize the hydrodynamics and turbidity within the central portions of the SMIIL prior to and during dredge material placement. Pre-dredge monitoring found that apart from punctuated wind events, the study area waters were generally calm and clear with small waves, <0.25 m, slow current speeds (~0.1 m/s), low turbidity (~10 ntus), and low suspended sediment concentrations (~10–20 mg/L). In March 2020, 2,475 m^3 of dredged sediment was placed on the northern portion of Sturgeon Island within the SMIIL. Turbidity in the waters surrounding the island was monitored to quantify extent of the sediment plume resulting from the placement. Observations found little to no turbidity plume associated with the dredging operations beyond 20 m from the island and that the plume was largely limited to areas near a tidal creek draining the placement area. Additionally, turbidity levels quickly returned to background conditions at times when the dredge was not in operation.

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Preface

This study was conducted for the US Army Corps of Engineers, Philadelphia District, under Funding Account Code 665JK9, AMSCO Code 031398, MIPR 665JK9.

The work was performed by the Field Data Collection and Analysis Branch and the Coastal Engineering Branch of the Navigation Division, US Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL). At the time of publication of this report, Mr. William Butler was Chief, Field Data Collection and Analysis Branch, and Ms. Lauren Dunkin was Chief, Coastal Engineering Branch; Ms. Ashley Frey was Acting Chief, Navigation Division; and Mr. Charles E. Wiggins was the Technical Director for Navigation. The Deputy Director of ERDC CHL was Mr. Keith Flowers, and Dr. Ty V. Wamsley was the Director.

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

1 Introduction

1.1 Background

Increases in rates of sea-level rise and frequency of coastal flooding in recent decades have helped bring about a change in perception regarding dredged sediment in coastal areas. Instead of viewing these sediments as a contaminant to dispose of, many coastal managers are seeking to emphasize regional sediment management practices that utilize dredged material as resources for beneficial use across various coastal environments for both storm protection and environmental restoration. In line with this view of coastal sediment management, the US Army Corps of Engineers, Philadelphia District (NAP), in conjunction with the State of New Jersey and The Wetlands Institute (TWI), announced the launch of the Seven Mile Island Living Lab (SMILL) in March of 2019 (Figure 1). In December 2019, the name was changed to Seven Mile Island Innovation Laboratory (SMIIL) to better capture the goals and intent of the program, to advance innovative approaches to restoring marshes.

A key aspect of the SMIIL initiative is to evaluate innovative dredge material management practices and alternatives in coastal New Jersey to advance and improve dredging and marsh restoration techniques through research, collaboration, knowledge sharing, and practical application. NAP is proposing to perform multiple pilot studies involving the placement of dredged sediment from the nearby New Jersey Intracoastal Waterway (NJIWW) within the laboratory for wetland restoration. To help inform placement strategies for these studies, data that describe the wave energies, current velocities, and suspended sediment concentration (SSC) in the vicinity of the proposed study areas are required. To obtain these data, NAP requested the US Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), to deploy instrumentation to measure hydrodynamic and SSC conditions within portions of the SMIIL.

Shark and Sturgeon Islands were identified as potential pilot study sites for dredge material placement following a kickoff meeting held in April 2019 (Figure 1C). The Shark Island site was selected to evaluate whether the hydrodynamic conditions within local tidal creeks were sufficient for efficiently transporting sediment into the marsh. If so, a potential dredged material placement strategy would be to place sediment near these creeks and allow the natural hydrodynamics to passively transport sediment throughout the marsh system as opposed to actively placing sediment across the marsh with dredge equipment. The second study site, Sturgeon Island, was selected based on its critical bird nesting habitat that was deteriorating due to increased flooding frequency. Plans were discussed to place dredged material on the northern end of the island to increase elevation and potentially dissipate wave energy to reduce marsh edge erosion. For both study sites, a series of instruments were deployed to measure pre-placement hydrodynamic and SSC conditions during the fall of 2019.

In March 2020, NAP dredged 2,475 m^3[*†] of sediment from the channel and placed this material on the northern portion of Sturgeon Island. ERDC CHL performed turbidity monitoring in the waters surrounding the island during placement.

1.2 Objective

The goal of this study was to characterize the pre-placement hydrodynamic and suspended sediment conditions of the study area, and document the turbidity generated by dredged sediment placement upon Sturgeon Island. Additionally, results from the study were used to inform recommendations for future placement studies and long-term monitoring needs within the SMIIL.

1.3 Approach

A variety of surveys were conducted, and instruments deployed to collect observational data to support this project. Specific details on the methods used to collect these data are described in section 2 of this report.

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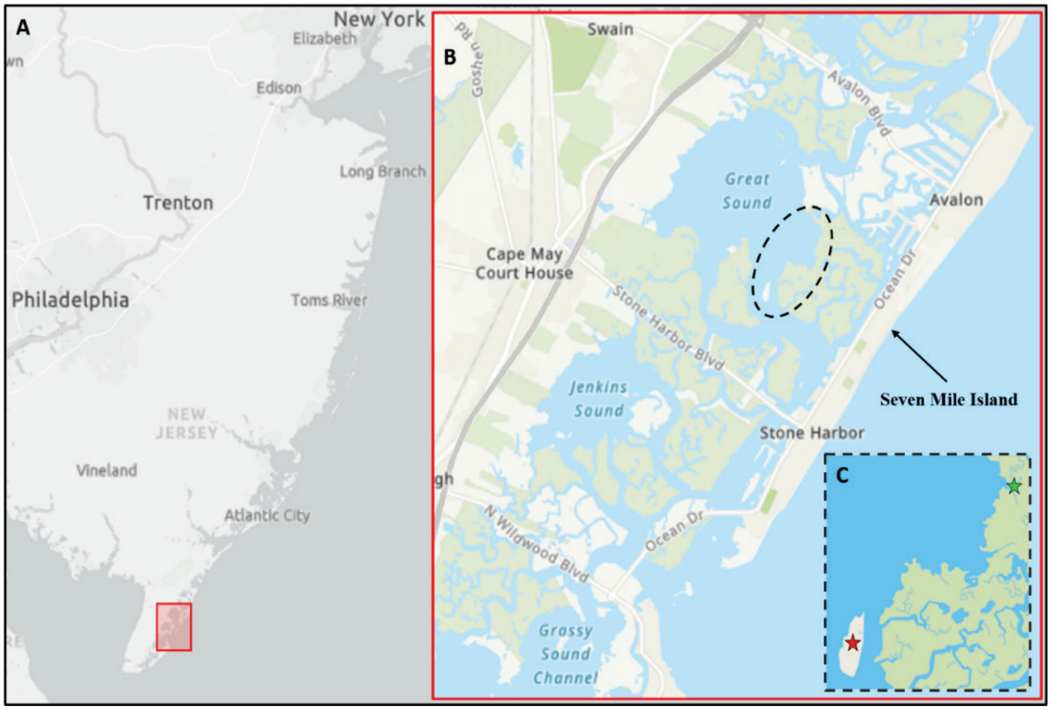
[*] For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248-52, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

[†] 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.

1.4 Study site

Seven Mile Island is a barrier island located along the southern coast of New Jersey in Cape May County (Figure 1A). The SMIIL extends between the inlet boundaries of Seven Mile Island and includes 6000 acres of state-owned marshland that provides an essential habitat for wildlife and coastal resilience for barrier island communities (Figure 1B). Water depths within the SMIIL are typically less than 1 m at Mean Lower Low Water (MLLW). Tidal conditions are characterized as mixed semidiurnal with a tidal range of approximately 1–2 m. Marshes in this area are showing signs of degradation and are vulnerable to impact from rising seas and storms. Following Hurricane Sandy in 2012, NAP partnered with the state of New Jersey and other private, non-profit organizations to conduct multiple marsh restoration projects utilizing dredged material from the nearby NJIWW. Additional dredged material placement projects are being conducted and planned within the central portion of SMIIL, indicated by the dashed oval in Figure 1B. To help inform potential placement strategies within this area, initial hydrodynamic and SSC observations were collected at Shark and Sturgeon Islands (indicated by the green and red stars, respectively, in Figure 1C) in the fall of 2019. In March 2020, dredged material was placed along the northern section of Sturgeon Island. Turbidity and SSC monitoring were conducted around the northern portions of the island throughout this placement activity.

Figure 1. Study area map. The regional location of the study area is shown with the red box in (A). The areas that constitute the SMIIL are indicated in (B). The dashed oval within (B) represents the specific portions of SMIIL that are a focus of this report, which is also shown in insert (C). The green and red stars in insert (C) indicate the locations of Shark (green) and Sturgeon (red) Islands, which were the areas that hydrodynamic and SSC observations were collected in 2019 and turbidity monitoring associated with active placement was done in 2020 (Sturgeon Island only).



2 Methods

2.1 Pre-dredged material placement monitoring

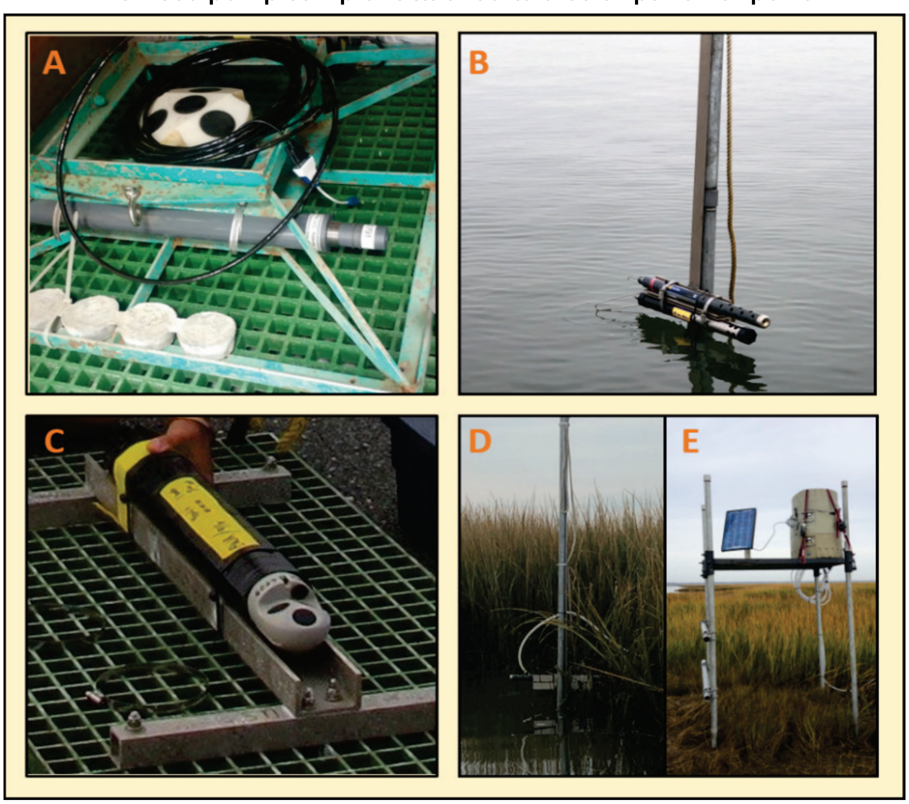
Three data collection sites were established to measure hydrodynamics, turbidity, and SSC within the study area prior to dredged material placement (Figure 2). Instrumentation was deployed at all three stations in October 2019, and monitoring continued through December 2019. Due to limited instrument availability in October, water quality sondes used to measure conductivity, temperature, depth, and turbidity were deployed at each station over different time frames. YSI 600 OMS sondes were deployed in early October; however, concerns over the battery life of these instruments required that In-Situ Aquatroll 600 sondes be deployed when they became available. A brief description of the instrumentation deployed at each site is presented in the following paragraphs and is summarized in Table 1 at the end of this section.

Figure 2. Instrument locations for the Fall, 2019 deployments. Instruments were deployed at (1) Shark Island Embayment, (2) Shark Island Tidal Creek, and (3) Sturgeon Island.

2.1.1 Shark Island Embayment

To assess the wave energy and current velocities within the water column near the mouth of a tidal creek, an upward-looking, bottom-mounted, Nortek, 1MHz acoustic wave and current profiler (AWAC) was deployed along the northwestern end of Shark Island, indicated by station 1 in Figure 2. To measure turbidity, temperature, and salinity a YSI 600 OMS sonde and an In-Situ Aquatroll 600 sonde were co-located with the AWAC on a pole mount approximately 75 cm above the bottom (Figure 3A and 3B). This elevation was selected so that collected turbidity data would be outside the vertical acoustic blanking distance of the AWAC and allow for direct comparison between turbidity and acoustic backscatter measurements. The YSI 600 OMS and In-Situ Aquatroll 600 sondes were programmed to sample at 15 min increments. Waves and current velocity profiles were measured using the AWAC. Wave data were sampled at 2 Hz every half hour while current velocities throughout the water column were collected in 50 cm vertical bins, every 15 min.

