# MEMORANDUM

**DATE** January 2, 2019 **JOB NO.** 2015-0121-01

**TO** John Kelly, Town of Orleans
Jacqueline Beebe, Town of Eastham

**FROM** Leslie Fields
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## Task 5: Field Data Collection for the Evaluation of Nauset Estuary

This memo summarizes the field data collection conducted by Woods Hole Group, Inc. for the purpose of monitoring and assessing the Nauset Estuary in Eastham and Orleans, MA as described in Task 5 of the Scope of Services dated September 21, 2018. To assess the existing channel geometry and tidal patterns in the estuary, bathymetric and water level data were collected during the months of October and November 2018.

### A. Water Level Measurements

Water level elevations in the estuary were measured using two Sea-Bird Scientific MicroCat 37SM CTDs that collected pressure, temperature and conductivity readings at 6-minute intervals for the duration of the deployment. The two gages were deployed on September 27, 2018 and retrieved on November 20, 2018 (Table 1). The first gage was deployed on a bottom mount located at the mouth of Salt Pond in the northern end of the estuary and the second on a 2x4 fastened to a piling on the pier located at the end of Cove Road (Figure 1).

At deployment and recovery, the sensor elevation of each tide gage was surveyed using a Trimble real-time kinematic global positioning system (RTK GPS). The system operates by receiving position corrections in real time from the KeyStone KeyNet Virtual Reference Station (VRS) network over a cellular data network. The RTK GPS measurements were used to correct the raw pressure measurements collected by the instruments to elevations relative to North American Vertical Datum 1988 (NAVD88). The installation and recovery elevations were compared to test for instrument shift during deployment.

In order to calculate water levels from the two stations, barometric pressure was subtracted from the instrument's absolute pressure record. Barometric pressure data were downloaded from the nearby Chatham Municipal Airport, along with precipitation data for the deployment period. Data were recorded every five minutes and were available for the duration of the measurement period. Upon removing barometric pressure from the absolute pressure records, and applying an equation of state for seawater, the remaining pressure records were converted to the height of water (distance) above the pressure sensor. The height of water was then converted to water surface elevation using the surveyed elevation of each gage.

