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Effect of Vessel-Generated Waves in Near Low Tide Conditions on Shorelines in the Intracoastal Waterways

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EFFECT OF VESSEL-GENERATED WAVES IN NEAR LOW TIDE CONDITIONS ON SHORELINES IN THE INTRACOASTAL WATERWAYS

by

Mackenzie Sanchez, B.S.

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I dedicate my thesis with the utmost gratitude to my loving family for their continued support and encouragement. You have never missed the opportunity to remind me that I can do anything I set my mind to. To my parents, I appreciate your many sacrifices and hope that this milestone will make you both very proud. To my loving boyfriend, Robert Schubert, for being my loving partner in all things, every step of the way. To the yoga practice, for keeping me sane during these stressful times and reminding me to always be grateful.

Namaste.

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ABSTRACT

Erosion is caused when there is a net loss of sediment in a coastal system, i.e. when the amount of sediment leaving a system is more than the amount of sediment entering that same system. This investigation will focus on vessel-generated waves and their effect on the shorelines of the Jacksonville, Florida Intracoastal Waterways near low tide conditions. The investigation conducted herein examines variations in turbidity and pressure measurements in response to passing vessels at a single site location previously selected in 2016. The primary water/shoreline interaction recorded during this investigation is located below the visible scarp (near low tide conditions). It was concluded that vessel-generated wave height and water level influenced turbidity levels. Turbidity measurements were greater during lower water levels. Vessel passage reduction or no wake zones during low water levels is recommended to reduce the erosion of the intracoastal shorelines into the channel. Future research is recommended to better determine the influence of low tide conditions on turbidity.

CHAPTER 1: INTRODUCTION

Erosion is a process that most coastal areas endure. It is caused when there is a net loss of sediment in a coastal system, i.e. when the amount of sediment leaving a system is more than the amount of sediment entering that same system. Northeast Florida Intracoastal Waterways consist of many channels and tributaries that connect the St. Johns River Inlet to the St. Augustine Inlet. These waterways provide habitat for a variety of plant and animal species, all of which play vital roles within our ecosystem. The effects of vessel-generated waves represent a potentially important factor to consider in quantifying shoreline evolution and ecological impacts (Ries, 2016). Vessel-generated waves occur when a vessel travels, displacing water equivalent to the volume of the vessel. When waves impact the shoreline, small amounts of sediment become suspended within the water column which can then be transported away within the current before settlement of the suspended material can occur. Over time, these small amounts of sediment being transported away can significantly impact shorelines and cause erosion. Bank erosion and sediment suspension negatively impact submerged vegetation and therefore indirectly impact aquatic and benthic organisms (Parchure, McAnally, and Teeter, 2001). Increase in vessel traffic and activity will lead to more vessel-generated waves impacting intracoastal shorelines and increase erosion rates in this region. Suspended sediment could then be deposited elsewhere in navigable channels of the Intracoastal, increasing accretion rates and affecting the timing of necessary maintenance dredging (Ries, 2016).

Waves in intracoastal waterways are predominantly generated by wind and vessels. Estuarine environments with large fetches are the most likely to be impacted by wind-generated waves (Sanford, 1994). At the location chosen for this study the fetch is too small to produce significant wind waves, but large vessels navigate these channels generate substantial wakes that

are a potential source of wave-generated erosion (Ries, 2016). Therefore, the focus of this study is on vessel-generated waves and their impacts on turbidity levels within intracoastal waterways.

This study augments the data collected by Ries in 2016. The following questions will be investigated:

- How is the amount of suspended sediment affected as vessel-generated wave heights increase?
- How do water depths and the type of shoreline impact turbidity levels and therefore erosion?

Results of this investigation show a relationship between wave height, water depth and shoreline erosion. Findings could lead to improved erosional solutions to the intracoastal waterways of Jacksonville, Florida; ranging from regulations on vessel activities within the waterways, to potential mitigation measures, such as living shorelines, to protect the coastal banks within the estuarine and riverine areas.

CHAPTER 2: LITERATURE REVIEW

The following literature review describes the previous work that is closely related to this thesis. Maa and Mehta (1987) used a wave flume to analyze the impacts of waves on different mud types and the process of bed erosion. It was concluded that the longer the duration of waves, the greater the suspended sediment concentration. These researchers determined that the waves decreased the bed's resistance to erosion and suspend sediment, but they could not conclude that the sediment would be transported away from its area of origin due to the design of a flume model (Maa & Mehta, 1987).

Garrad and Hey (1987) examined suspended sediment concentration patterns after the passage of a vessel to investigate whether algae growth was the most significant factor for high turbidity levels in the Broadland Waterways. The Norfolk Broads are a group of intertidal rivers that contain brackish water due to their connection to the North Sea, similar to the site conditions within the intracoastal waterways of Jacksonville, Florida (Ries, 2016). When material goes into suspension it increases the turbidity levels in the water column. Garrad and Hey determined that the effect varies for different boat types and for the distance from the instrument to the passing vessel (greater distances leading to shorter settling times and decreased turbidity). It was also observed that the daily pattern of the suspended sediment reflected boat traffic and larger variations in concentration occur in sections with higher speed limits. This study did not account for the variations in hull characteristics among vessels which could also impact the turbidity levels.

Parchure, et al. (2001) studied the relationship between vessel passage and suspended sediments using a model that analyzed sediment suspension in relation to wave heights, changing depths, and varying sediment types within the Upper Mississippi River-Illinois Waterway (UMR-IWW). However, the UMR-IWW is not strongly influenced by tides and contains a lower salinity level, unlike the intracoastal waterways in Jacksonville. Sediments in this model had the lowest

critical shear strength needed to erode, and the hard sediment having the highest. The sediments were characterized using a particle size distribution, percentage of total organic content, and sediment bulk density. It is known that soft sediments can more easily be suspended because of the low bed shear stress needed to suspend them and hard sediments have a greater fall velocity reducing sediment suspension time. It was determined that a decrease in water depth caused an increase in bed shear stress, while an increase in wave heights caused an increase in the suspended sediment concentrations.