Figure 3. Photos of deployed instrumentation. (A) Nortek AWAC in upward-facing bottom mount. (B) Pole-mounted YSI 600 OMS (top) and In-Situ Aquatroll 600 (bottom). (C) Nortek Aquadopp in upward-facing bottom mount. (D) Pole-mounted turbidity sondes and Isco intake line. (E): Platform with Isco pump sampler attached to a solar panel for power.



2.1.2 Shark Island tidal creek

A bottom-mounted, upward-looking Nortek 2 MHz Aquadopp acoustic doppler current profiler (ADCP), as shown in Figure 3C, was deployed within the tidal creek at station 2 (Figure 2) to measure current velocities and water levels within the channel. Turbidity within the creek was measured with a YSI 600 OMS sonde and an In-Situ Aquatroll 600 sonde that were pole-mounted approximately 60 cm above the bottom. These water quality sondes were deployed near the ADCP, along the southern bank of the channel (Figure 3D). As with station 1, the elevation of the sondes was such that they were above the vertical blanking distance of the ADCP. Additionally, an Isco water pump sampler, with a carousel containing twenty-four, 1 L bottles, was deployed on top of a constructed platform along the southern bank of the tidal creek (Figure 3E). The intake line for the Isco sampler was co-located with the sondes (Figure 3D). While sampling intervals varied throughout the deployment, generally two water samples were collected each day at various stages of the tidal cycle. Multiple service trips were performed by personnel from TWI to recover pumped samples, refill the carousel with empty bottles, and reprogram the Isco sampling interval. Collected water samples were delivered to ERDC CHL for SSC analysis (ASTM 2019). Both the YSI 600 OMS and In-Situ Aquatroll 600 sondes sampled at 15 min increments. ADCP current velocity profiles were collected at 10 cm vertical bins throughout the water column every 5 min.

2.1.3 Sturgeon Island

To assess the wave energy, current velocities, and turbidity within the water column near Sturgeon Island, an instrumentation package identical to that deployed at Shark Island Embayment (Figure 3A) was placed on the northwestern portion of Sturgeon Island as indicated by station 3 in Figure 2. Instrumentation setup and sampling frequencies at Sturgeon Island replicated the instrument setup at Shark Island.

Table 1. Descriptions of sensors deployed at each station in late 2019 for initial SMIIL monitoring effort. The table includes instrument name, the parameters measured, sampling rate, and respective dates the different water sondes (Aquatroll and YSI) were deployed.

Instrument	Parameter Measured	Sampling Rate
Shark Island Embayment		
Nortek AWAC	Wave Height, Wave Period, Water Level, Current Velocity	30 min/15 min
In-Situ Aquatroll Sonde (Nov 2019 – Dec 2019)	Turbidity, Temperature, Salinity, Water Level	5 min
YSI 600 OMS Sonde (Oct 2019 – Dec 2019)	Turbidity, Temperature, Salinity, Water Level	5 min
Shark Island Tidal Creek		
Nortek Aquadopp ADCP	Current Velocity Profile	5 min
In-Situ Aquatroll Sonde (Nov 2019 – Dec 2019)	Turbidity, Temperature, Salinity, Water Level	5 min
YSI 600 OMS Sonde (Oct 2019 – Dec 2019)	Turbidity, Temperature, Salinity, Water Level	5 min
Isco Water Sampler	Total suspended solids	1–2/day
Sturgeon Island		
Nortek AWAC	Wave Height, Wave Period, Water Level, Current Velocity	30 min/15 min
In-Situ Aquatroll Sonde (Nov 2019 – Dec 2019)	Turbidity, Temperature, Salinity, Water Level	5 min
YSI 600 OMS Sonde (Oct 2019 – Dec 2019)	Turbidity, Temperature, Salinity, Water Level	5 min

2.2 Sturgeon Island dredged material placement monitoring

Monitoring of dredged material placement activities on Sturgeon Island took place March 16–19, 2020, in accordance with New Jersey State Environmental Permitting. Dredging was performed by the *FULLERTON*, a cutterhead dredge (owned and operated by Barnegat Bay Dredging Company) with a 14 in. discharge pipeline. The discharge pipe was positioned on the northern end of Sturgeon Island and equipped with a wye-valve which directed material through either a branch segment of 12 in. pipe terminating in either a spreader plate or spray nozzle, or the branch segment of 12 in. sediment distribution pipe (Figure 4). Figure 5 shows a photograph of the entire discharge pipeline network on Sturgeon Island. Outflow from the dredge was intermittingly switched between the spreader bar/spray discharge pipe and sediment distribution pipe branch segments or flowed through both pipes throughout dredging activities.

Figure 4. Sturgeon Island dredge material placement. Moored turbidity stations during dredge material placement along with the location of the 2019 AWAC deployment are indicated by numbered markers. The approximate location of the dredge's discharge pipeline network is indicated by black lines.

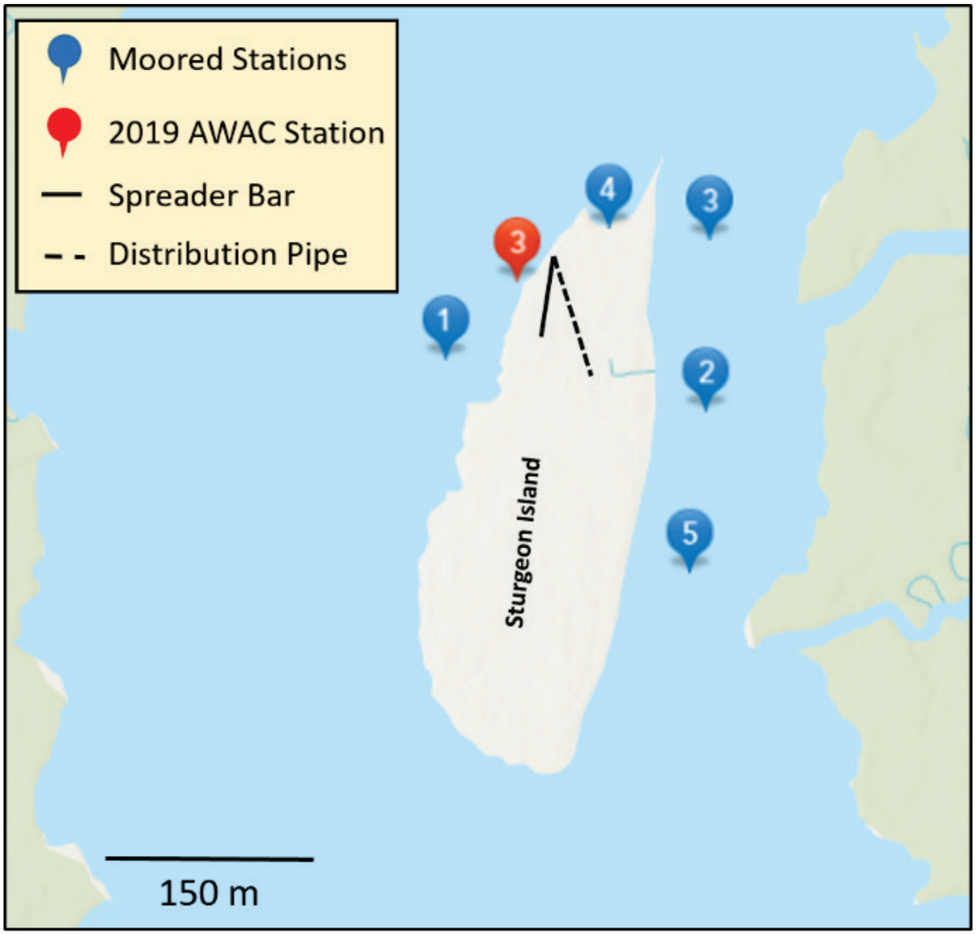
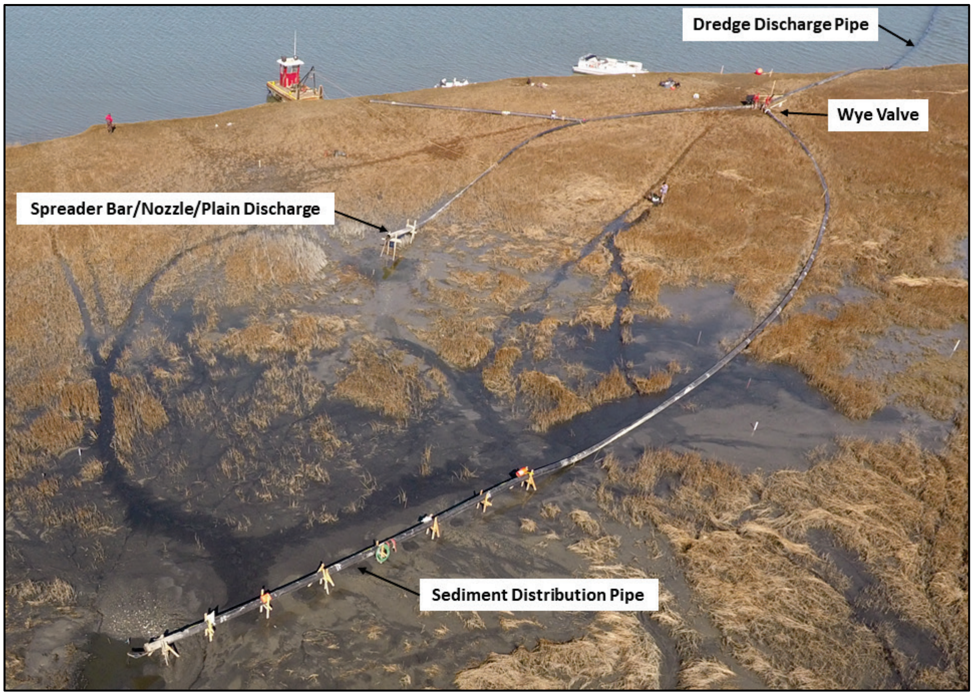


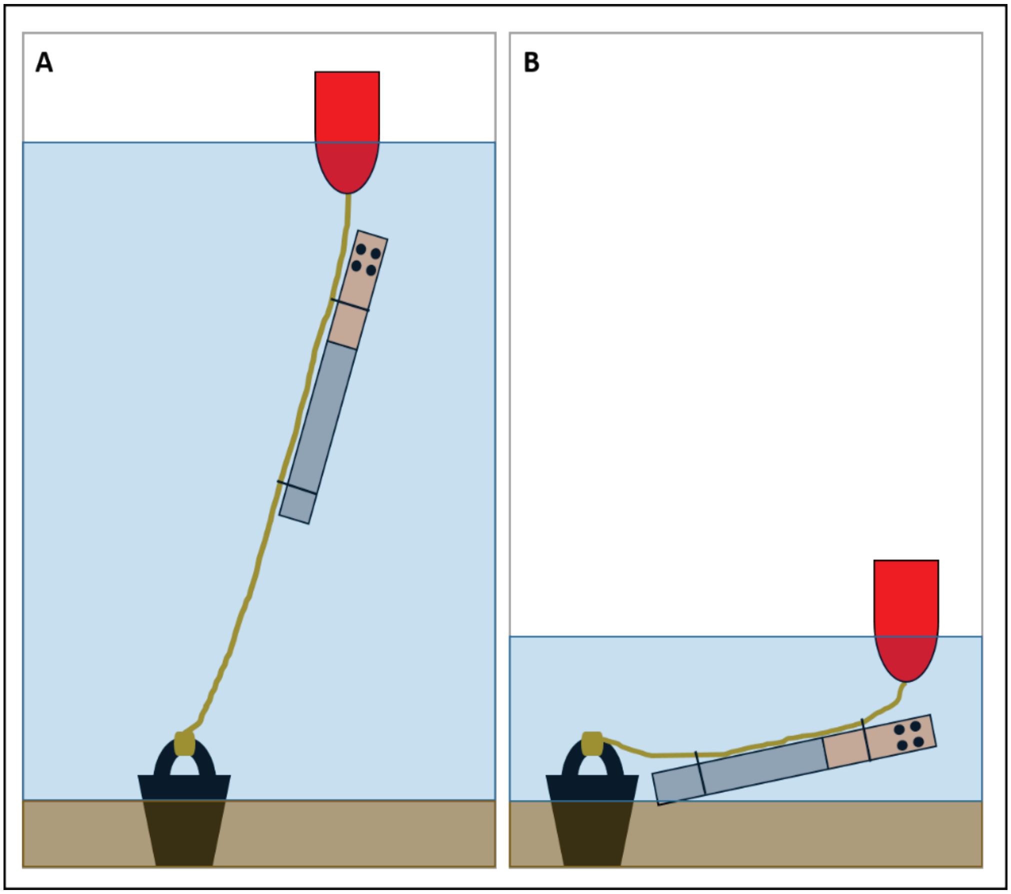
Figure 5. Photograph of the dredge *FULLERTON*'s discharge pipeline network on Sturgeon Island.