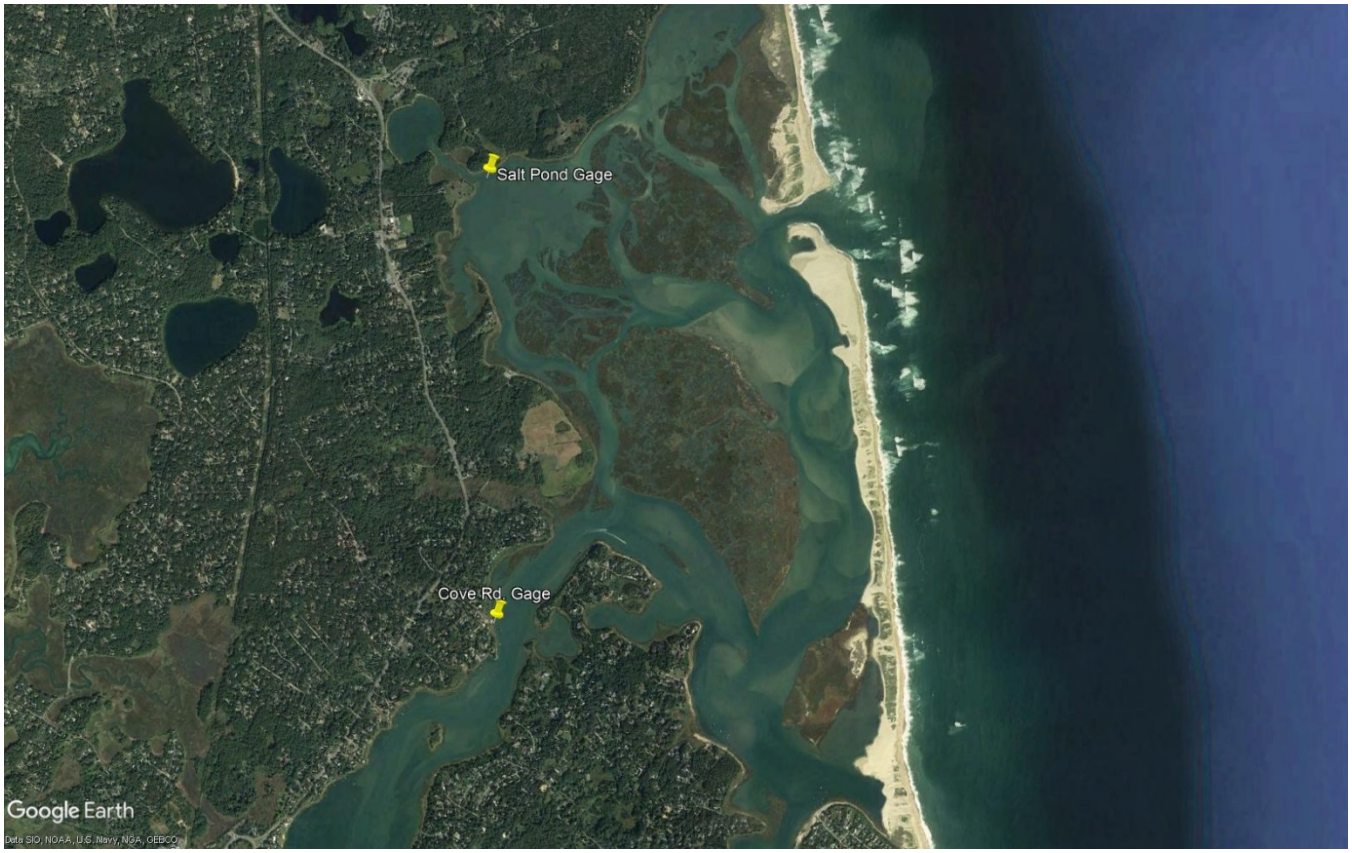


**Figure 1: Location of tide gages installed in Fall 2018.**

**Table 1. Nauset Estuary Tide Gage Locations**

| Gage ID | Latitude (Decimal Degrees WGS84) | Longitude (Decimal Degrees WGS84) | Sensor Elevation (NAVD88, feet) |
|---|---|---|---|
| Salt Pond | 41.83323146 | -69.96596963 | -1.85 |
| Cove Road | 41.81051646 | -69.96624348 | -2.68 |

Water temperature decreased during the deployment period, with a brief warming in early November (Figure 2). Temperature was nearly identical at both stations, with Salt Pond experiencing a greater range. Salinity remained relatively constant at the Salt Pond station, averaging 28.4 PSU over the deployment with a clear tidal signal of +/- 2 PSU (Figure 3). The salinity was consistently higher at the Cove Road Pier station, with an average of 29.4 PSU. A tidal signal was observed in the record for the first two weeks, then disappeared for the remainder of the deployment, likely due to biofouling of the conductivity sensor. Decreases in salinity occurred at both stations following precipitation events of 18.3 inches on October 11$^{th}$, and 5.6 inches on November 16$^{th}$.