Parchure, et al. (2007) continued previous work with a similar model in which wave period and water depth were kept constant, while boat passage intervals and wave heights varied. This study was to relate wave height and the frequency of boats passing to a time-series of turbidity. It was determined that as wave heights increased, so did the sediment suspension concentration. When the wave heights were kept constant and the frequency of boat passage was increased, sediment suspension concentration increased as well. This study concluded that sediment suspension concentration is strongly influenced by both maximum wave height and the frequency of boat passage. However, this model did not take into consideration the variations in hull characteristics among vessels or the varying shoreline characteristics.

Nanson et al. (1994) determined there was a threshold in the erosive potential of vessel-generated wave trains on sandy river banks with wave power showing the highest correlation with bank erosion rate. The study showed that maximum wave height indicated a threshold in wave erosive potential at a height of about 30-35cm in relatively granular sandy alluvium and a similar wave-energy threshold would exist for the more cohesive sediment on the river, albeit with a slower rate of erosion. Wave heights greater than 5-10cm had sufficient wave energy to eroded material at the foot of the bank out into the channel. This study lead to the correlation between reducing maximum wave heights to < 30cm by limiting boat speeds, and reducing the frequency of boat passages, and a decline in bank erosion along the river.

Osborne and Boak (1999) showed that regularly produced wave groups which have significant heights and periods which are approximately double that of the maximum wind generated waves. The vessel generated waves had a gross sediment transport potential which is greater than the sustained influence of the wind generated waves on the beach. Osborne determined that as the vessel generated wave group progresses, suspended sediment concentrations increased in the water column than can settle completely in a half wave cycle. This has a cumulative effect on the instantaneous suspended sediment and is also responsible for inducing the phase lag between the event maximum suspended sediment concentration and the occurrence of the largest waves in the group. The gradual accumulation of fine sediments contributes to enhanced turbidity in the nearshore for up to several minutes following the passage of a vessel generated wave group. Both wind and vessel generated waves appear to have a relatively minor effect on the sediment transport and foreshore response at Torpedo Bay. However, it is important to note that this study, unlike the thesis herein, is based on commercially operated vessels entering and leaving the Waitemata Harbor in Auckland.

Osborne et al. (2007) continued work with model simulations combining the hydrodynamics of super-critical wakes with steady currents and a sand transport model. The term super-critical is used to describe high-speed vessels while and sub-critical to describe displacement vessels traveling at slow speed. It is stated that super-critical refers to the state where the vessel is moving faster than the speed at which a wave of the same length can travel in that depth of water (depends on the speed of the vessel and the depth of the water). Models produced by Osborne et al. (2007) indicated that wakes re-suspend sand in the nearshore that would otherwise be immobile. This showed that sand is transported both alongshore and offshore incrementally away from the shoreline eventually reaching deeper water where stronger ambient flows can transport the sediment (Osborne et al., 2007).

Bauer et al. (2002) used a cross-shore array of electromagnetic current meters and optical back-scatterance (OBS) sensors to measure the character of boat wakes and associated suspended sediment plumes. In this study, a primary wave packet was defined as the first three wave crests in a boat-wake event. It was determined that boat wakes in this region, entrain rather than resuspend new material and gradually erode levee banks. Two different methods for estimating the magnitude of boat- wake-induced bank erosion was developed. Method 1 uses only the OBS measurements and assesses erosion on the basis of a representative ''mean'' suspended sediment concentration (SSC) during the boat-wake event (generally pertaining to any system dominated by suspended sediment transport in which the horizontal gradients in sediment flux are small relative to the absolute magnitude of sediment flux). Method 2 incorporates both the OBS and current meter time series, as is conventional for nearshore sediment transport studies. The erosion estimates derived from either method were similar showing a range from less than 0.01 mm/boat passage for the weakest boat-wake event to 0.22 mm for the most energetic boat-wake event. Two multiple boat-passage experiments yielded erosion rates of roughly 0.01–0.03 mm/boat passage. It is important to note that the erosion rates derived are applicable only to the cohesive mud bank in this location and other sites and circumstances may be invalid except for purposes of determining general tendencies.

Houser (2010) conducted a field study between October 2007 and February 2008 to examine the relative importance of wind-generated and vessel-generated waves in the retreat of the salt marsh along the Savannah River. Houser determined that even though the vessel-generated waves represented a small percentage of the total wave energy at the site, their larger size means that they account for 25% of the total wave force applied to the retreating scarp. However, Houser also determined that the locally generated wind waves were primarily responsible for the retreat of the marsh especially during storm force winds. The study also concluded that an increase in vessel traffic and the use of larger, post-Panamax vessels will not significantly accelerate the retreat

of the marsh and it is still argued that active management of vessel speeds is not required and that many parts of the scarp are now protected by a wedge of sand.

Houser's work continued in 2011 where it was concluded that, firstly, suspended sediment concentrations increase with increasing turbulent kinetic energy of the wave group, with the amount of sediment resuspended dependent on both the efficiency of the excess shear stress and the availability of sediment on the bed. Second, Houser concluded that the resuspended sediment is transported landward by the individual waves of the group, but net transport is offshore due to a low-frequency oscillation resulting from the largest waves of the group. Houser stated that the direction of net transport can be reinforced or reversed depending on the timing of the pilot-boat wake with the seiche forced by a passing container ship. Lastly, Houser concluded that sediment transport by the subcritical container ship wakes observed is directed landward or weakly offshore depending on the timing of the wave group with the low-frequency draw- down and surge. If the wave group of the container ship occurs with the surge of the seiche leading there is a landward current coincident with sediment resuspension. The strength of this landward current depends on the relative strength of the under- tow current generated by the grouped waves.

Ries (2016) concluded that the presence of vegetation did reduce turbidity levels within the Intracoastal Waterways of Jacksonville Florida and the gradually sloped shorelines minimized turbidity compared to shorelines with an escarpment. It was also concluded that wave height has a direct impact on the turbidity level; large wave heights lead to maximum turbidity spikes and therefore the most erosion. Ries (2016) also stated that other parameters seem to affect turbidity as well, from boat characteristics to additional wave parameters and other external forces.