To monitor turbidity, roving turbidity measurements were acquired throughout the monitoring area with a vessel-mounted In-Situ Aquatroll 600 sonde. Due to vessel depth restrictions, turbidity surveys were restricted to the 3–4 hr before and after high tide. The vessel surveyed transects approximately parallel to the island, at various distances, typically within 200 m from the bank line. Distance from the bank was determined by the distance in which a turbidity plume was detected, such that turbidity was observed to be greater than typical background conditions of the area. The vessel maneuvered at dead slow speed (~1–2 kn) to limit the potential for vessel induced turbidity. The sonde was pole mounted and deployed over the side of the vessel 0.2–0.6 m below the surface. To correlate turbidity measurements to sediment concentration, water samples were periodically collected during the roving surveys. These samples were transported back to ERDC CHL for SSC analysis.

In addition to the roving survey, five In-Situ Aquatroll 600 water-quality sondes were moored around the northern portions of the island on the afternoon of March 16, prior to active placement (Figure 4). Water depths throughout the monitoring area were approximately 0.5 m (MLLW). To ensure that the turbidity sensor heads remained submerged and above the bed, sondes were fixed to lines and buoys such that the sensor head was positioned approximately 15–20 cm below the waterline. Therefore, turbidity measurements from these moored stations had a near consistent depth below the water surface but varied in elevation above the bottom with tidal stage throughout the monitoring (Figure 6).

Figure 6. Moored water quality sondes. Sondes were attached to lines with the turbidity sensor closest to the buoy, approximately 15–20 cm below the waterline. Schematic A shows instrument orientation and position in the water column at high tide while schematic B illustrates low tide conditions.



Active turbidity monitoring surveys during dredging operations were conducted March 17–19, 2020. Due to public health concerns in response to COVID-19, ERDC personnel were recalled to Vicksburg, MS, roving turbidity surveys were suspended, and dredge operations were shut down on March 19. Turbidity monitoring around Sturgeon Island and the newly placed dredged material continued with the five moored stations through March 24, 2020.

3 Results

3.1 Pre-dredged material placement monitoring

3.1.1 Resolution of waves with acoustic wave and current profiler (AWAC)

Data processing of the AWACs deployed at both stations (Sturgeon Island and Shark Island) found there was too much noise in the acoustic surface tracking (AST) data to resolve wave characteristics. The instrument's acoustic signal level was set to HIGH during programing, and it is suspected the signal strength was too strong for the water depths at these stations, typically 1–2 m, and contributed to the noise in the wave data. Instead, the AWACs pressure signal was used to determine wave height and period (Nortek 2018). However, due to the attenuation of pressure with depth, resolution of these wave parameters was dependent on the water level. In general, shallow water allows for the resolution of smaller waves. However, as water depth increases, the pressure signature of small waves is attenuated before reaching the sensor, and therefore only larger waves can be resolved. Pressure limitations for the conditions observed at SMIIL were such that at water levels ≤1 m, the AWACs could resolve wave periods down to 1–1.5 s, for wave heights of least 0.15–0.2 m. When water depths exceeded 2 m, the AWACs could at best resolve 1.5–2 s waves that were approximately 0.5 m in height.

3.1.2 Shark Island Embayment

During the 2019 deployment, salinity within the embayment was 33 ppt, and water temperature steadily decreased from 20°C at the start of the deployment in October to 10°C at the end of December. Tidal range was on the order of 0.5–2 m (Figure 7A), and current speeds approximately 1 m above the bed were generally less than 10 cm/s (Figure 7B).

Waves were generally small, with heights often less than 0.5 m with peak periods between 1.5–2 s (Figure 7C, D). Due to the limitations of the AWAC pressure-based measurement of waves, outlined at the beginning of Section 3, it is suspected that wave heights in Figure 7C are slightly misleading at high water levels. The drops in wave height in Figure 7 to ~ 0.1 m at water levels greater than 1 m should be interpreted qualitatively rather than quantitatively, such that they were small enough to be below resolution (~0.5 m), but the exact heights are not known. Local wind and tidal data were obtained from nearby stations for the three month deployment period and are plotted in Figure 8. Peaks in wave height were generally well correlated to wind speeds. The highest observed wave conditions occurred approximately 10/15/19 to 10/18/19 and on 10/29/19–11/01/19. Wave heights were > 0.5 m and periods >2 s. Both followed strong wind events and are denoted with pink bars on the top of the panels in Figures 10 and 11. The former corresponded to a Nor'easter passing through the area as seen in the rapid change from 5 to 8 m/s southerly winds to 5 to 7 m/s northerly winds that persisted for a few days (Figure 8A). Field notes from TWI personnel reference this particular event, as it was anticipated to be a major storm system with high winds and heavy rains following a week of higher than normal tidal levels*.

Observations found this period corresponded to a rapid change in water level, a decrease of approximately 2 m. This change is observed at the gauge station (Figure 8B) as well as the water level from the AWAC (Figure 6A). Waves are well resolved during this event, in part due to the lower water levels. The latter event (10/29/19 to11/01/19) coincides with strong southerly winds, blowing near 10 m/s for almost 24 hr (Figure 8A). This wind event was also noted in field notes from TWI personnel. Both events correspond to a slight increase in near-bed current speed to 15–20 cm/s (Figure 7B). There are two other events highlighted by pink lines in Figure 7 and 8 (11/24/19 to 11/26/19 and 11/28/19 to 11/29/19). Though these also saw high wave activity and slightly increased currents, these were flagged because they corresponded to notable peaks in turbidity greater than 100 ntus, which are discussed in the following paragraph. As evident in Figure 7C, other instances of wave heights nearing 0.5 m do occur during the deployment, but these did not coincide with periods of peaks in turbidity and are not discussed in further detail in this report.

* Dr. Lenore Tedesco, personal communication, March 2020, Executive Director, The Wetlands Institute, Stone Harbor, NJ.

Figure 7. Observations of (A) Water level, (B) current speed from a meter above the bed, (C) significant wave height, and (D) peak wave period from Shark Island Embayment from October to December 2019. Pink bars indicate time of notable turbidity events discussed in text. Times are in GMT.

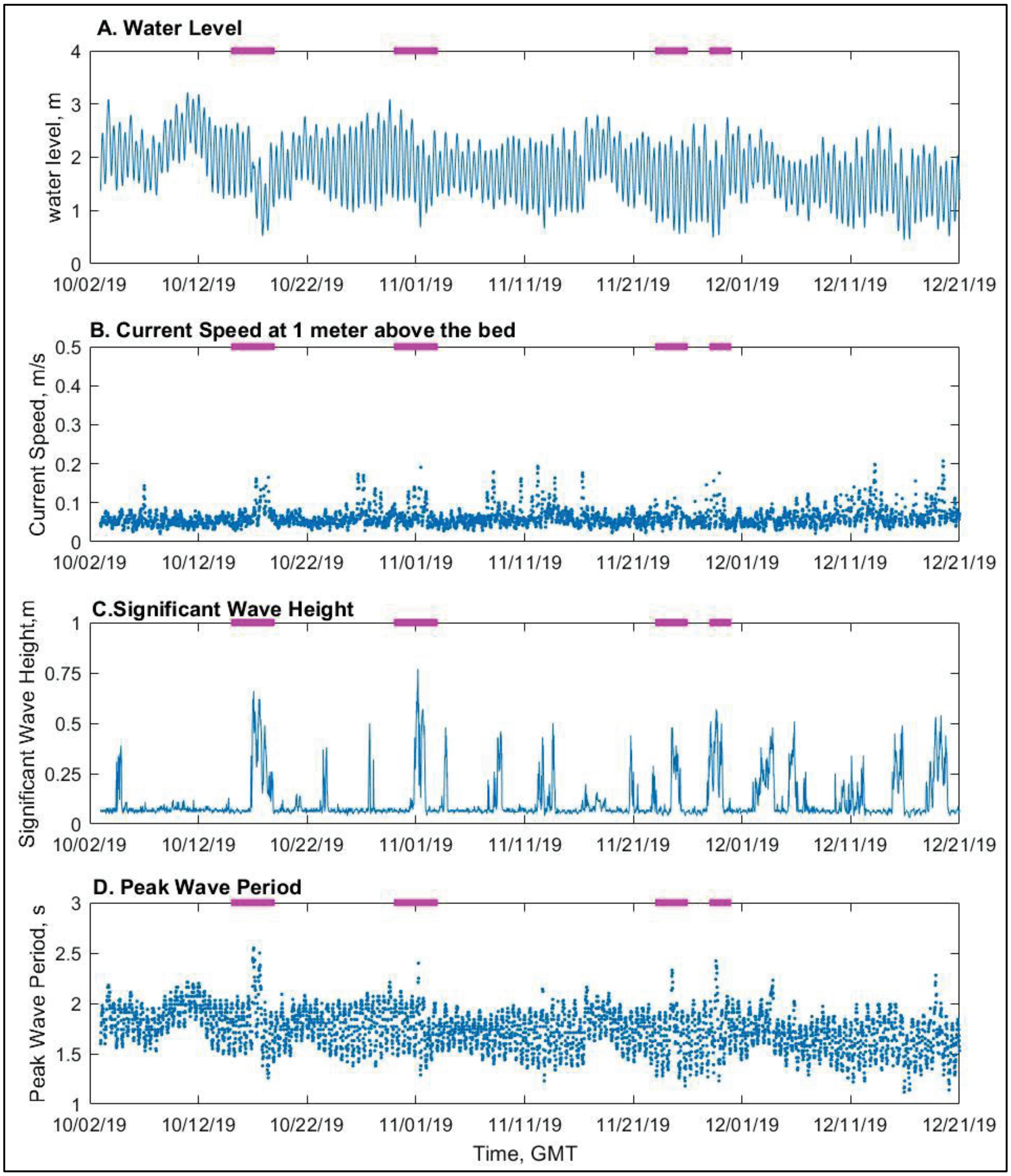
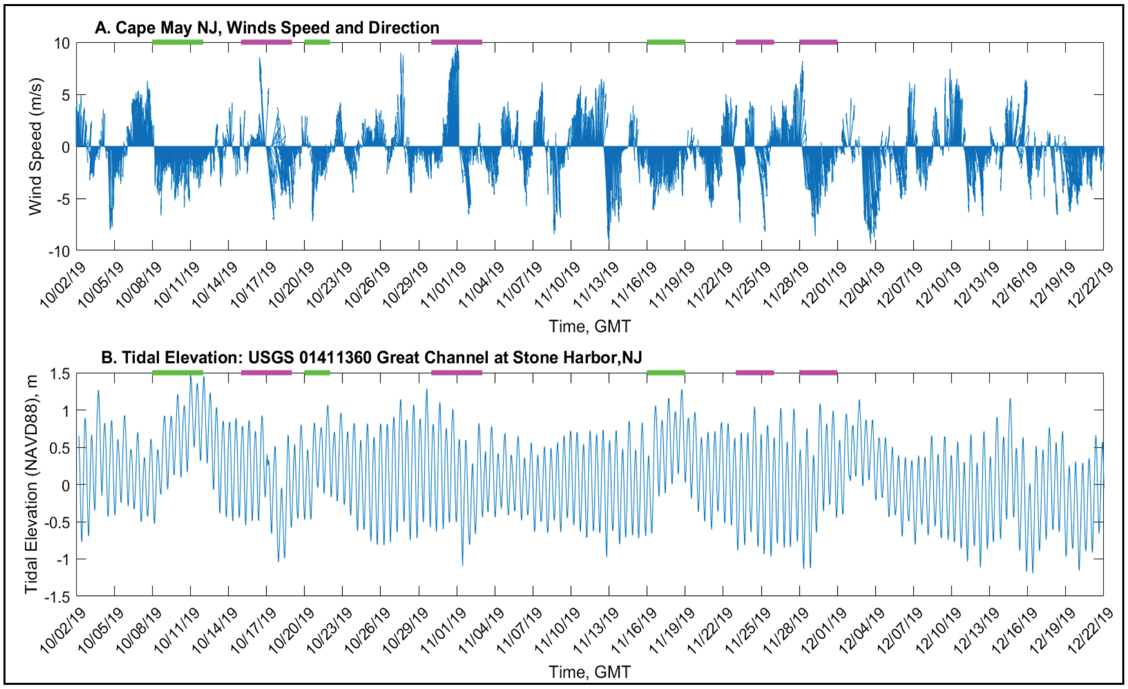
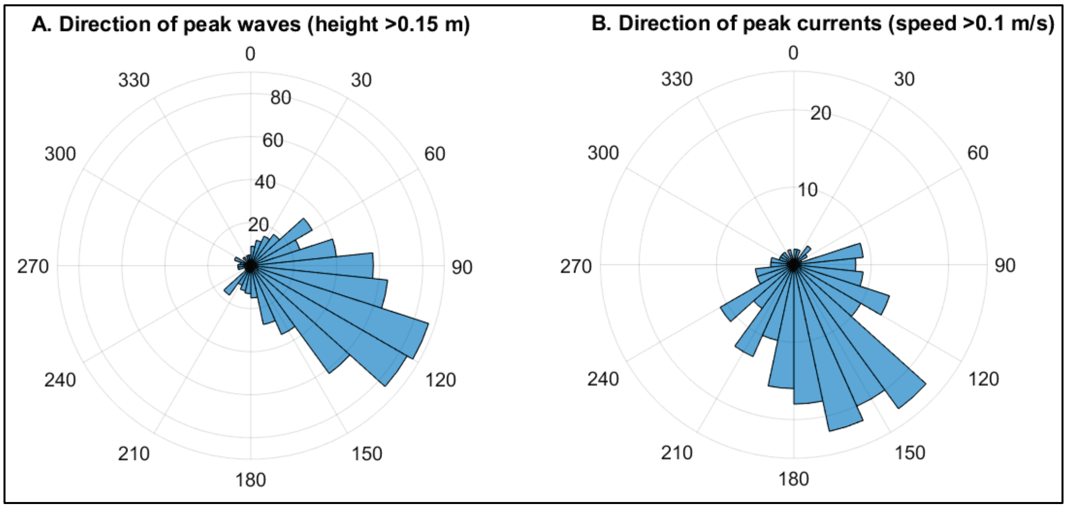


Figure 8. (A) Wind speed and direction from NOAA meteorological station 8536110 at Cape May, New Jersey, approximately 14 mi southeast of SMIIL. Wind direction is plotted assuming oceanographic convention such that the arrow points to the direction winds are blowing towards. (B) Tidal elevations from USGS gauge station 01411360 at Stone Harbor, New Jersey, approximately 2 mi south of SMIIL. Pink bars indicate time of notable turbidity events observed at Shark Island Embayment and Tidal Creek and green bars on (A) denote time of notable peak wave heights and current speeds observed at Sturgeon Island discussed in the text. Times are in GMT.