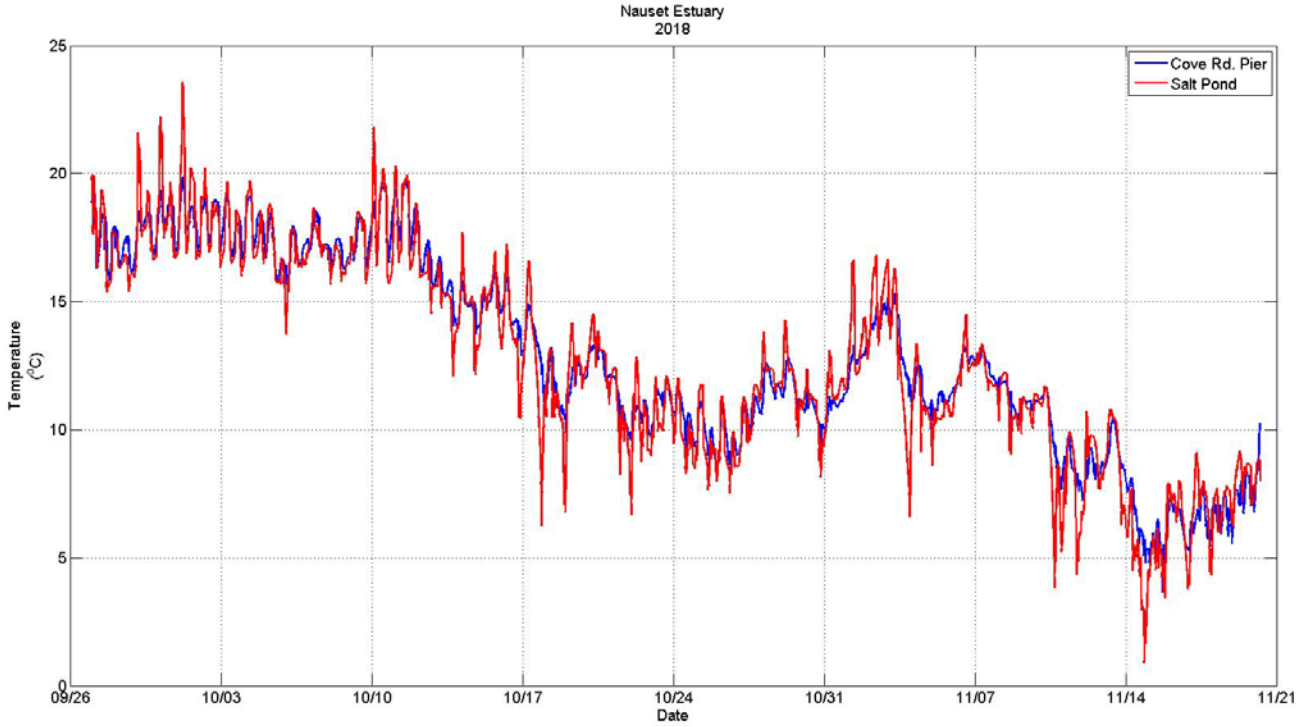


**Figure 2: Temperature record at Salt Pond and Cove Road Pier.**

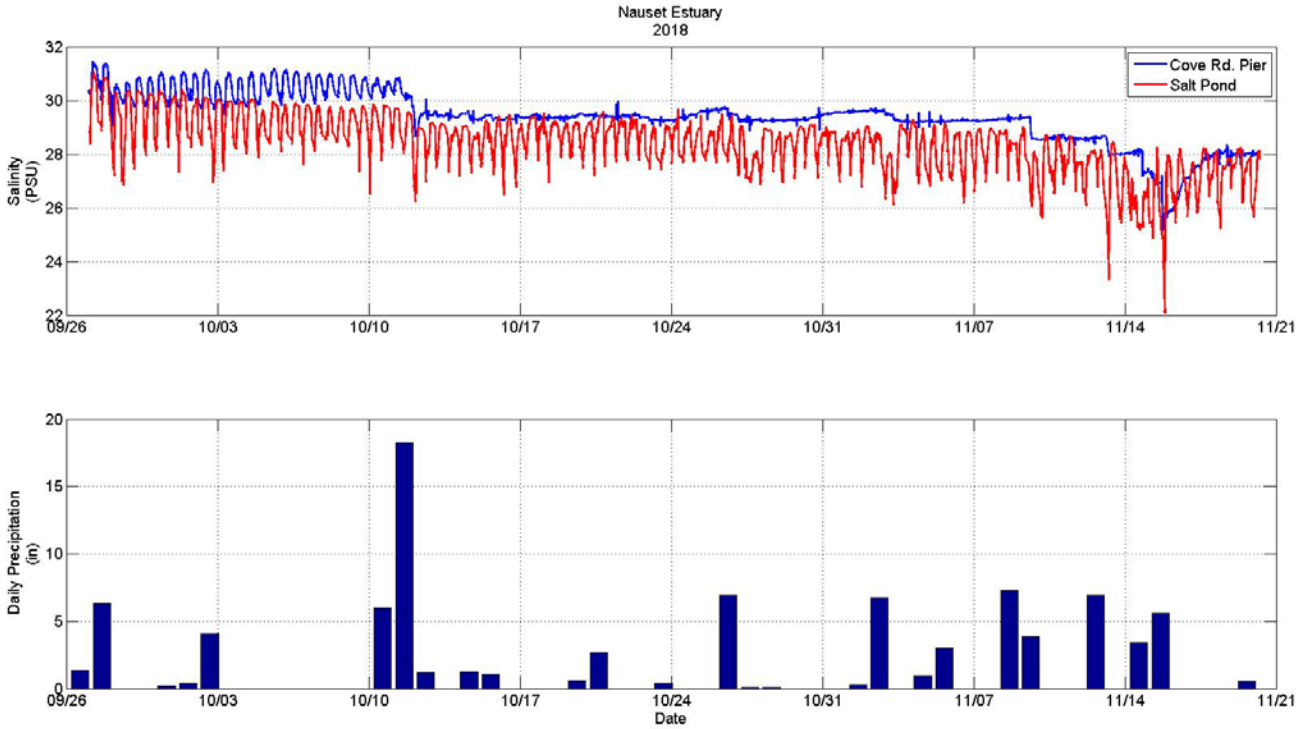


**Figure 3: Salinity record at Salt Pond and Cove Road Pier (top). Daily precipitation in inches measured at Chatham Municipal Airport (bottom).**

