Port of Charleston Entrance Channel Dynamics

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Harbor Entrance, Charleston, SC

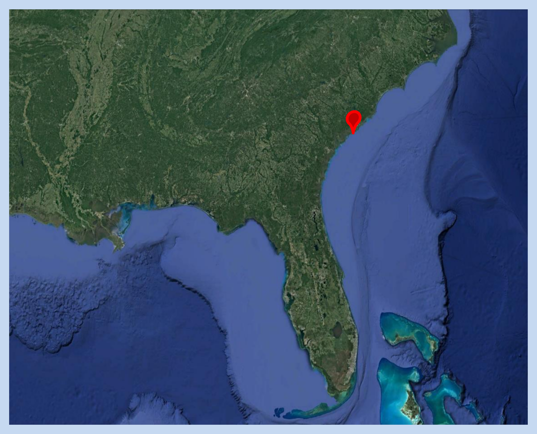

Figure 1a. Google Earth Image with geographic location of study area within the South Atlantic Bight. Charleston, South Carolina is located at the red pin.

Figure 1b: Google Earth Images of Charleston Harbor with the jetties outlined in black and the surveyed transect shown as a red arrow.

ABSTRACT

Water flow and subsequent changes in bedforms were examined around the mouth of the Charleston Harbor, SC, throughout a series of tidal levels to determine how changes in velocity affect bedforms in the entrance channel, and how the changing bedforms may have long-term affects in onshore/offshore dynamics. Changes in harbor entrance bedforms were analyzed using a sidescan sonar, and current velocities were measured using Acoustic Doppler Current Profiler (ADCP). Measurements made over a complete tidal period were interpreted to further understand sediment deposition and composition throughout varying current velocities. Datasets from the current profiler, sidescan sonar, and grainsize analyses were related to one another to further understand their relationships.

BACKGROUND

The Charleston Harbor jetties (Figure 1) were completed at the end of the 19th Century to maintain a direct and open pathway for commerce entering the port of Charleston. The harbor lies in the South Atlantic Bight within a region where most inlets produce ebb tidal deltas containing coarse grained sediments (Hayes 1980), and is classified as a mixed energy coast with respect to tide and wave influences. Mixed energy areas have net seaward flux of sediment because the ebb tide is stronger than the flood tide, along with only moderate wave influence to transport sediment back into the inlet or harbor (Hayes and Fitzgerald 2013). The purpose of this project was to further understand how tidal changes and related currents impact sediment transport within the main entrance channel between the jetties. A time-series water-column and seafloor survey was conducted to document currents and bedform responses within the channel throat. The study took place four days before a full supermoon with above-normal tide levels, which causes an increase in tidal exchange. Surface water conditions were very calm during the expedition which provided an ideal environment for data collection.

METHODS

On November 29th, 2017 a group of College of Charleston undergraduates conducted an 8 hour survey aboard a 7-m center console Pioneer power boat. A Universal Sonar Mount was attached to the gunwale of the Pioneer, equipped with a Lowrance HDS12 StructureScan 3D and Teledyne RDI Workhorse Monitor Acoustic Doppler Current Profiler (ADCP). Where the jetties narrow (Figure 1b) surveys were conducted along the same NE- SW cross-channel transect approximately every 30 minutes. After each survey a CTD cast was taken at mid-channel. Castaway software was used to plot salinity changes through the inlet profile, and ADCP data were analyzed in WinRiver II to quantify the discharge and current velocity. Discharge was then segmented vertically into the top, middle, and bottom thirds of the water column. Side scan sonar data were processed and analyzed using SonarWiz 7.