Herbert et al. (2018) showed that the Intracoastal Waterway is a heavily trafficked boating area with an active wake climate. Herbert stated that boat wakes, especially from large or fast-moving vessels, suspend and transport nearshore soil particles into deeper water offshore, leading

to shoreline steepening. Based off the work earlier reference by Nanson et al. (1994), it was also stated that major erosive events are believed to occur with wave heights between 30-35 cm (Herbert et al., 2018; Nanson et al., 1994). Many waves in this study were documented in this range, therefore, Herbert concludes that this could be the reason for the erosion and retreat of vegetation in this region. This study was conducted slightly south of the thesis herein but was also along the Intracoastal Waterway in Florida. However, the purpose of this study was to gather larger datasets from each specialization area (ecological, geotechnical, coastal) to contribute to the existing literature in hopes that porous energy-absorbing breakwalls will protect the salt marsh and oyster reefs from extreme hydraulic conditions and promote their growth.

The thesis herein focuses on the relationship between vessel passage and suspended sediments. This investigation specifically studies the relationship between wave height and turbidity within varying water depth which is unlike the previous studies cited.

CHAPTER 3: METHODS AND DATA COLLECTION

3.1 Site Location

The study was located within the Intracoastal Waterways of Jacksonville, Florida just south of the Butler Blvd. Bridge at 30.240754, -81.421332 (Figure 2). The same site location was used as Ries (2016) to allow further augmentation of data.

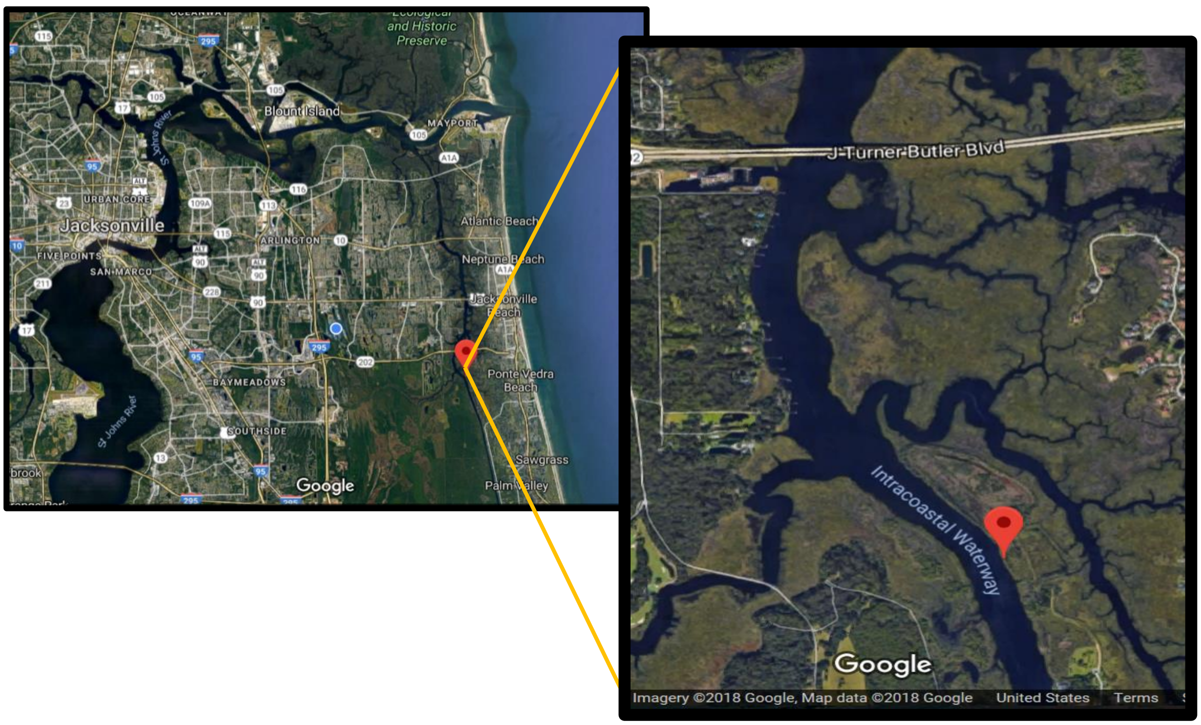

Figure 1: Study site at 30.240754, -81.421332 along the Jacksonville Florida Intercoastal Waterway.

This site contained natural shorelines, away from man-made development and provided a variation of shoreline characteristics with the tide cycles. The bank slopes were uniform at the site and exhibited a large escarpment 15.24cm-40.64cm in height that would be impacted during mid to high water elevations. A basic profile can be found in Appendix A. Above the 15.24cm-40.64cm escarpments were a continuous band of native vegetation. The

plants here are primarily *Distichlis spicate* (seashore saltgrass), *Spartina patens* (salt marsh hay) and *Spartina alterniflora* (smooth cordgrass). However, this investigation will only analyze the shoreline near low tide conditions, therefore only to the escarpment and below depending on tide.

Four different sediment samples, from where the sensors were located to about 30ft shoreland, were taken at the site to conduct a grain size distribution. A sieve analysis was done on all sediment samples to determine grain size distribution (results can be found in Appendix A). Sediment was then classified in accordance to the Unified Soil Classification System (USCS) which represents silty gravels and gravel-sand-silt mixtures. Fifty percent of all sediment sampled showed a diameter of less than 0.2mm. From the Hjulström diagram (Puscas, 2010) in Figure 2, it can be determined that a 0.2 mm diameter particle of sand will have a fall velocity of about 20 mm/s. The slower the fall velocity of the particle, the longer the particle will remain suspended in the water column before resettling, allowing it to possibly be carried away by the current. Figure 2 also shows that the sediment at this site location is classified as the most erosive, requiring the least erosion velocity of about 10-15cm/s.