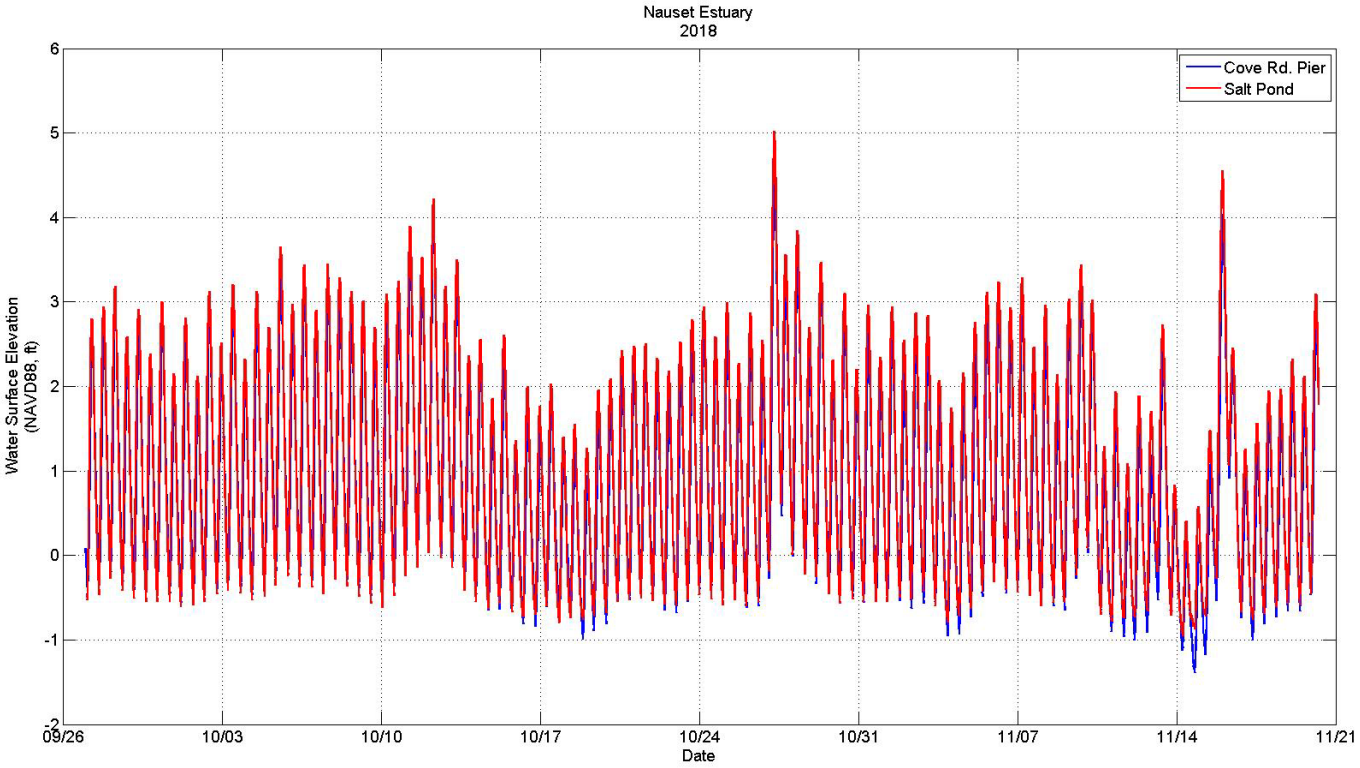


**Figure 4: Water surface elevation in feet relative to NAVD88 record at Salt Pond and Cove Road Pier.**

The nearly-identical water surface elevation records at Salt Pond and Cove Road are shown in Figure 4. Data from the gages were used to determine tidal datum elevations with respect to NAVD88 for mean higher high water (MHHW), mean high water (MHW), mean tide level (MTL), mean low water (MLW), and mean lower low water (MLLW). Results of the tidal datum calculations for each gage are summarized in Table 2. The data shows a slightly greater tide range of 3.49 feet at the Salt Pond gage as compared to a range of 3.29 feet at the Cove Road gage. The elevations of MLLW and MLW are nearly equal at the two locations, while the MHW and MHHW datums are greater at the Salt Pond gage, thus leading to the increase in tide range (Figure 4).

Sharp water level increases were observed on October 26$^{th}$ and November 16$^{th}$ likely due to precipitation events of 6.9 and 5.6 inches per day, respectively. The largest precipitation event on record, 18.3 inches on October 12$^{th}$ did not make a significant impact on the water level signal, likely a result of differences in precipitation between Chatham and the survey location.

Water level data from the closest NOAA gages at Boston and Chatham (Aunt Lydia's Cove) were downloaded for the same September 27 to November 20, 2018 time period (Figure 5). Comparison of the data show significant attenuation of the Nauset Estuary tidal signal over both of the nearby NOAA recording stations. The tidal range decreased from approximately 8.7 feet at the Chatham Fish Pier to 6.0 feet at the Cove Road Pier.

The computed tidal datums were also used to adjust the bathymetric survey data collected in 2015 and 2018 to MLLW, so that revised dredge volumes could be calculated for the project. The updated NAVD88 to MLLW datum correction was 0.3 feet higher than the correction used in 2015, based on a tidal record from Town Cove.

**Table 2. Nauset Estuary Tidal Datums**

| Datum | Cove Rd. Elev. (ft, NAVD88) | Salt Pond Elev. (ft, NAVD88) |
|---|---|---|
| MHHW | 2.73 | 2.94 |
| MHW | 2.43 | 2.65 |
| MTL | 0.97 | 1.08 |
| MLW | -0.49 | -0.49 |
| MLLW | -0.56 | -0.55 |