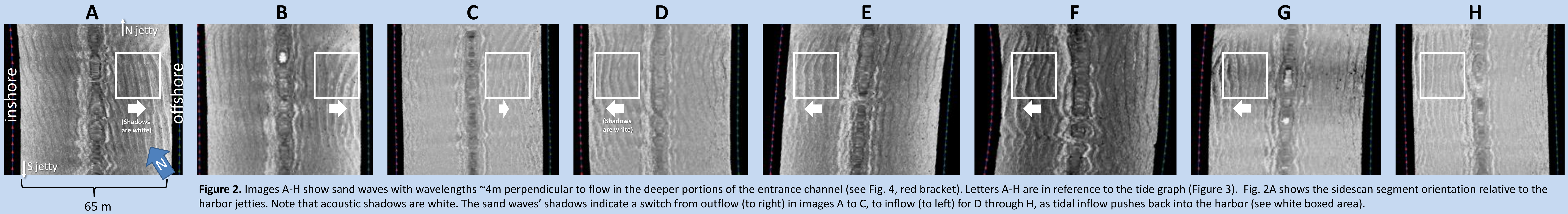

Figure 2. Images A-H show sand waves with wavelengths ~4m perpendicular to flow in the deeper portions of the entrance channel (see Fig. 4, red bracket). Letters A-H are in reference to the tide graph (Figure 3). Fig. 2A shows the sidescan segment orientation relative to the harbor jetties. Note that acoustic shadows are white. The sand waves' shadows indicate a switch from outflow (to right) in images A to C, to inflow (to left) for D through H, as tidal inflow pushes back into the harbor (see white boxed area).

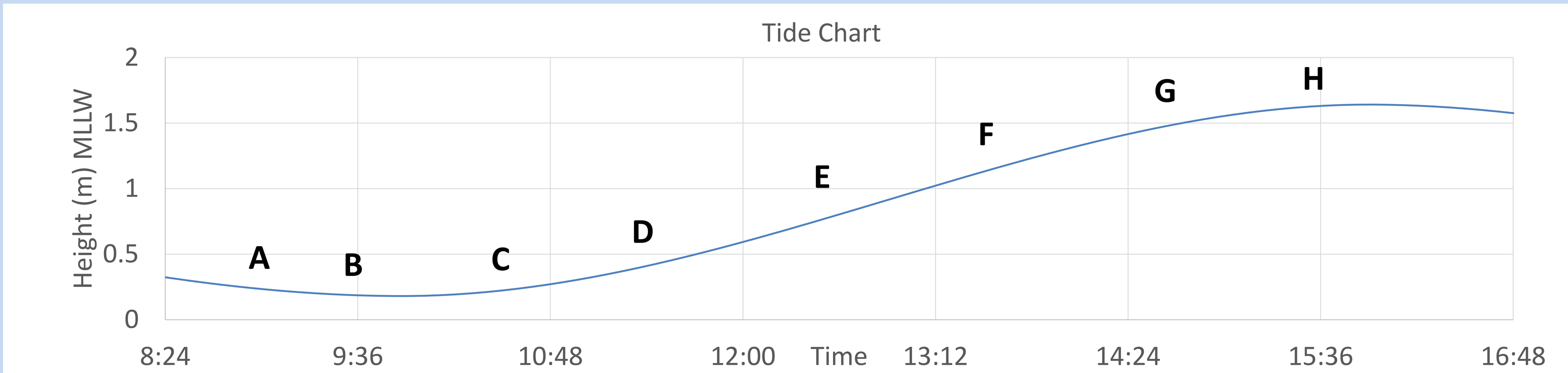

Figure 3. NOAA tide graph for the Charleston Harbor. Letters A-H indicate times associated with data collections shown in Figures 2 and 8.

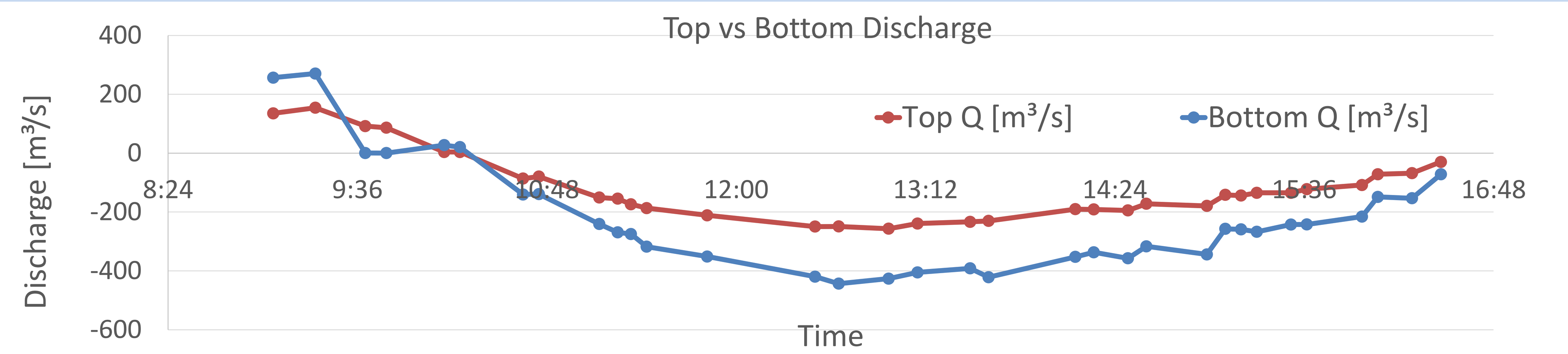

Figure 5. Relationship of top (near surface) and bottom discharge over the study period (Fig. 3).