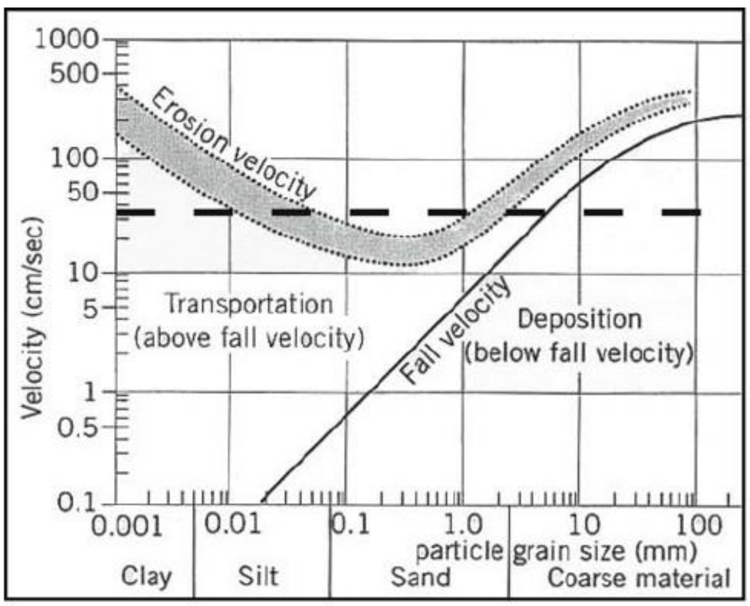

Figure 2: Hjulström diagram (Puscas, 2010). The red line indicates 50%-60% of the sediment at the site location.

It is important to note that two large hurricanes have impacted this site location since it was last visited as well as numerous storm events. Figure 3 shows the same location during Ries (2016) study in comparison to present day. Significant erosion in the past two years is visible.


Figure 3: Image on the left of site location (Ries, 2016) (Left). Same site location in image on the right. Image taken during peak low tide conditions on February 2nd, 2018. Blue arrows indicate the same tree as a marker during both studies. Red arrows indicate the same wood plank as a marker during both studies. More images can be found in Appendix C.

Figure 4: Image of escarpment at the site near peak low tide conditions on February 27th, 2018. Red arrow in the upper right corner indicates the same PVC pipe location from both studies. More images can be found in Appendix C

Figure 4, again, shows the erosion that has taking place over the past two years. This figure illustrates larger scarps than previously recorded in Ries (2016). Large round balls of displaced sediment can be seen

along the shoreline in both figures, 3 and 4, depicting the unstable shoreline conditions at this site location.

3.2 Instrumentation and Variables Measured

The following instrumentation was used in this study. The main equipment listed below was used to measure sediment characteristics, turbidity, and vessel-generated wave heights.

- YSI ProDSS Handheld:

  The YSI ProDSS handheld worked in conjunction with the ProDSS turbidity sensor. When deployed the YSI ProDSS handheld was connected to the ProDSS turbidity sensor by a 10-m cable through a water-tight connection (Ries, 2016). This device is not water proof and was kept in the inflatable raft when the tide came up.

- ProDSS Turbidity Sensor:

  The ProDSS Turbidity Sensor was fixed to the middle earth anchor a couple of inches above the sediment. It collected data using Nephelometric - Optical, 90° scatter, which uses an infrared light beam, with a light detector 90° to the side of the light beam, in order to measure the suspended particles within the water column. Prior to field deployment, the turbidity sensor was calibrated using standards of 0 and 124 Formazin Nephelometric Unit (FNU). Unlike the Nephelometric Turbidity Unit (NTU), FNU uses infrared light instead of white light to measure turbidity. Readings were taken at 10 second intervals (0.1 Hz).

- Pressure Sensors:

  The GT RTU TS-7250_V2 device, created by Kent Hathaway, was used to record the pressure. Two Pressure sensors were used during each collection for redundancy. The pressure sensors record 10 measurements per second (10Hz) in centimeters.

- GoPro Hero 6 Camera:

  The GoPro Hero 6 camera recorded passing vessels and the wakes produced traveling to the shoreline. It recorded with a screen resolution of 1080p at 240 frames per second (FPS). The GoPro Hero 6 camera was held in the same position for each passing vessel. It was also used to take photo documentation of the site conditions each day.

- Bushnell Velocity Speed Gun:

  An easy point-and-shoot speed gun. Records speeds above 10 MPH with +/- 1 MPH accuracy.

- PVC Pole (3 m):

  The PVC pole left from the previous study in 2016 and was used as a marker from which to record passing vessels with the GoPro Hero 6.

- Sieve Plates and Sediment Shaker:

  A sieve analysis was conducted to determine sediment characteristics. Four samples were taken from the site and then dried in the lab to move all excess water before analysis. Sieve numbers 10, 20, 40, 80, 100, 140, and 200 (US) were used. Once the sieves were placed in order, from largest (10) to smallest (200) within the sediment shaker, the shaker was run for five minutes. The sediment retained on each sieve was weighed in order to calculate the percent retained and percent passing. From this, the general particle diameter of the sediment was found. Then, using the Unified Soil Classification System (USCS) (Table 1), the classification of the sediment was determined.

3.3 Data Collection

Data was collected on Sunday March 25th , 2018 from 1:28PM-2:38PM (peak low tide occurring at 12:04PM) and on Saturday April 7th , 2018 from 10:47AM-12:48PM (peak low

tide occurring at 10:46AM). In Ries 2016, shorelines were classified as non-vegetated scarp (NVS), vegetated scarp (VS) and vegetated shoreline with no scarp (classified as VWNS). Results of this investigation show supplemental area and not a direct comparison to Ries 2016, in which it was concluded that turbidity decreased when water level reached vegetated shoreline with no scarp. This investigation focused on water level that reached VWNS shoreline and below and is centered around low tide to augment the work of Ries (2016).

Data was collected for a minimum of 1 hour during each site visit. The pressure sensors were attached with zip ties, parallel to the earth anchor facing downward approximately 2 inches above the soil surface. Pressure sensors recorded in centimeters; at a frequency of 10 Hz per second for that hour. Two pressure sensors were placed during each collection (5 feet from the turbidity sensor on each side) for redundancy. The turbidity sensor was also zip tied to an earth anchor approximately 2 inches above the soil surface. Turbidity recorded measurements every 10 seconds (0.1 Hz) and collected for over an hour to account for any lag time in turbidity response after a spike in pressure. Figure 5 shows the placement of the equipment in relation to the shoreline and the tidal difference between the two studies. Note that low tidal conditions allowed the equipment to be placed 30 feet closer to the channel.