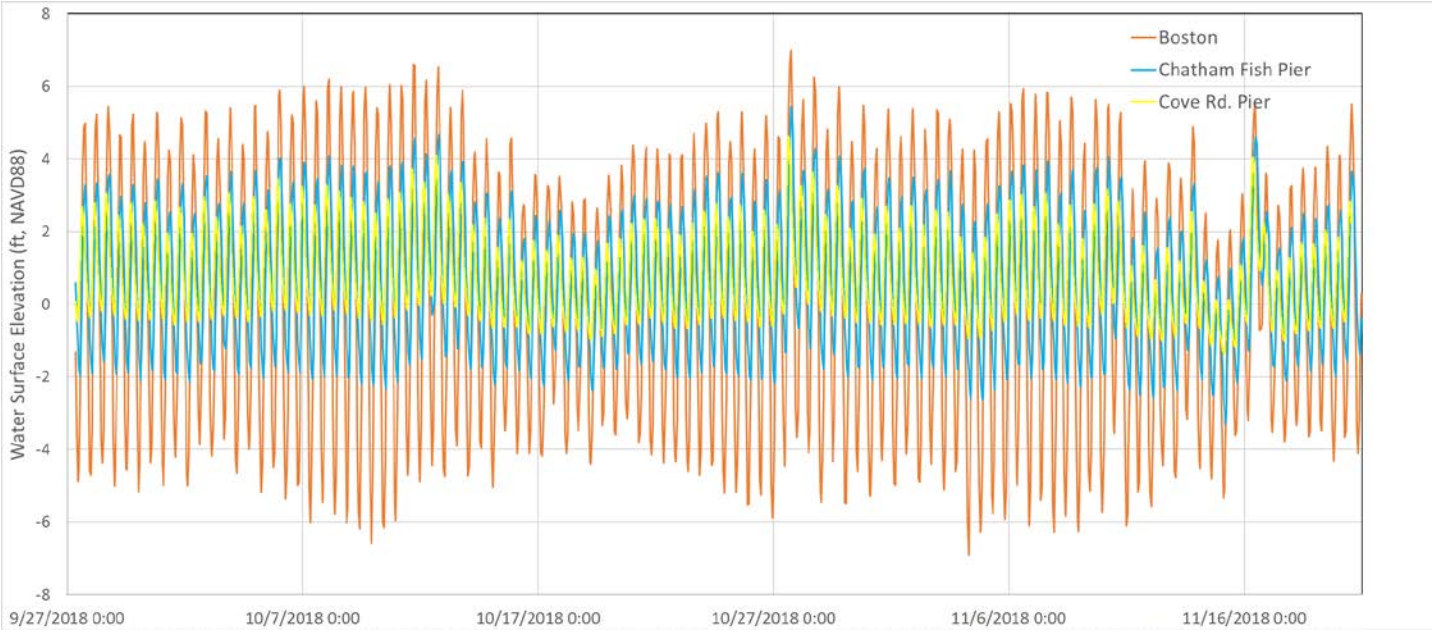


**Figure 5: Water level elevations at Nauset Estuary compared to NOAA gages located in Boston and Chatham.**

### B. Bathymetric Survey

The existing water depths and shoal configurations in the Nauset Harbor estuary were mapped via a bathymetric survey conducted on October 22, 2018. Additional bathymetry data were collected on November 20, 2018 at two new potential channel locations in the town of Eastham; the Hemenway Spur which connects the main channel to the Town Landing at Hemenway, and the Cable Creek channel which connects the Town Landing with the estuary entrance. The purpose of the survey was to document existing conditions to provide necessary information to evaluate potential dredge channel layouts and to compute dredge volumes.

The bathymetric survey was performed by a two-person crew, one surveyor from Woods Hole Group and the Town of Orleans Harbormaster. An Odom Hydrotrac 200 kHz single-beam echosounder was mounted to the side of the hull and recorded water depth at 6 Hz intervals. The Trimble RTK GPS was integrated with the echosounder to allow for real-time tide corrections by measuring the height above the WGS-84 Ellipsoid above the static water line. Post-processing included the removal of bad data, smoothing of the 6-second sounding measurements, and comparison of RTK tidal corrections with the tidal record collected by the co-located tide gages. To allow for simple comparison to channel design and navigational purposes, the soundings were converted from elevation relative to NAVD88 to MLLW tidal datum. The MLLW datum determined from the 2018 tidal record was used for both the new survey data and to correct the 2015 data as well.