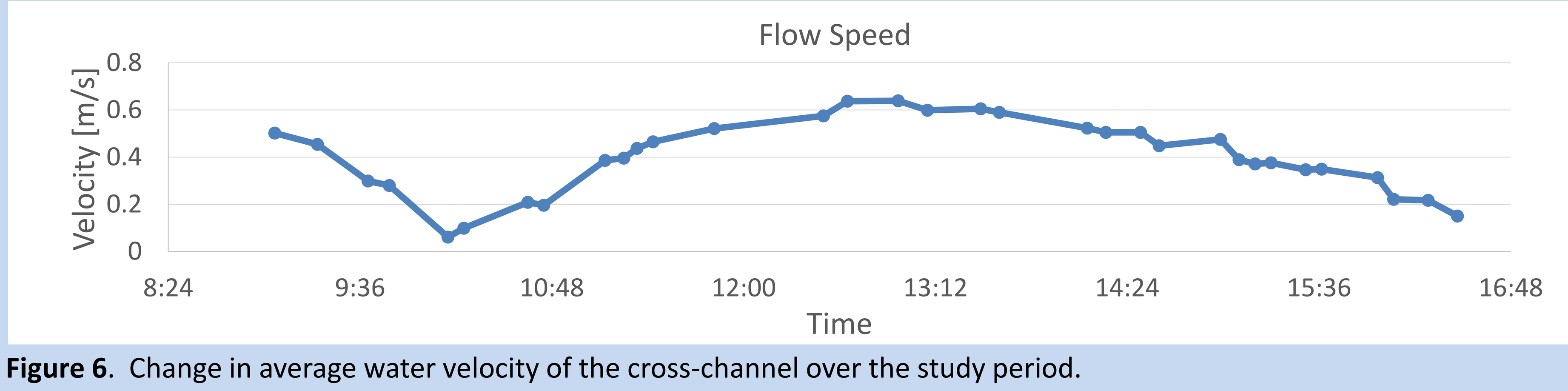

Figure 6. Change in average water velocity of the cross-channel over the study period.

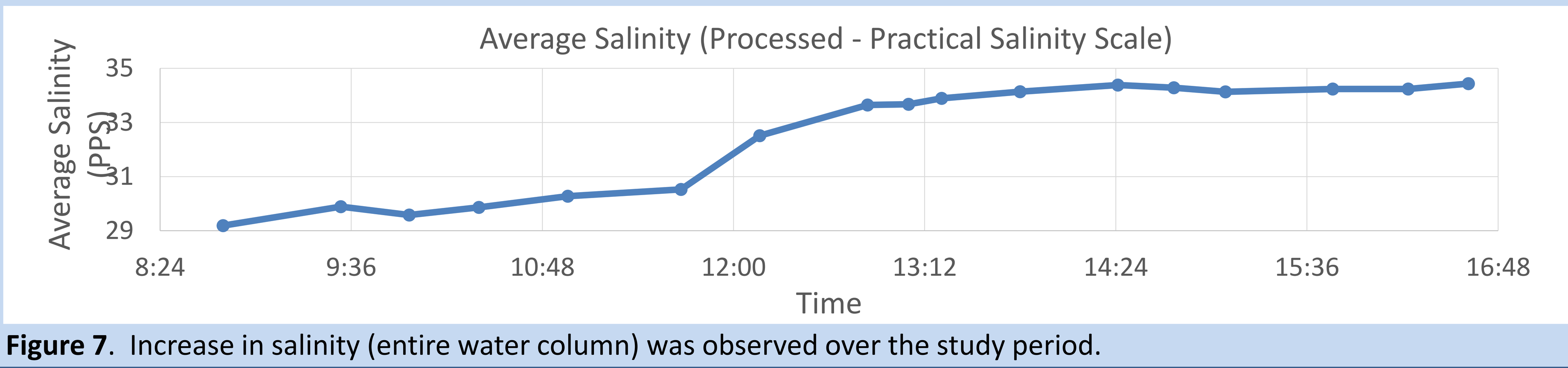

Figure 7. Increase in salinity (entire water column) was observed over the study period.