Figure 5: Image on left is the placed equipment (turbidity sensor) from Ries (2016). Image on the right was taken at 10:21AM on March 7th, 2018 near peak low tide conditions. Yellow arrows indicate the turbidity sensor placement.

Blue arrows indicate the same tree for reference in both studies. Red arrows indicate the pressure sensor placement. More images can be found in Appendix C.

Videos, pictures, and speed were taken for every vessel passing the site during data collection. Videos also recorded the respective wakes passing vessels created and the shoreline where wakes were breaking. Videos were used later for further processing such as vessel size and time of passing. Table 1 shows the organization of collected information. April 7th, 2018 vessel data contained 65 vessels and can be found in Appendix A.

Table 1: Table 1: Data collected on March 25th, 2018. Same data was compiled for April 7th, 2018 in Appendix A. Note: Radar could only record minimum speed of 10MPH.

March 25th, 2018					
Vessel	Time	Type of Vessel	Speed (mph)	Vessel Direction	Shoreline
1	1:42pm	Small	25	South	No Scarp - T2
2	1:42pm	Med	14	North	No Scarp - T2
3	1:46pm	Med	23	South	No Scarp - T2
4	1:52pm	Jet Ski	43	North	No Scarp - T3
5	1:52pm	Jet Ski	34	North	No Scarp - T3
6	1:52pm	Jet Ski	30	North	No Scarp - T3
7	1:55pm	Med	35	South	No Scarp - T3
8	1:59pm	Small	24	North	At Scarp
9	1:59pm	Med	<10	South	At Scarp
10	2:00pm	Large	26	North	At Scarp
11	2:05pm	Small	18	South	Low Scarp
12	2:05pm	Sailboat	<10	North	Low Scarp
13	2:07pm	Large	17	North	Mid Scarp
14	2:10pm	Small	25	South	Mid Scarp
15	2:11pm	Small	14	North	Mid Scarp
16	2:23pm	Med	20	North	High Scarp
17	2:23pm	Med	30	North	High Scarp
18	2:25pm	Small	<10	North	High Scarp
19	2:25pm	Large	<10	South	High Scarp

Days and times for data collection were selected based on maximum possibility in vessel traffic for more data collection and low tide conditions to emphasize shoreline sediment and turbidity interaction. It became apparent early on that more vessel traffic could be expected during midday, especially on a weekend. Weather also became a deciding factor since more vessels were observed on calm, sunny days versus overcast, strong winds and cool temperatures.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Turbidity related to Pressure

Speed did not seem to be a large factor in turbidity levels. Table 1 in conjunction with Figure 6 shows that some of the faster vessels recorded lower turbidity responses than the slower moving vessels. This is probably due to a wide range of vessel types and displacement traveling at different speeds. However, larger vessels did tend to show larger pressure responses and in turn larger turbidity. Three of the largest peaks in pressure (2:00PM, 2:07PM, and 2:25PM) in Figure 6 correlate with the largest vessels recorded even though they are not showing the highest speeds. This is expected since larger vessels have a higher volume and therefore displace more water, causing a larger pressure and turbidity response.

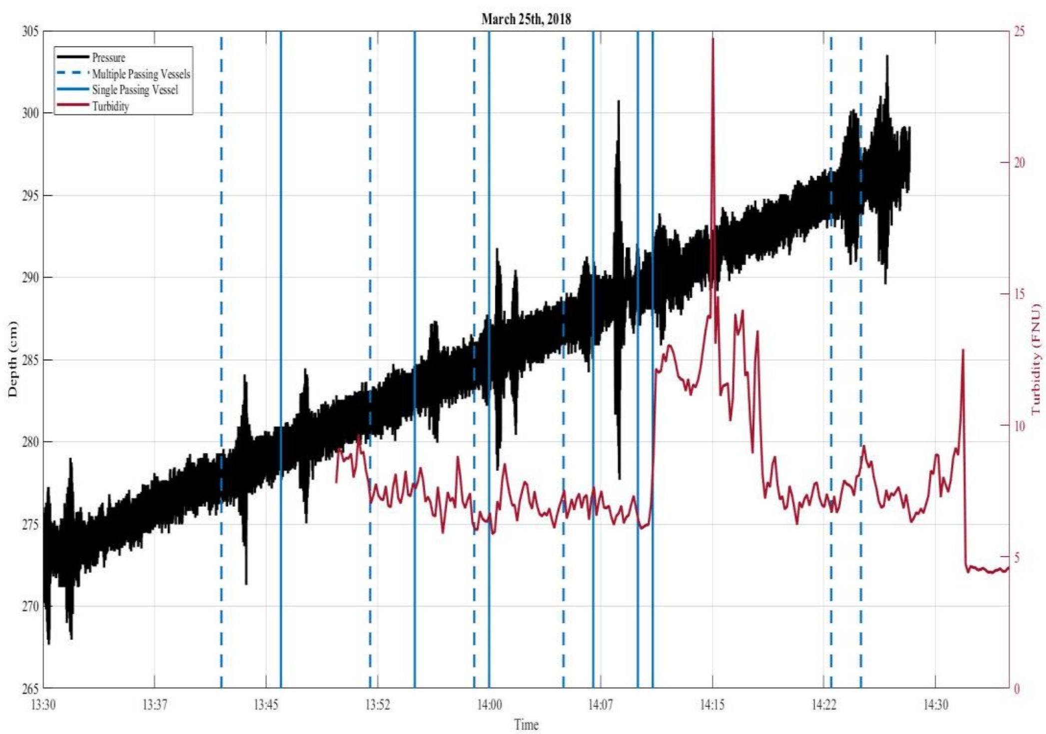

Figure 6: Single and Multiple vessels passing on March 25th, 2018 were recorded and laid over the first plots to see a correlation between vessels passing and peaks in pressure and turbidity.