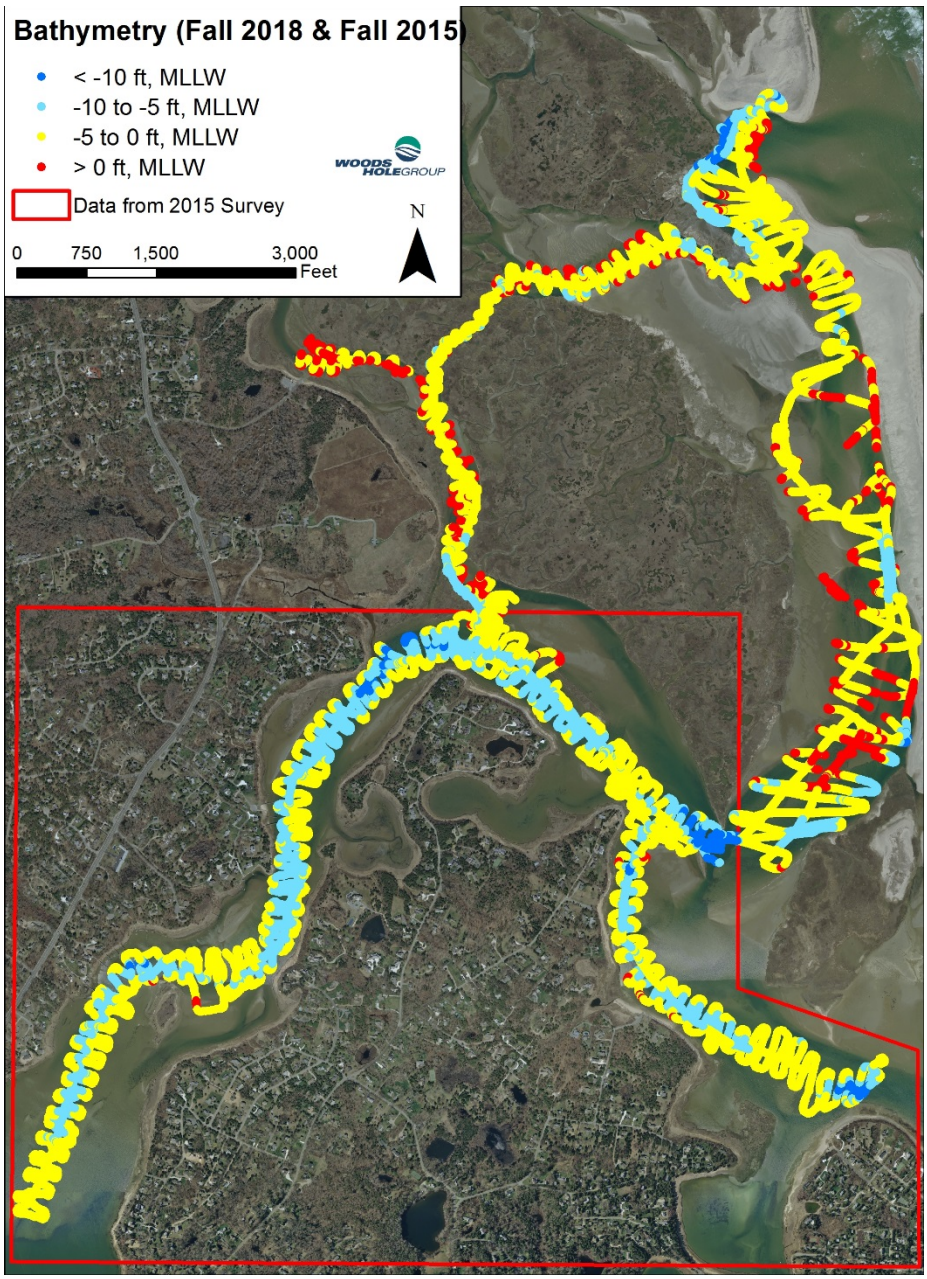


**Figure 6: Bathymetry of Nauset Estuary measured October 21, 2018, November 20, 2018 and fall 2015 relative to MLLW.**

Figure 6 shows the bathymetry data collected during the 2015 (outlined in the red box) and 2018 surveys. The soundings plotted in yellow and red highlight the channel areas that are shallower than the -5 MLLW channel elevation design. Depths in the main channel range from -25.5 to 6.8 feet MLLW. The shallowest areas of the channel are located at the northern and southern ends of the Hemenway spur, along with a number of isolated shoals in the main channel behind the barrier beach.