RESULTS

- The acoustic shadow of sand waves was observed to reverse from facing offshore to facing inshore (Figure 2) through the tidal change (Figure 3) in the deepest part of the channel (Figure 4).
- There was greater discharge at the bottom of the water column (at the seabed) than at the top. Seabed water volume had a peak inward flow of 443 m^3/s compared to the top inward flow maximum of 256 m^3/s (Figure 5).
- The harbor channel had an observed minimum velocity of 0.06 m/s and a maximum of 0.639 m/s (Figure 6).
- Minimum average salinity was 29.2 PPS at low tide and the maximum was 34.4 PPS at max high tide (Figure 7).
- Salinity from the CTD casts shows an increase of more saline water in the lower part of the water column at the onset of the tidal change (Figure 8, curve B). This water column salt wedge increases in thickness until the water column is nearly isohaline at high tide (Figure 8).
- Peak total discharge was observed at 12:39 and had an input of 5205 m^3/s into the harbor. Total inflow: 39.77 x 10^6 m^3
- Sand wave wavelength and amplitude stayed nearly constant with an average of 4.3 m and 0.28 m, respectfully.
- Depths of the sand waves ranged from 13 to 15m.
- Average cross-channel water temperature (not shown) was 15°C and did not fluctuate a significant amount throughout the study.

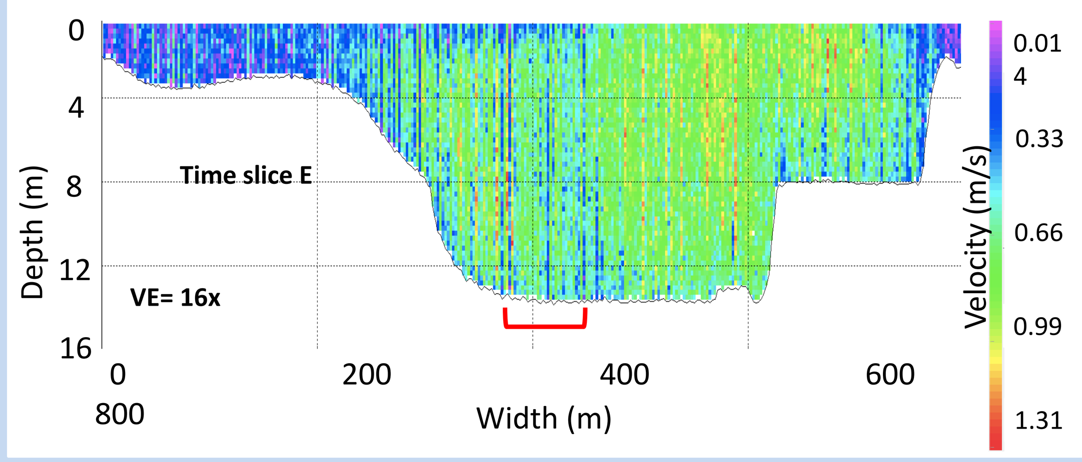

Figure 4. Current velocity along the channel profile. Red bracket shows Fig. 2 sand wave location. This profile is associated with figure 3E.

Figure 8. CTD salinity data and how salinity changed in the water column of the Jetties over time. The letters in the graph refer to the tide graph in figure 3.

DISCUSSION

According to ebb-dominated systems, there should be an overall seaward flux of sediment within the Charleston area. The purpose of this project was to further understand how the tidal changes and subsequent currents impact sediment transport within the main entrance channel between the jetties. Quantifying the net flux of sediment would allow us to make projections on sediment accumulation rates within the port which would be beneficial to the commercial and recreational community who utilize the Port of Charleston. The CTD salinity data show the flood tide produces a salt wedge that enters the harbor (Figure 8). This bottom water current can also be seen in the discharge data which show the bottom water column having nearly twice the discharge of the surface discharge (Figure 5). Side scan sonar data provide a visual representation of the bottom water current effects on moving bedforms. To fully understand the net flux of sediment, this survey would have to be repeated over several full tidal ranges with high-resolution bathymetric surveys. Once a full data set is complete for this area and other segments of the harbor system, need for dredging projects could be predicted over a longer period of time.

REFERENCES

Hayes, M.O., and Fitzgerald, D.M., 2013, Origin, Evolution, and Classification of Tidal Inlets, *J. of Coastal Research*, Special Issue No. 69, 2013 , p. 1–28.

Hayes, M.O., 1980, General Morphology and Sediment Patterns in Tidal Inlets, *Sedimentary Geology*, v. 26, p. 139–156.

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