Wave direction and current direction followed wind direction, specifically related to the direction associated with the greatest wind fetch. The direction of waves and currents with peak wave heights and current speeds (wave heights >0.15 m and speed >0.1 m/s) were predominantly directed towards the southeast (Figure 9). Note, overall, the embayment was relatively calm; peak wave heights and current speeds were less than 1 m and barely greater than 10 cm/s, respectively.

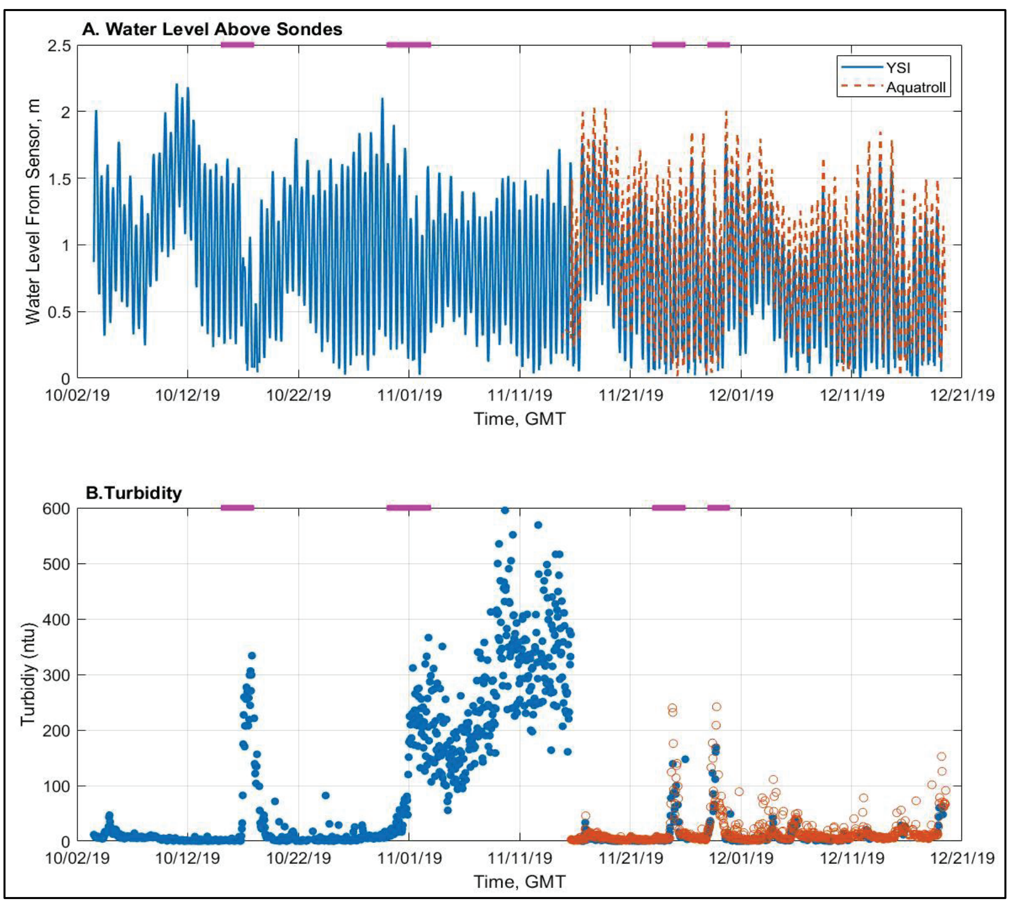
Figure 9. Direction of peak (A) waves (wave height greater than 0.15 m) and (B) currents (current speed greater than 0.1 cm/s) measured at Sturgeon Island. North is indicated as 0 deg, and the bars indicate the direction waves/currents are going towards. Peak wave heights and current speeds were only observed 18% and 1%, respectively, of total deployment time (October 2019–December 2019).



Water level and turbidity obtained from the water quality sondes for the 3-month deployment are presented in Figure 10. Turbidity data were filtered to remove times when the instruments were out of the water (<1% of deployment duration), and an hourly averaged turbidity was calculated (Figure 10B). On average, turbidity within Shark Embayment was approximately 10 ntus. In general, higher observed turbidities corresponded to low water levels. However, a period of elevated turbidity, in which measurements exceeded 200 ntus, occurred from 10/15/19 to 10/18/19. This peak in turbidity coincides with the Nor'easter and associated increase in significant wave heights and currents (Figure 7B,C) and decrease in water level (Figure 7A, 8B, 10A). A prolonged period of turbidity values exceeding 100 ntus was observed in the YSI 600 OMS sonde data for the first 2 weeks in November (Figure 10B). While wind and wave data indicate strong southerly winds (~10 m/s) and wave heights approaching 0.75 m on 11/1/19, these conditions were not sustained throughout the 2 weeks of elevated turbidity (Figures 8 and 9). Instead, wind and wave conditions measured during the first 2 weeks of November were similar to conditions seen throughout the 3-month deployment. A service trip in mid-November to deploy the In-Situ Aquatroll sonde revealed that the YSI 600 OMS sonde had significant biofouling around the sensor (Figure 11). The YSI sonde was cleaned and redeployed at this time, and turbidity levels were observed to immediately return to average background levels and to agree with the In-Situ Aquatroll sonde (Figure 10B). While it is possible that the high wind and wave conditions on November 1 produced elevated turbidity, the sustainment of measurements >100 ntu through November 15 is not believed to be accurate.

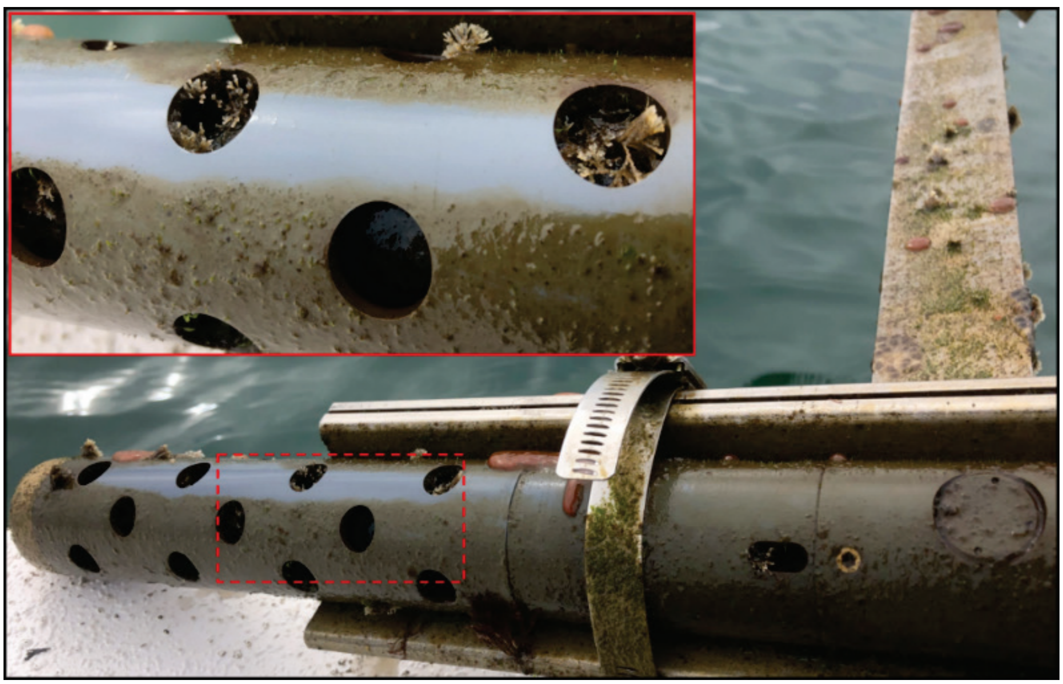
Other, smaller, peaks in turbidity (>100 ntu) were observed in the latter half of the deployment, near the end of November. These events corresponded with low tide conditions in conjunction with winds >5 m/s (Figure 8A) and peak wave heights and near-bed current speeds of 0.5 m and 20 cm/s, respectively (Figure 7). The lower water levels were evident in data from the tidal gauge (Figure 8), AWAC (Figure 7A), and sondes (Figure 10A).

Figure 10. Hourly averaged (A) water level and (B) turbidity from the water quality sondes observed at the Shark Island Embayment station from October to December 2019 with a YSI 600 OMS CTD (blue) and an In-Situ Aquatroll CTD (orange). Water level is given as water level measured from the CTD sensors, which were approximately 75 cm above the bottom. Pink bars indicate time of notable turbidity events discussed in text. Times are in GMT.



Observations from the Shark Island Embayment AWAC and sondes suggest that overall, the embayment waters are relatively calm and clear such that, apart from a few periodic wind events (pink lines, Figures 7, 8, 10), the area experiences low current speeds, small waves, and low turbidity levels. Turbidity values were compared to corresponding acoustic backscatter measurements from the AWAC in an effort to establish an empirical relationship between the two that would allow for a turbidity profile throughout the water column. Unfortunately, a strong correlation between the turbidity and acoustic backscatter could not be resolved ($r^2<0.3$). It is suspected that the overall low level of turbidity in the water column contributed to the weak correlation with acoustic backscatter.

Figure 11 . Pictures of YSI 600 OMS taken during the November 2019 service trip. Extensive biofouling was observed around the turbidity sensor.



3.1.3 Shark Island tidal creek

Salinity within the tidal creek was approximately 30 ppt, and the temperature steadily decreased from 20°C at the start of October to 10°C at the end of December. The ADCP was deployed approximately 0.2 m above the bed and provided observations of water level and current velocities within the tidal creek channel (Figures 12–14). Water levels within the channel typically ranged from 0.3 m to 2 m, though there were few instances (0.2% of the time) in which the ADCP was out of the water. In general, water levels in the tidal creek decreased throughout the deployment, with the highest levels observed in October (Figure 12A) and the lowest in December (Figure 14A). Pink bars on the top of panels in Figures 12–14 denote timing of the high turbidity events marked in the Shark Island data (Figures 7, 10), as well as the meteorological station and tidal gauge (Figure 8).

Monthly time series of the measured current speed profiles for the tidal channel are shown in Figure 12B, 13B, and 14B. The number of vertical bins in the water column that the ADCP resolved was dependent on the water level in the channel; thus, the current speed profiles follow the tidal water elevations in Figure 12-14A. Typically, current speeds throughout the water column were approximately 0.1–0.2 m/s. Faster currents, 1–2 m/s, were not as common and were typically only observed within 0.5 m of the bed. The highest recorded current speeds, near 3 m/s, were observed approximately 10/15/19–10/16/19 and extended to between 0.7 to 0.8 m above the bed (Figure 12B, event timing indicated by pink bar).This time frame corresponds with the onset of the previously discussed Nor'easter (Figure 7B, C, and Figure 8). High current speeds at 0.7–0.8 m above the bed only persist for approximately 2 days because of the decrease in water level during the event (Figure 12A). Current velocities during the other flagged events were less, between 0.5 to 0.75 m/s, with faster speeds focused near the bed.

While the water quality sondes deployed in the tidal creek were close to the ADCP, their placement along the southern bank of the marsh and out of the creek thalweg increased the frequency at which these instruments were out of the water (Figure 3D). Both sondes were submerged only for approximately 5–7 hr for each tidal cycle, bracketing high tide. This corresponds to approximately 50% of the total deployment time. Data from the sondes were filtered to remove times when the instruments were out of the water and hourly averaged water depth and turbidity were determined (Figure 15). Note that water depth reported from the sondes is relative to the elevation of the sensor, which was positioned approximately 0.6 m above the bed. Therefore, water levels in Figure 15A indicate the amount of water above the sensor, not depth in the creek.