The first data collection occurred from 1:30PM to about 2:40PM, which was about an hour and a half after peak low tide (12:04PM). During this period, nineteen vessels were recorded passing the study site. Pressure and turbidity measurements were plotted over time (Figure 6). Videos of the vessels were then analyzed to determine the time of passing vessels and whether there was a single vessel or multiple vessels passing at that time. Solid vertical blue lines indicate a single vessel passing, while dashed vertical blue lines indicate multiple vessels passing at that time (Figure 6). During this collection, the turbidity sensor was not started until almost 20 minutes after the pressure sensors which explains the lag time on Figure 6. This figure shows a clear pressure response to vessels passing the study site and a positive correlation between an increase in pressure and an increase in turbidity. There is a lag time from when a vessel passes and when the pressure increases due to the distance of the passing vessel to the pressure sensor. As tide changes and water depth increases, there is also a lag time between the pressure response and the turbidity response from a vessel passing. This is due to the location at where the waves are breaking on the shoreline. As the tide increases and water level moves higher onto the shoreline, the sediment and wave breaking interaction is occurring further from the turbidity sensor and it is taking longer for the sediment plume to move back towards the sensor.

The data collection on April 7th, 2018 (Figure 7) shows similar patterns to Figure 6. This data collection was taken over a longer period than the first data collection. During this time there were 65 recorded passing vessels versus the previously recorded nineteen vessels. Although turbidity measurements were taken during the entire time, there was a large pressure collection gap of about 50 minutes due to equipment malfunction. However, since the turbidity began measurements at peak low tide (10:46PM) and continued for two hours, there is significant evidence that turbidity levels decrease as water depth increases as shown in Figure 7.

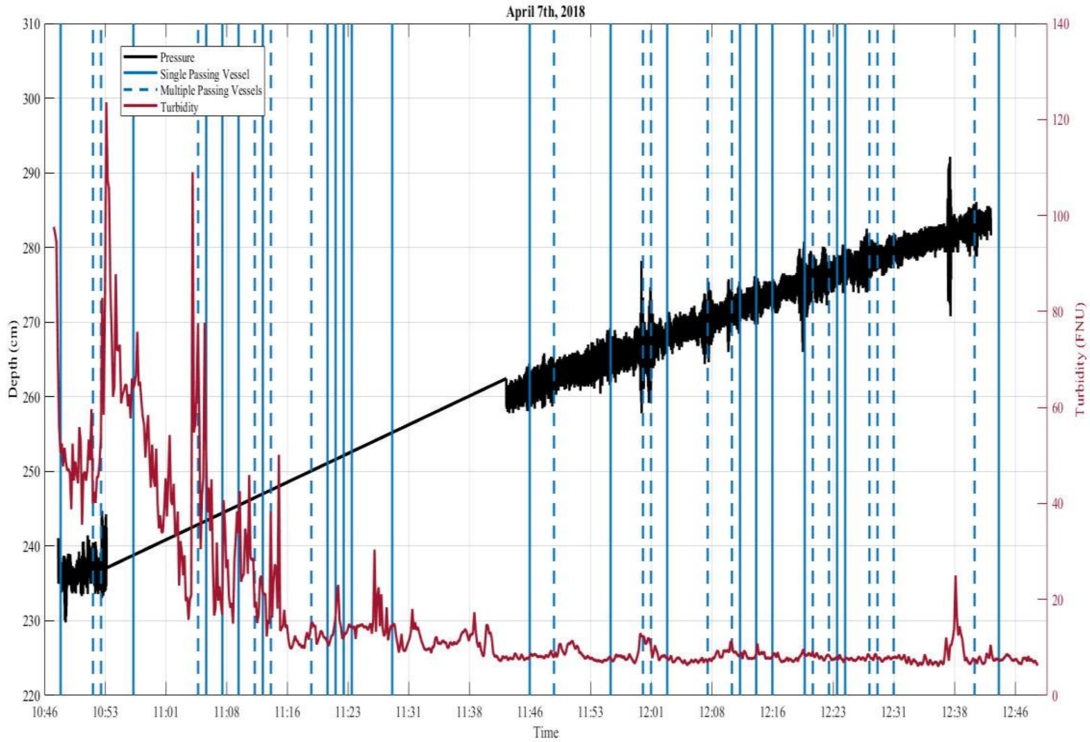

Figure 7: Single and Multiple vessels passing on April 7th, 2018 were recorded and laid over the first plots to see a correlation between vessels passing and peaks in pressure and turbidity.

4.2 Turbidity Related to Wave Heights

To expand the scale of the wave heights a running average was taken of both data sets. The running average was then subtracted from the original pressure data sets to show the approximated wave heights during that time instead of the water depth (show in Appendix B). The resulting wave heights were then plotted over the turbidity and passing vessels. By plotting the wave heights rather than pressure, the scale drops from 300 cm to 15 cm (Figure 8 and 9). This allows a clearer visual of vessel-generated waves.

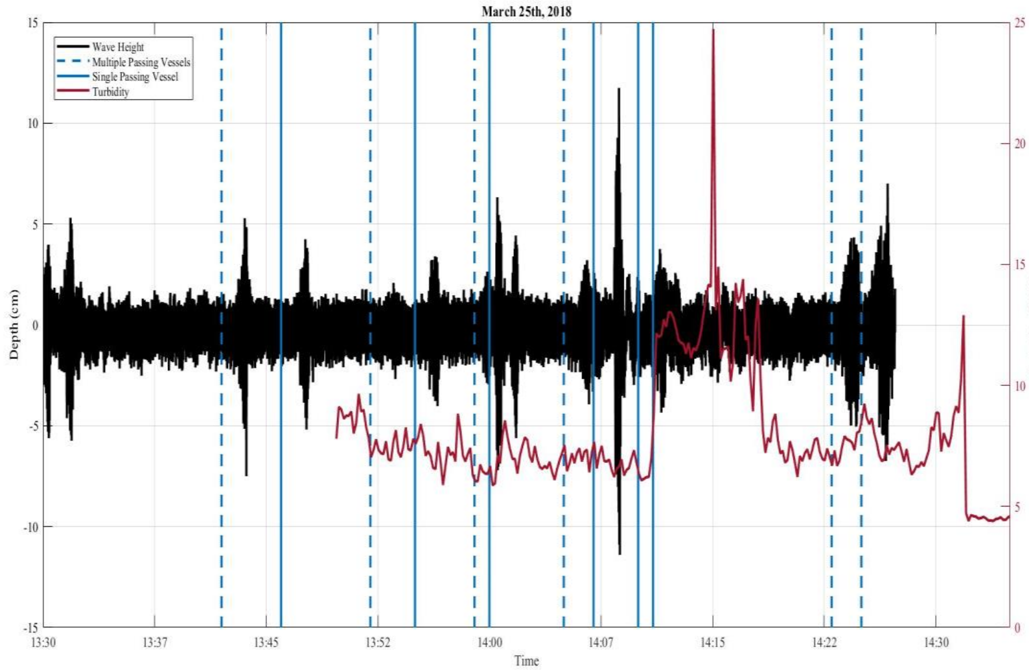

Figure 8: Turbidity plotted over approximate wave heights versus time on March 25th, 2018 with recorded passing vessels.