In conjunction with the turbidity measurements recorded by the sondes, a total of 71 water samples were collected by the Isco sampler over the 3-month deployment and filtered for SSC. Turbidity measurements corresponding to SSC sample collection times were used to establish an empirical relationship between the two parameters. The majority of the turbidity measurements were confined to the lower end of the sondes calibration range (<5 ntus). Corresponding SSC values typically ranged from 5 to 40 mg/L, resulting in significant scatter and a positive, but relatively weak, correlation between SSC and turbidity (r^2 0.54–0.57). Similar to the instruments deployed within the embayment, a direct comparison between turbidity and acoustic backscatter measurements from the ADCP was also investigated, but no correlation was observed ($r^2<0.1$). It is suspected that correlations between the turbidity and both SSC and acoustic backscatter were negatively impacted by both the low and narrow range in measured turbidity and reduced data due to the limited time the sondes were submerged.

Figure 12. Measured (A) water depth and (B) current speeds profiles within the tidal creek in October 2019. HAB=height above the bed. The red line indicates the water level representative of bankfull conditions; water levels are high enough to spill onto the surrounding marsh, approximately 0.7 m. Pink bars indicate time of notable turbidity events discussed in text. Times are in GMT.

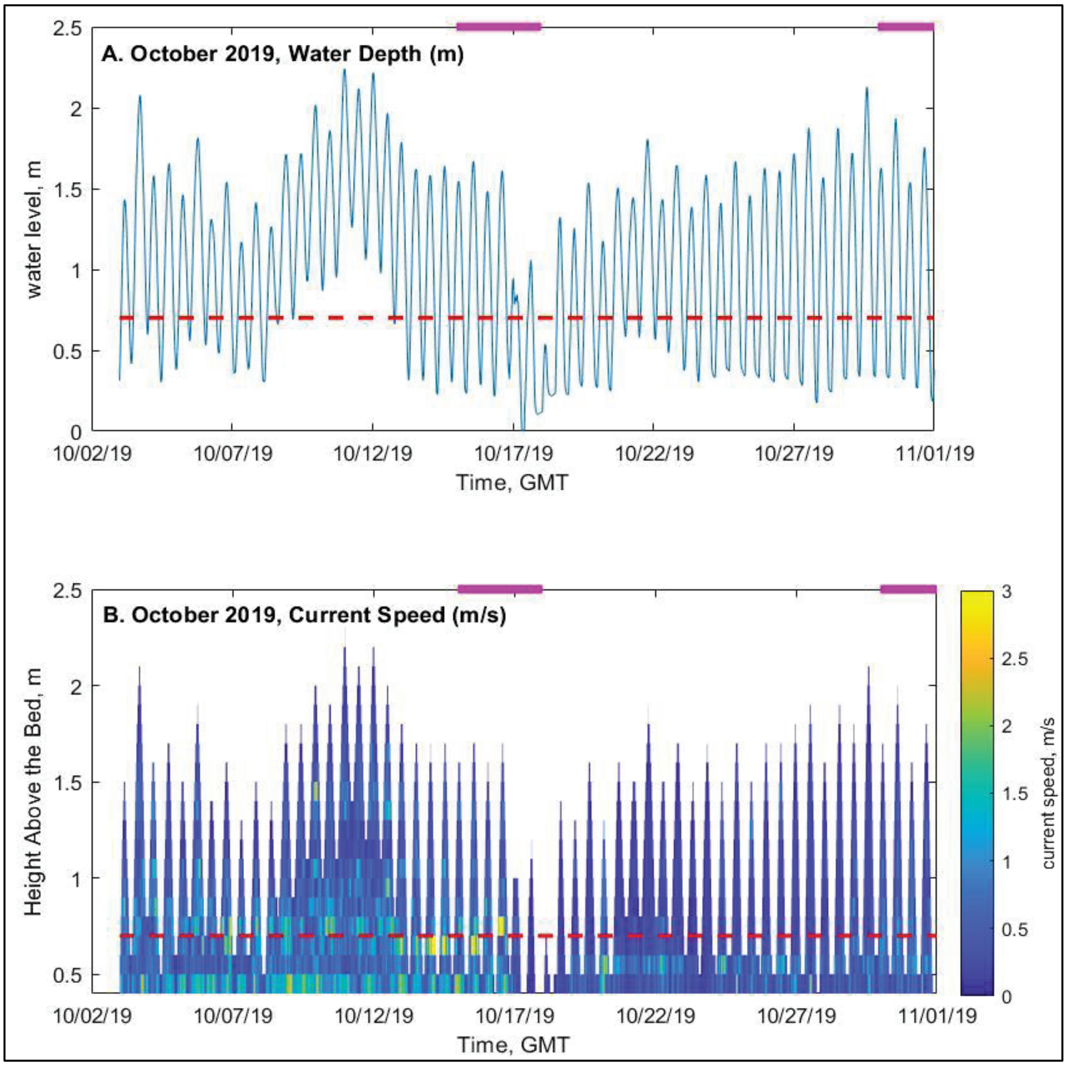


Figure 13. Measured (A) water depth and (B) current speeds profiles within the tidal creek in November 2019. HAB=height above the bed. The red line indicates the water level representative of bankfull conditions; water levels are high enough to spill onto the surrounding marsh, approximately 0.7 m. Pink bars indicate time of notable turbidity events discussed in text. Times are in GMT.

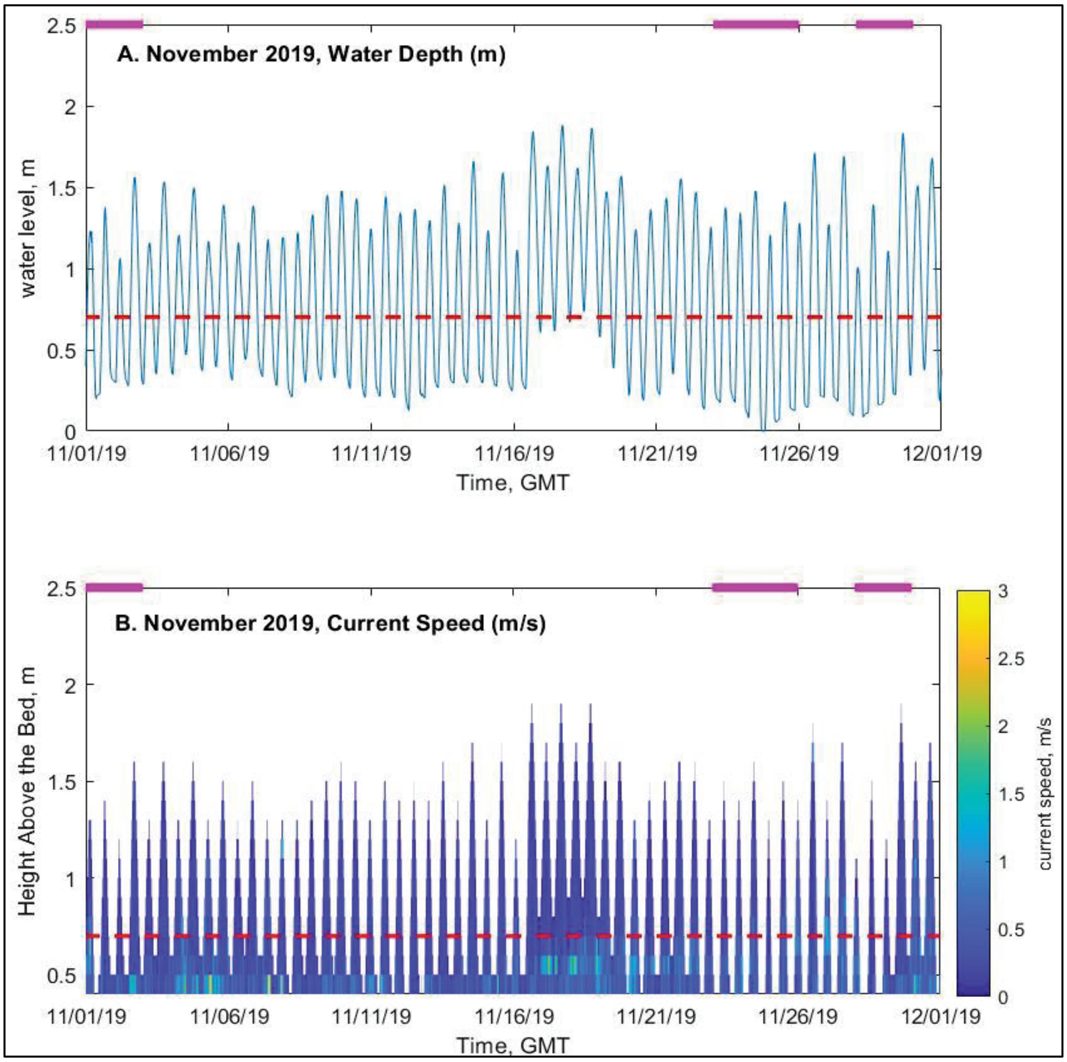


Figure 14. Measured (A) water depth and (B) current speeds profiles within the tidal creek in December 2019. HAB=height above the bed. The red line indicates the water level representative of bankfull conditions; water levels are high enough to spill onto the surrounding marsh, approximately 0.7 m. Times are in GMT.

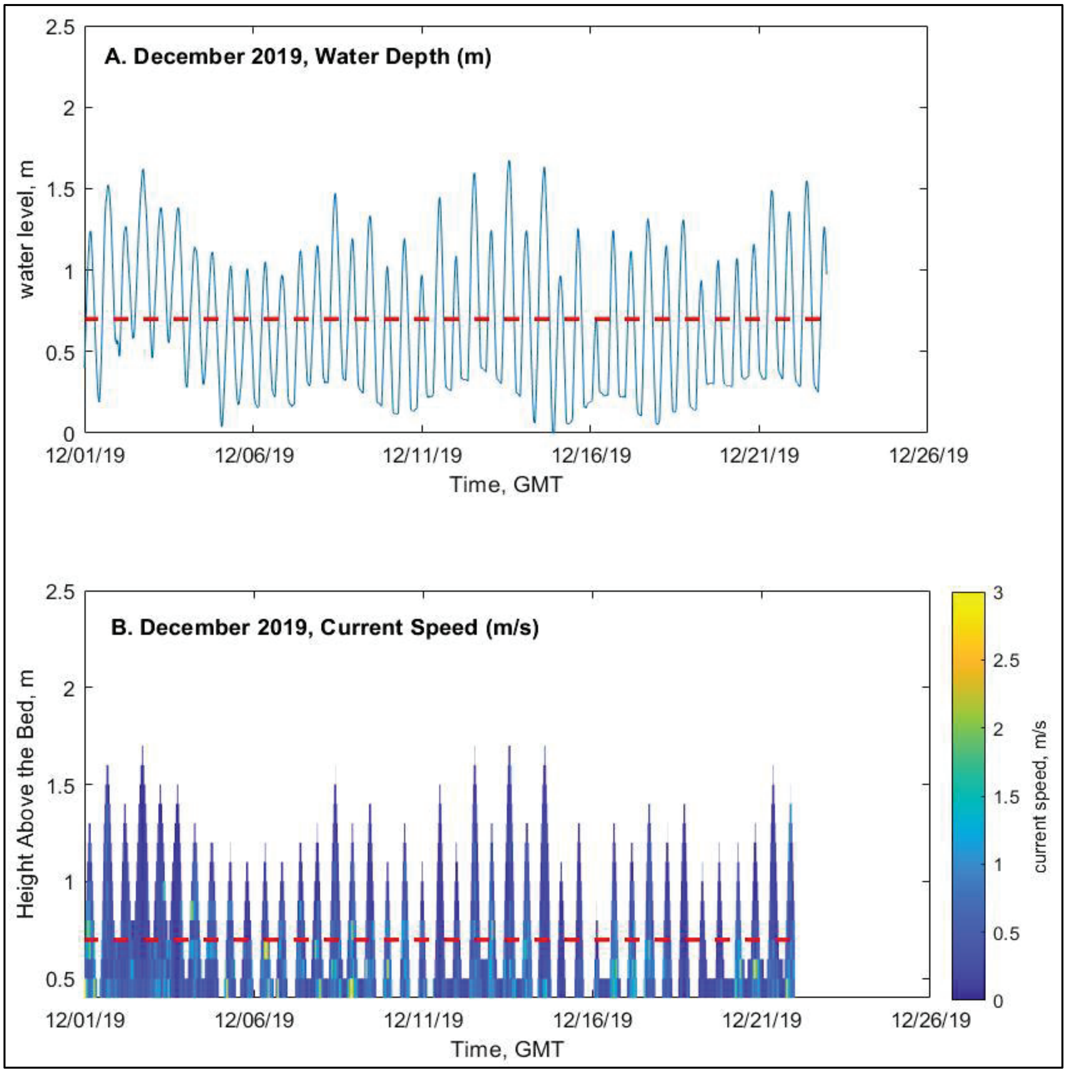
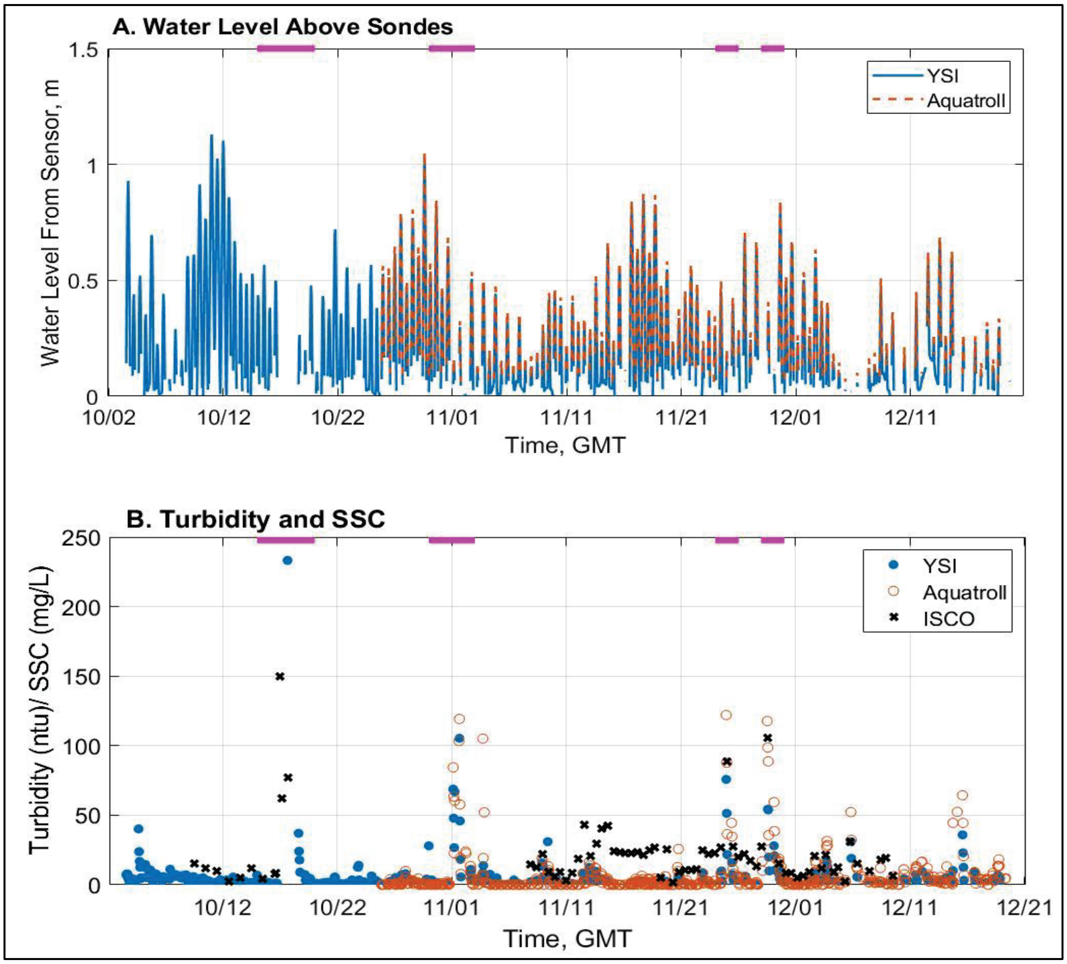


Figure 15. Hourly averaged (A) water level from sondes and (B) turbidity observed at Tidal Creek site from October to December 2019 with a YSI 600 OMS (blue) and an In-Situ Aquatroll (orange). Water level is given in reference from the sondes sensors, which were approximately 0.6 m above the bottom. Black x's represent SSC determined via gravimetric filtration of water samples collected with the Isco sampler. Pink bars indicate time of notable turbidity events discussed in text. Times are in GMT.



Apart from a few wind events, observations suggest little material is suspended in the tidal creek (Figure 15B). On average, turbidity within the tidal creek was approximately 3–4 ntus. Measured SSC values that correspond to these turbidity levels were less than 10 mg/L. Turbidity measurements on the order of 20–30 ntus were often observed during lower water levels in the creek and corresponded to total suspended solids concentrations between 20 to 50 mg/L. As noted by the pink bars on the top of the figure panels (Figure 15), a few larger turbidity events, in which turbidity levels surpassed 100 ntus and suspended solids concentrations were greater than 50 mg/L, were observed. Notable events include 10/15/19 to 10/18/19; 10/31/19 to 11/2/19; 11/24/19 to 11/25/19; and 11/28/19 to 11/29/19. These events correspond to wind events with wind speeds exceeding 5 m/s and correspond to peak turbidity events observed at the sondes deployed in the embayment (Figure 10B). The largest observed turbidity, 10/15/19 to 10/18/19 , corresponds with the highest observed currents speeds in the adjacent channel (Figure 12B). It is suspected that the high turbidity event observed approximately10/31/19 to 11/2/19, in the tidal creek (Figure 15B) does correspond to a high turbidity event in the embayment, but it was not well resolved due to biofouling (Figure 11). This peak corresponds to larger waves and currents in the embayment (Figure 7) as well as sustained, strong southerly winds (Figure 8A).

Marsh elevation around the tidal creek, inferred from surveys conducted in 2017, was estimated to be approximately 0.7 m (OCM Partners 2020). The dashed red lines in Figures 12–14 indicate this elevation and highlight times that water level was above bankfull stage and would have started flowing onto the marsh. Over the whole deployment, bankfull stage or higher was observed 58% of the time. Average current speeds during the 3-month deployment at 0.7 m above the bed or assumed bankfull were approximately 0.35 m/s (Figure 12–14). The ability of flows of this level to suspend and transport sediment was theoretically evaluated using well-established transport relationships (Garcia 2007). Particle Rouse values, a non-dimensional parameter that balances gravitational settling and turbulent mixing driven by current speed, and particle settling velocities were calculated assuming a range of grain sizes (2–2000 microns; or using Wentworth scale classification, clay-very coarse sand) for the typical bankfull height current speeds, 0.35 m/s (Wentworth 1929). Results of these estimations indicated that current speeds would only be capable of maintaining very fine-grained (<125 microns) material in suspension. Grain size analysis was not performed in conjunction with the water samples collected for SSC; however, observations of SSC and turbidity suggest the sediments in the area are not frequently suspended to a height of 0.6 m above the bed, the height of the sondes and Isco intake. One notable exception to this observation occurred during the onset of the Nor'easter in mid-October (October 15–16, 2019). During this time, current velocities were greater at higher locations in the water column and reached 1 m/s at bankfull stage (Figure 12B). As previously mentioned, sediment concentrations in the water column were also elevated (>50 mg/L). This type of event, however, was only observed once during the 3-month deployment, and conditions were only sustained for approximately 2 days, until water levels dropped below bankfull. The frequency and typical duration of events like this cannot be confidently defined given the short duration of this deployment. However, assuming events like this are not very frequent or prolonged (e.g., once every 3 months for 2 days), a limited amount of transport from the tidal creek to the marsh occurs. Rather, typical conditions observed during this 3-month deployment indicate that a shallow water column with low current velocities throughout the entire Shark Island area, promote rapid deposition of any material suspended in the water column over sustained transport of that material in suspension.

3.1.4 Sturgeon Island

At Sturgeon Island, water level measured with the AWAC found tidal ranges on the order of 0.5–2 m (Figure 16A). On average, current speeds a meter above the bed were approximately 0.1 m/s with peaks near 0.5 m/s (Figure 17B). Wave heights were generally less than 0.5 m, and peak periods were on average approximately 1.5 s (Figure 16C, D). Spans of elevated wave heights coincide with winds near 5 m/s, typically blowing from north to south (Figure 8A), which is consistent with the wind direction expected to produce the greatest fetch. Peaks in current velocities coincided with peaks in wave heights. Wave direction and current direction followed wind direction. Peak wave and current events (wave heights >0.15 m and speed >0.2 m/s), were predominantly directed towards the south/southwest (Figure 17). As with Shark Island Embayment, the direction corresponds to the direction of maximum wind fetch for the site. Overall, these peaks in wave height >0.15 m and currents >0.2 cm/s occurred only approximately 10% of the total deployment and are still considered fairly low.

In general, wave conditions agreed with wave conditions at Shark Island Embayment. A few instances of discrepancy were noted between the two stations, particularly in regard to magnitude of waves and current speeds observed (e.g., 10/8/19, 10/22/19, and 11/16/19, green bars on Figure 16B, C). During these time periods, peak wave heights and current speeds ranged from 0.5 to 0.75 m and 0.3 to 0.5 m/s, respectively. These values are approximately 2–5x larger than wave and current conditions observed at the same time at Shark Island Embayment. These discrepancies may in part be explained due to the difference in water depths and fetch conditions at the two stations. Due to the limits to wave measurements imposed by the attenuation of pressure signal with water depth (previously described), shallower water at Sturgeon Island would have allowed the AWAC to resolve waves over a larger portion of tidal cycle compared to

Shark Island Embayment, thus potentially allowing for larger measured wave heights during the times in question. However, the Sturgeon Island site is also exposed to a much larger northerly fetch in comparison to the sheltered Shark Island Embayment site (Figure 2). Field notes from TWI staff indicate these periods were associated with high winds and choppy waters*. Meteorological data showed that these three periods were associated with northerly winds >5 m/s (Figure 8A) and thus more favorable for higher waves and currents at Sturgeon Island relative to Shark Island Embayment (Figure 1). Fetch may also explain the delay in high waves and currents following the October Nor'easter. Sturgeon Island site would not have been as exposed until winds switched directions, which was observed on the latter half of the event (Figure 8A).

Unfortunately, no turbidity data were recovered from this station. The In-Situ Aquatroll and YSI 600 OMS sondes from this station experienced instrument malfunctions. The In-Situ Aquatroll turned off after only collecting one sample, and the YSI 600 OMS was non-responsive upon recovery. Since no strong relationship was able to be defined to relate turbidity to AWAC acoustic backscatter from the instruments at Shark Island, only speculations can be made regarding turbidity at this station. It is speculated that trends in turbidity at Sturgeon Island would be comparable to those observed at Shark Island Embayment (Figure 10), given the similarities in wave and current conditions. This is assuming the sediment bed composition is similar between the stations. Thus, apart from periodic wind events, turbidity would be predicted to be low. This aligns with physical observations frequently made by staff at TWI* that note typically clear waters are observed around the Island and as demonstrated on the cover photo of this report.

* Dr. Lenore Tedesco, personal communication, March 2020, Executive Director, The Wetlands Institute, Stone Harbor, NJ.

Figure 16. Observations of (A) Water level, (B) current speed from a meter above the bed, (C) significant wave height, and (D) peak wave period from Sturgeon Island from October to December 2019. Pink bars indicate time of notable turbidity events observed at Shark Island Embayment discussed in text, and green bars denote time of notable peak wave heights and current speeds at this station. Times are in GMT.