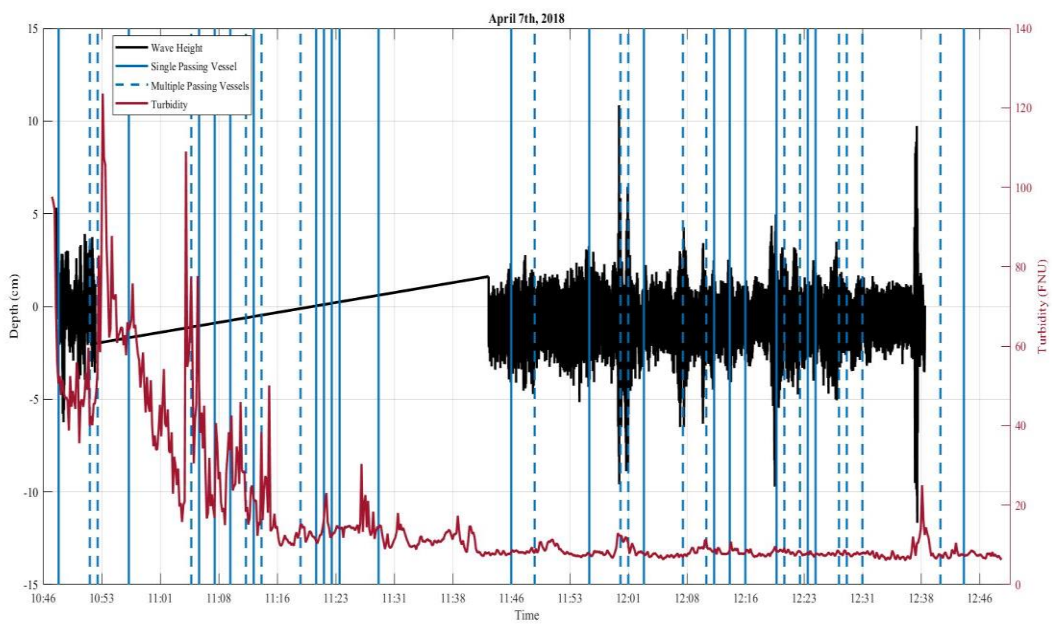

Figure 9: Turbidity plotted over approximate wave heights versus time on April 7th, 2018 with recorded passing vessels.

4.3 Turbidity Related to Wave Heights Near Low Tide

Both data sets were then plotted from their respective peak low tides to 2.5 hours after that time (Figure 10). Video analysis allowed an estimated wave height to be determined during the gap in pressure data. This helps determine some of the cause behind the largest turbidity peaks. By putting both data collections on the same time scale, it is evident that turbidity response to vessel-generated waves decreases with the increase in water depth as the tide moves from low to high. Figure 10 shows a significant decrease in turbidity response as quickly as 30 minutes after peak low tide. After this time, turbidity tends to drop from a scale of 150FNU to less than 30FNU.

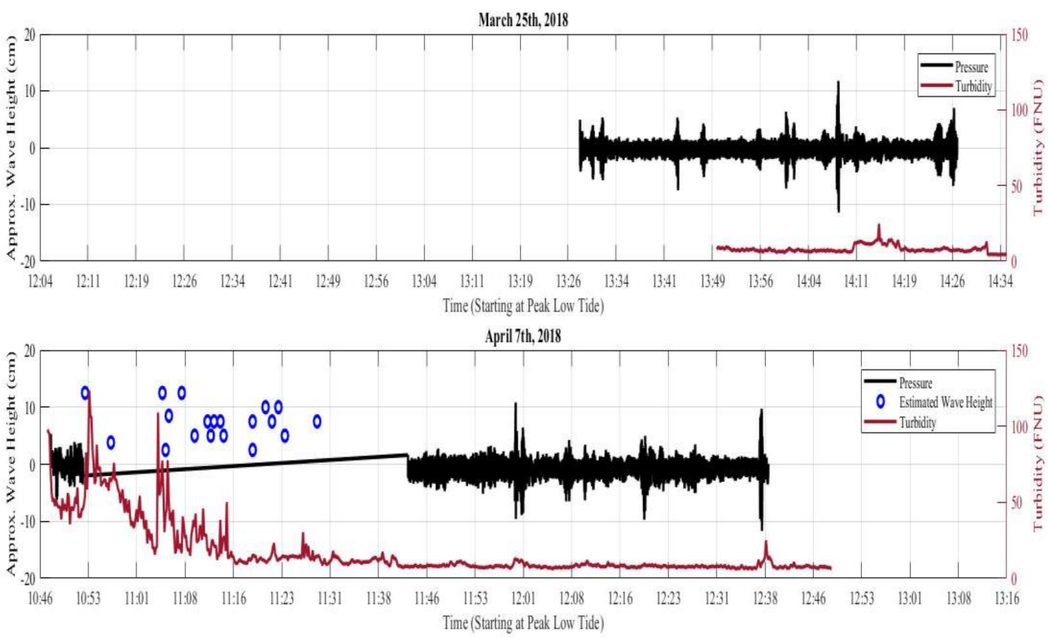

Figure 10: This plot includes estimated wave heights during the gap in pressure readings, determined through video analysis.