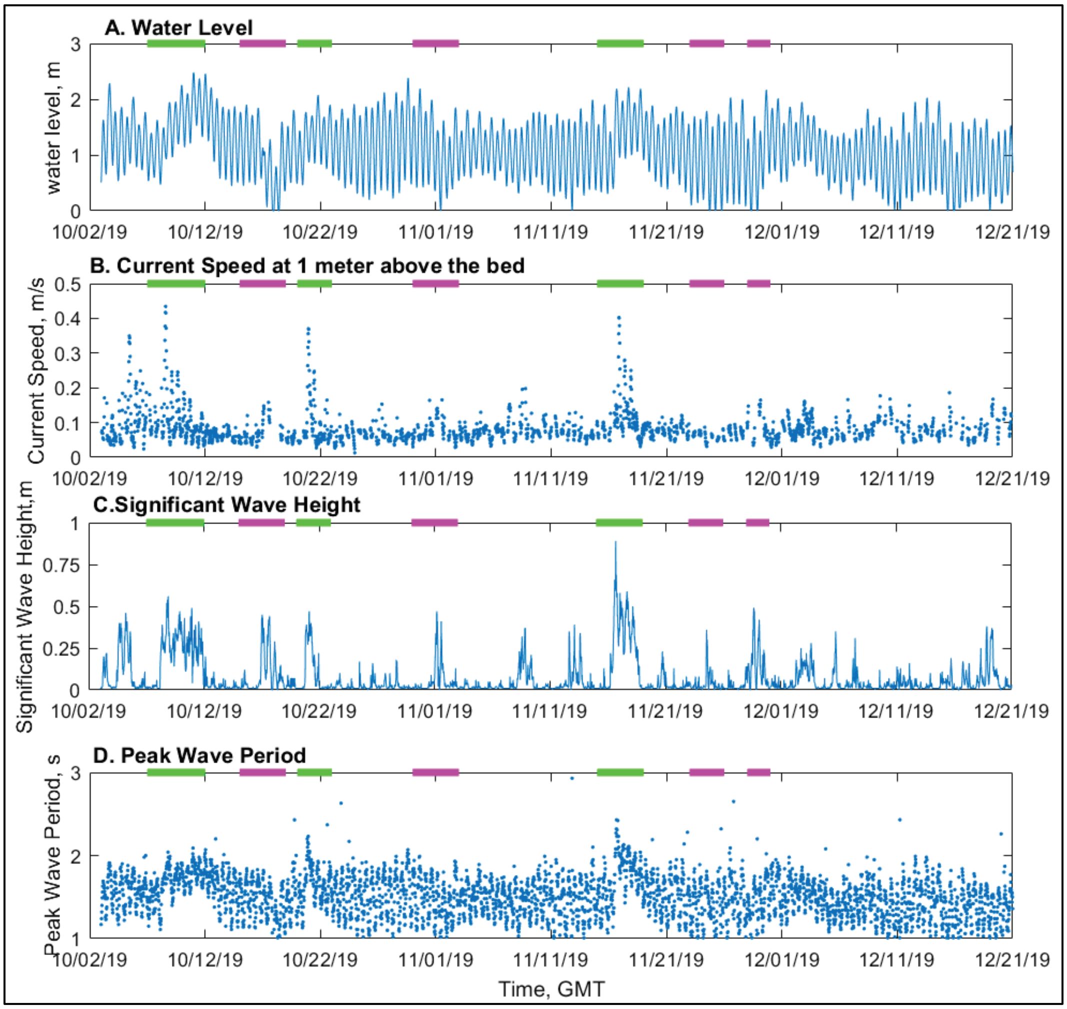
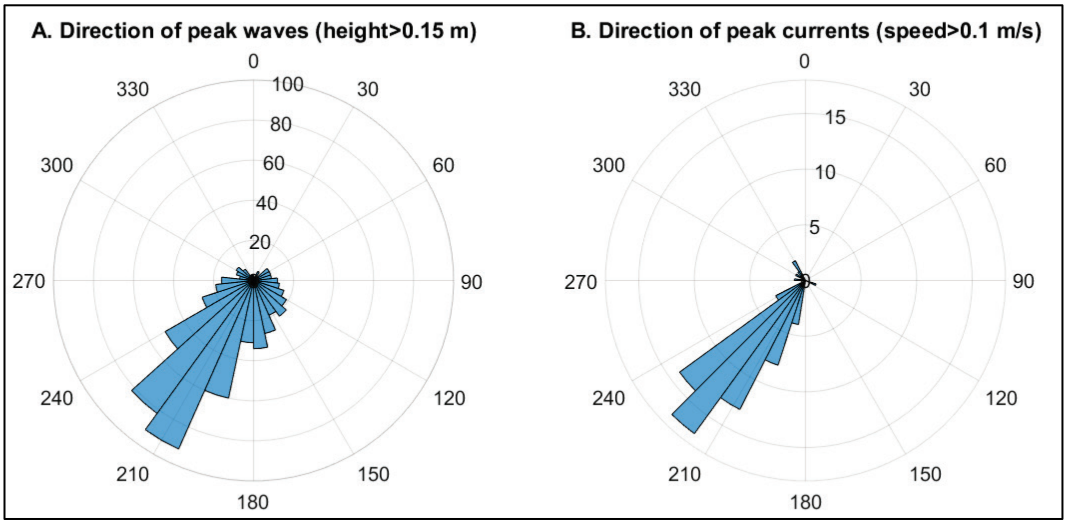


Figure 17. Direction of peak (A) waves (wave height greater than 0.15 m) and currents (current speed greater than 0.2 cm/s) measured at Sturgeon Island. North is indicated as 0 deg, and the bars indicate the direction waves/currents are going towards. The peak wave heights and current speeds were observed only approximately 10% of total deployment time (October 2019–December 2019).



3.2 Dredged material placement monitoring at Sturgeon Island

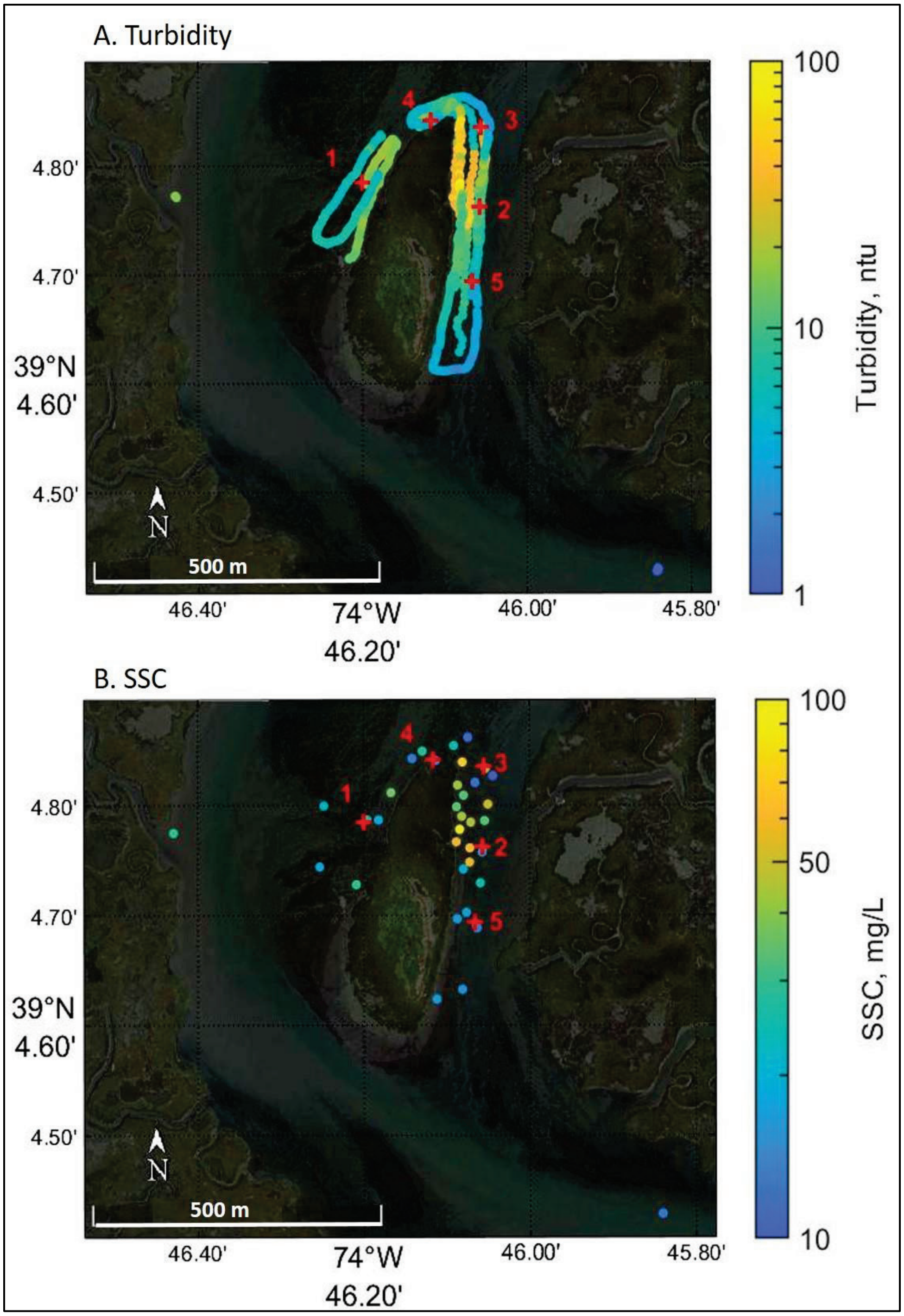
Active dredge placement occurred during daylight hours from the afternoon of March 16 to evening of March 19 (Table 2). In total, active placement spanned approximately 24 hr over the 3.5 day period. Roving turbidity measurements with an Aqualtroll sonde were made within 50–75 m of Sturgeon Island on 3/17/20 and 3/18/20 (Figure 18A). Physical water samples (n=38) were collected periodically along the roving survey and analyzed for SCC. The locations of these samples are shown on Figure 18B. Unlike comparisons between turbidity and SSC from the tidal creek, a strong correlation between the two parameters was observed with the samples collected during dredge monitoring (r^2=0.9). Peak turbidities corresponded to peak SSC near 100 mg/L, and areas of low turbidity corresponded to low SSC near 10–20 mg/L (Figure 18). Roving survey tracks passed over the locations of the five moored sondes, which are marked on Figure 18.

Table 2. Date and times of dredge operation during March 2020 placement. Times are in GMT.

Date	Time (GMT)	Total Hours
3-16-20	18:50-22:50	4
3-17-20	12:00-15:15	3.25
3-17-20	15:30-19:15	3.75
3-17-20	20:35-23:00	2.42
3-18-20	13:15-14:15	1
3-18-20	18:15-19:10	0.92
3-18-20	20:45-20:55	0.17
3-19-20	11:45-14:15	2.5
3-19-20	16:00-19:25	3.42
3-19-20	19:45-22:30	2.75

Roving survey data indicated that turbidity peaked near 100 ntus within 20 m of the shore on the northeast side of the island in close proximity of a tidal creek. However, turbidity levels quickly decreased to approximately 10–20 ntus within 75 m distance offshore of the island (Figure 18A). These lower turbidity values were commonly observed around the remainder of the island throughout the roving surveys. Turbidity observations collected from October to December 2019 (Figure 10), as well as measurements collected farther away from the island during dredge monitoring (Figure 18A), indicate turbidity levels of approximately 10 ntus were typical of background levels for the area. Thus, apart from the northeast portion of Sturgeon Island, measured turbidities were near background levels during active dredging. Surveys suggest dredged material was transported off the northeast side of the island upon placement, following the slope of the landscape in this area.

Figure 18. (A) Survey tracks around Sturgeon Island during dredge material placement on March 17–19, 2020. The color corresponds to turbidity, in ntus, measured with the In-Situ Aquatroll sonde. (B) Location of physical water samples collected during the roving surveys. Symbol color corresponds to the total suspended solid concentrations, in mg/L, of the water samples determined through filtration. The red numbers correspond to the locations of the moored In-Situ Aquatroll sondes. Background turbidity and SSC were measured farther from the island to the northwest (upper left corner) and southeast (lower right corner).



Turbidity observations from the five moored sondes, located approximately 40–50 m off the island during the week of active dredge placement, are presented in Figure 19. On Figure 19, tidal elevation measured at the US Geological Survey (USGS) gauge station 01411360 at Stone Harbor, New Jersey, is plotted as a green line; time of active placement (Table 2) is indicated with pink lines on the top of each panel; and the coincident turbidity observations from the roving surveys are plotted as red stars. On the end of March 18, the sondes were retrieved for cleaning and to change batteries. They were redeployed on March 19. The maintenance time period is indicated below x-axis on Figure 19E.

Generally, at all stations, peaks in turbidity coincided with low tides, which usually, due to the constraints of daylight hours, also lined up with active dredge placement (Figure 19). These peaks were on the order of 30–50 ntus, at station 3 and 4, but peaks at stations 1, 2, and 5 are 20x–200x greater. It is suspected peaks in turbidity could be a repercussion of the deployment set up (Figure 6), such that at low water the instrument bottom made contact with the sediment bed and the sensors were close enough to the bed to be influenced by the disturbance. During tidal conditions that resulted in sufficient water depth to limit sensor contact with bed (i.e., when roving surveys were conducted) moored and roving survey data were in close agreement (Figure 19). Because dredge activity also coincided with low water levels, it was not possible to fully separate the influence of active dredging from turbidity induced by instrument disturbance. However, elevated turbidity levels at station 2, located along the northeastern portion of the island, near the creek mouth does follow the trend observed in the roving survey data (Figures 18, 19).

The idea that turbidity observations were quite sensitive to suspension events induced by instrument set-up (Figure 6) was further supported by data collected the week following active placement (Figure 20). Again, turbidity peaks were observed at all stations at low tide (Figure 20). The peaks are fairly short lived events (typically 3 hr or less) that were one to two orders of magnitude higher than background conditions. It is likely these are instrument-induced events. Low tide water levels were lower following the week of active dredging (Figure 20), and no significant wind events occurred that would drive high turbidity (Figure 21). Observations with sondes permanently mounted within 30 cm of the bed, rather than attached to a surface float, would be needed to confidently resolve turbidity conditions at low water levels.

While turbidity surveys conducted in this study showed limited spread of a turbidity plume off of Sturgeon Island, there were not sufficient data to make strong conclusions regarding lasting impacts of the dredge material placement or if the observed data would be representative of future placement events on or around the island. Due to Covid-19 public health concerns, the overall dredge placement pumping was limited to only 24 hr, spanning over 3.5 days, making total dredging volumes (~2,475 m^3) small in comparison to normal operations. Further, the longest continued interval of dredging was less than 4 hr. This type of dredge operation would not simulate a dredging activity in “production mode” with near continuous pumping. Additionally, due to timing of daylight hours, pumping was restricted to times corresponding to low water levels/tide. As a result, the small volume of placed material during shallow water conditions with minimal wave energy would favor limited transport distance before sediment settling out of the water column. This would be consistent for even the fine-grained, silt-sized sediment. For instance, using commonly applied settling velocity equations for fine sediment (Schiller and Naumann 1933) and assuming little to no turbulence, a 15-micron silt particle would settle 0.5 m (a water depth common throughout the monitoring area at MLLW) in approximately an hour. This makes resolving a strong turbidity signal difficult.

Figure 19. Turbidity measured at the moored stations (blue dots) and tidal elevations from USGS gauge station 01411360 at Stone Harbor, New Jersey (green line), during dredge placement, March 16–March 19, 2020. Note the differences in y-axis between stations. Times of active dredging are marked by solid pink lines on the top of each panel. Red stars show turbidity measured during the roving surveys when near the moored stations. Time is in GMT.

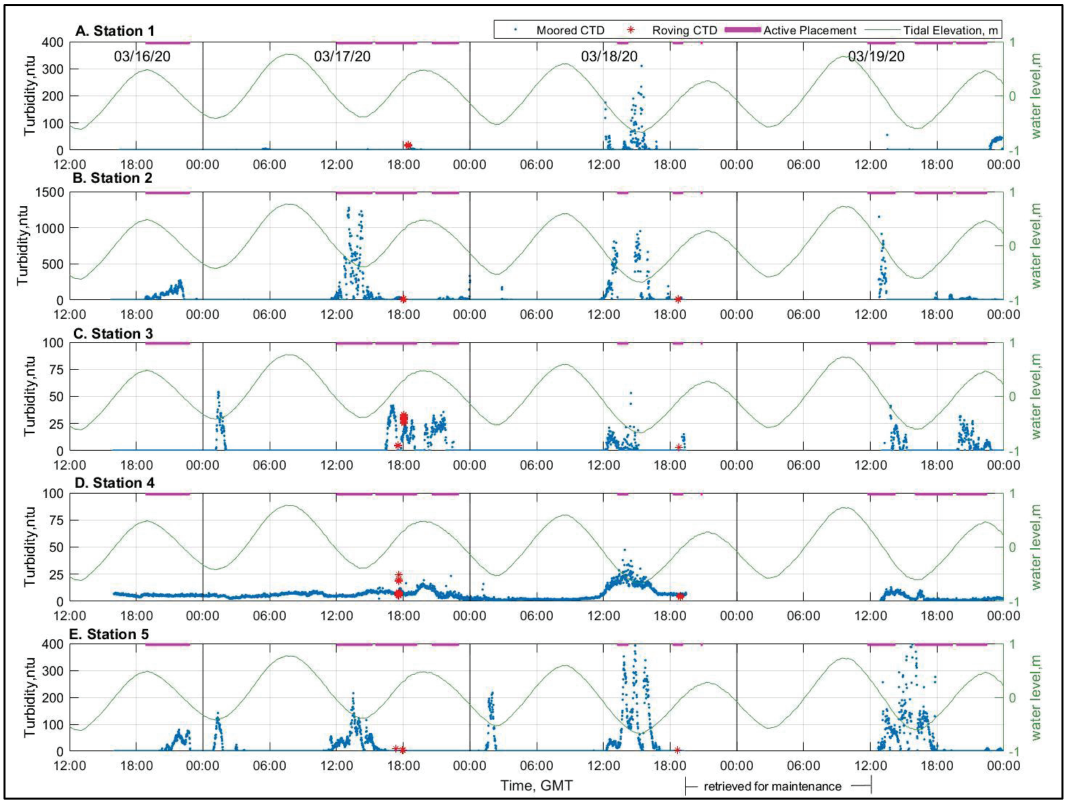


Figure 20. Turbidity measured at the moored stations (blue dots) and tidal elevations from USGS gauge station 01411360 at Stone Harbor, New Jersey (green line), the week following active placement, March 20-24, 2020. Note the differences in y-axis between stations. Time is in GMT.

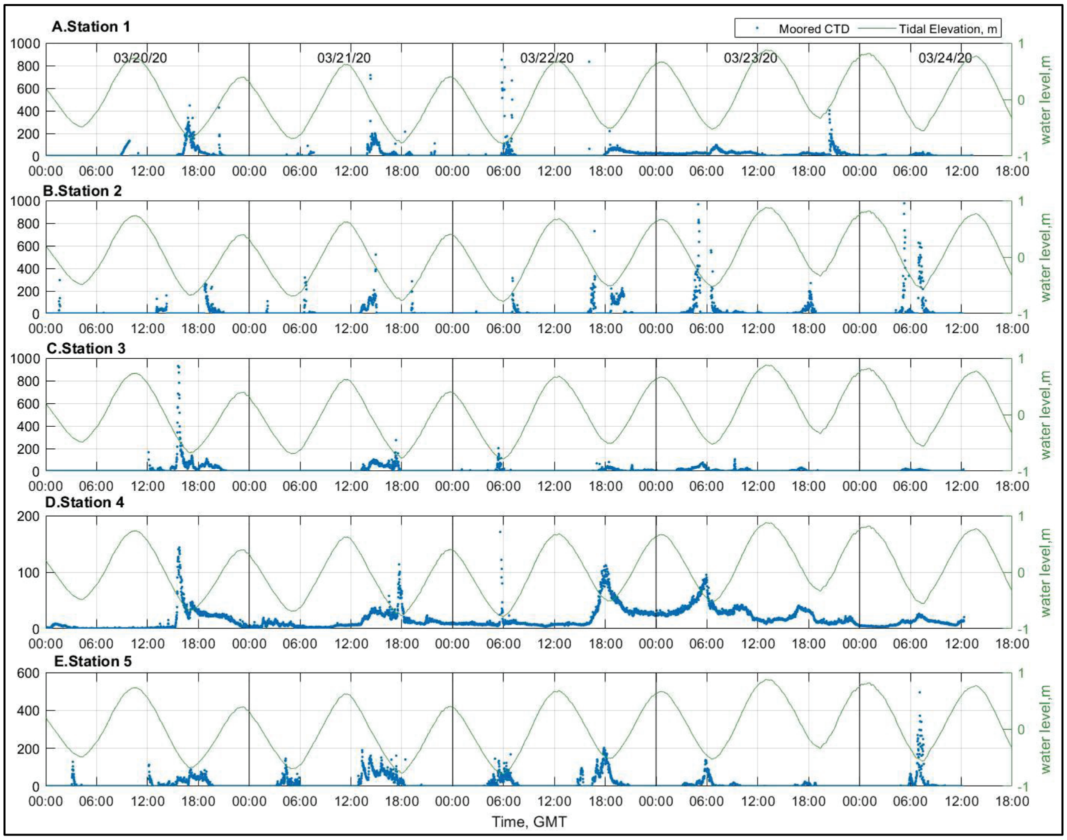
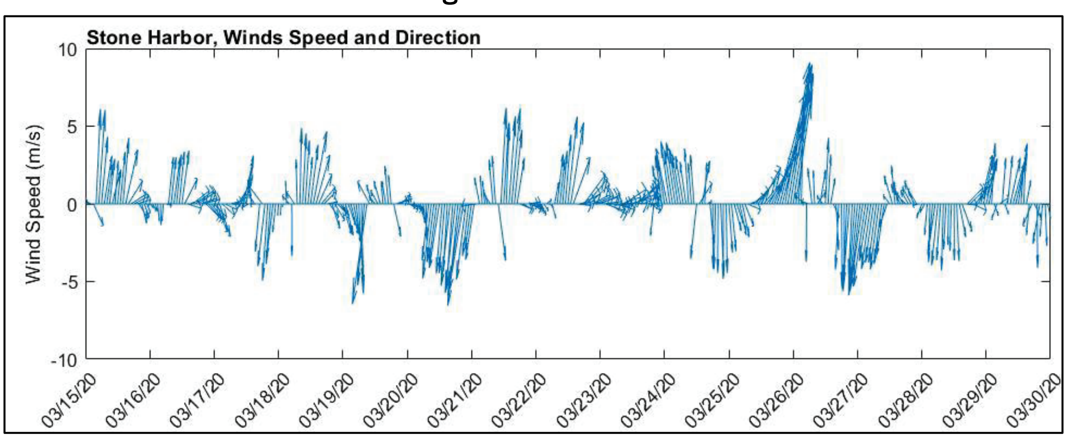


Figure 21. Wind speed and direction from USGS meteorological station at Stone Harbor, New Jersey, approximately 2 mi south of SMIIL. Wind direction is plotted assuming oceanographic convention such that the arrowhead denotes the direction wind is blowing towards. Times are in GMT.



4 Summary and Recommendations

- Preliminary monitoring of hydrodynamics, turbidity, and total suspended solids at three stations from October to December 2019 throughout the SMIIL area found that apart from punctuated wind events, the area is generally calm and waters are clear. Monitoring found generally small waves, <0.25 m, slow current speeds (~0.1 m/s), low turbidity (~10 ntus), and low suspended sediment concentrations (~10–20 mg/L).
- Results suggest that significant sediment transport and suspension in the area is dominated by wind events rather than tidally driven currents. Peaks in waves and currents corresponded to peaks in wind magnitude and direction of maximum fetch. At Shark Island, this direction was towards the south/southeast and towards the southwest at Sturgeon Island. In both areas, however, maximum wave heights and currents were fairly low. The greatest recorded wave heights were less than a meter, and peak current speeds were approximately 10 cm/s at Shark Island and 40 cm/s at Sturgeon Island. Further, these peak conditions were infrequent and observed 10%–20% of the total deployment time.
- Preliminary monitoring indicated that the Shark Island Tidal Creek would not be efficient in transporting material onto the surrounding marsh. Though faster current speeds were observed within the tidal channel (0.3–1 m/s) relative to the embayment or Sturgeon Island site, the fastest currents were focused near the bed (bottom 0.5 m) and were reduced in the upper water column. Area surveys (OCM Partners 2020) indicated that water levels >0.7 m are necessary to exceed bankfull stage and allow water to flood onto the surrounded marshes. Low turbidity and SSCs suggest the currents are not typically strong enough to maintain sediment in suspension at bankfull stage, apart from stronger wind events. This was observed once during the 3-month deployment, associated with a Nor'easter in mid-October, and conditions were only sustained for approximately 2 days. The observations of local hydrodynamics, turbidity, and concentrations suggest that within the tidal creek rapid deposition of suspended material is more likely than any significant transport of material.
- Monitoring of dredge material placement activities on Sturgeon Island took place March 16–19, 2020, through roving turbidity surveys and deployment of five moored turbidity sondes around the island. In general, roving surveys and moored stations showed little to no

turbidity plume associated with the dredging operations, outside of the tidal creek mouth on the northeast side of Sturgeon Island. Turbidity levels quickly returned to background conditions outside of this area and at times when the dredge was not in operation.

- There were not sufficient data to make strong conclusions regarding lasting impacts of the dredge material placement or if the observed data would be representative of future placement events on or around the island.
- The AST data collected by the AWACs deployed at both stations (Sturgeon Island and Shark Island) in 2019 were too noisy for resolving wave characteristics. It is suspected that the acoustic signal level was set too high upon programming. Due to acoustic blanking distances on the order of 25–50 cm associated with these types of instruments and the attenuation of sound through the water column required to reduce signal noise, deployment of these instruments in shallow water (<5 m) conditions is not recommended. If deployed in similar water depths in the future, the power level should be set to LOW in an effort to reduce acoustic noise as much as possible to allow for AST methods to be used for resolving waves.
- Data from the 2019 long-term monitoring and the 2020 plume monitoring suggest that fixed, horizontal position of turbidity sondes below MLLW would be favorable to other deployment methods used in this study.

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Acronyms and Abbreviations

ADCP	acoustic doppler current profiler
AWAC	acoustic wave and current profiler
CHL	Coastal and Hydraulics Laboratory
ERDC	US Army Engineer Research and Development Center
MLLW	Mean Lower Low Water
NAP	Philadelphia District
NJIWW	New Jersey Intracoastal Waterway
SMIIL	Seven Mile Island Innovation Laboratory
SMILL	Seven Mile Island Living Lab
SSC	suspended sediment concentration
TWI	The Wetlands Institute
AST	acoustic surface tracking
USGS	US Geological Survey

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14. ABSTRACT
The Seven Mile Island Innovation Laboratory (SMIIL) was launched in 2019 to evaluate beneficial use of dredge material management practices in coastal New Jersey. As part of that effort, the Philadelphia District requested that the US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, collect data to characterize the hydrodynamics and turbidity within the central portions of the SMIIL prior to and during dredge material placement. Pre-dredge monitoring found that apart from punctuated wind events, the study area waters were generally calm and clear with small waves, <0.25 m, slow current speeds (~0.1 m/s), low turbidity (~10 ntus), and low suspended sediment concentrations (~10–20 mg/L). In March 2020, 2,475 m3 of dredged sediment was placed on the northern portion of Sturgeon Island within the SMIIL. Turbidity in the waters surrounding the island was monitored to quantify extent of the sediment plume resulting from the placement. Observations found little to no turbidity plume associated with the dredging operations beyond 20 m from the island and that the plume was largely limited to areas near a tidal creek draining the placement area. Additionally, turbidity levels quickly returned to background conditions at times when the dredge was not in operation.

15. SUBJECT TERMS
Dredging, Dredging spoil, Hydrodynamics, Seven Mile Beach Island (N.J.), Suspended sediments, Turbidity

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