In Figure 11, an 8cm vessel-generated wave shows a turbidity response near 130FNU only minutes after peak low tide while a 23cm vessel-generated wave shows a turbidity response near 26FNU 1.5 hours after low tide begins to rise. That is a wave height of near three times smaller causing a five times higher turbidity response than the later vessel-

generated wave. The turbidity increase could be, indeed due to water levels during peak low tide as waves are breaking along the beach-like shoreline, well below the scarp line. However, turbidity levels could also be dramatically decreasing during this time due to the location of water and sediment interact from the turbidity sensor. As the tide increases the water sediment interaction site is moving further away from the turbidity sensor. Due to this, it is possible that the turbidity readings could be higher than what is recorded.

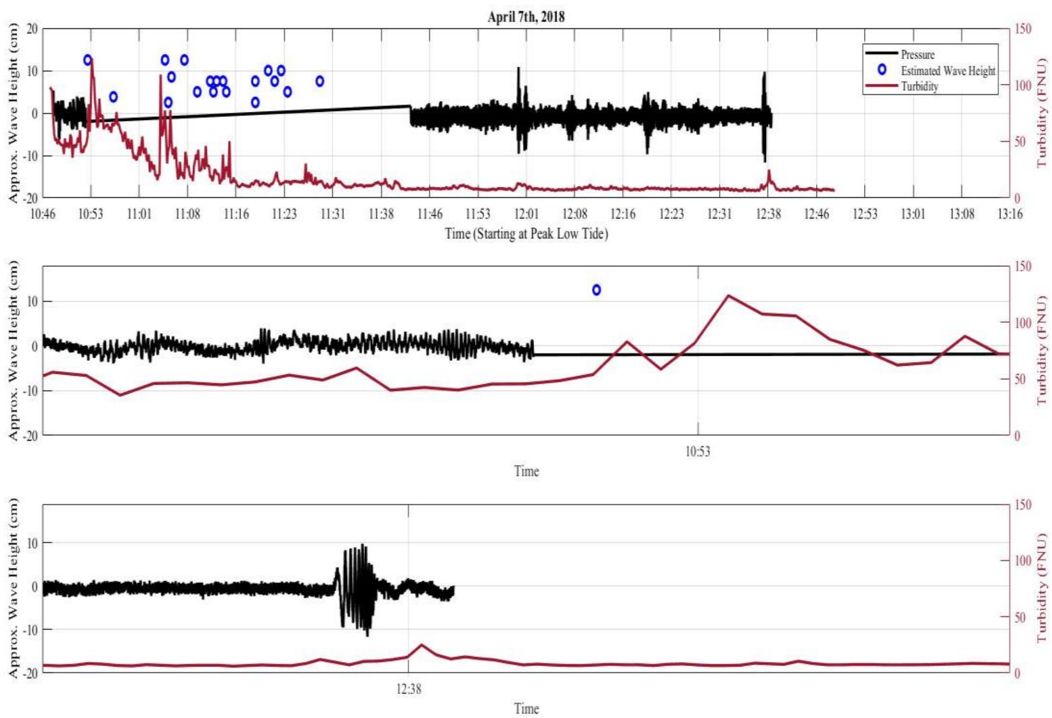

Figure 11: Comparison of a 5cm wave turbidity response and a 10 cm wave turbidity response after an increase in water depth.

CHAPTER 6: CONCLUSIONS

6.1 Pertinent Conclusions

Some of the more pertinent conclusions that can be drawn from the work shown here include the following:

- Water level had a significant effect on turbidity levels. Highest turbidity levels were recorded near peak low tide conditions.
- A vessel-generated wave height of 8cm near peak low tide conditions caused nearly 5 times the turbidity of a wave height over three times that height less than 2 hours after peak low tide conditions.
- Speed did not seem to be a large factor in turbidity levels. Larger vessels displaced more water and therefore cause a larger wave.
- During the peak low tide conditions, reduction of vessel passages is recommended or enforcement of no wake zones to help mitigate erosional damage.
- Multiple turbidity sensors should be used during a full tidal cycle in future research.

6.2 Preventative Measures

This investigation agrees with Ries 2016 that preventative measures could include regulations on vessel operators within the intracoastal waterways. Restricted to no wake zones during lower tidal conditions to decrease the number of waves breaking on the non-vegetated shorelines is recommended. Also, reduction of vessel passages is recommended near peak low tide conditions. This could reduce the amount of erosion occurring on the banks of the intracoastal. Living shorelines is still a viable option in these areas to help reduce the about of sediment erosion along the intercoastal since vegetated shorelines tend to have a lower erosion rate since they help to displace the incoming wave energy. Living

shorelines could also provide benefits to the environment such as planting the correct species at the proper elevations along the shoreline or the addition of artificial oyster reefs.

6.3 Improvements for Future Research

Future research should be done with multiple turbidity sensors. Sensors stationed parallel and perpendicular to the shoreline would help capture the sediment plume that is occurring and account for the rising tide. Multiple sensors could help distinguish whether turbidity is indeed higher near peak low tide conditions or, whether the sensors are only reading a higher turbidity since they are in shallower water at first and as tide increases so does the depth at which the sensor is placed. Also, this would help with the distance at which the sediment must travel back to the sensor which has also increased with the rising tide (sensor is no longer where the water meets the sediment as time passes). Multiple turbidity sensors at different water/shoreline interphases as the tide rises would be expected to show an increase in turbidity measurements during low tide, followed by the highest turbidity peaks when the water/shoreline interaction is on the scarp (wakes breaking on the scarp), then followed by the lowest turbidity once wakes begin breaking past the scarp into the vegetation.

It is also recommended that data collections be taken for one full tidal cycle, at least, to allow better understanding of tidal effects. Future research could also incorporate vessel hull characteristics and wave power in correlation to turbidity in varying water depths.

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APPENDIX A

April 7th, 2018 - Peak Low Tide 10:46AM					
Vessel	Time	Type of Vessel	Speed	Vessel Direction	Shoreline
1	10:48am	Sailboat	<10	North	Lowest low
2	10:52am	Sailboat	<10	North	No Scarp - T00
3	10:52am	Small	<10	South	No Scarp - T00
4	10:53am	Speed Med	20	North	No Scarp - T00
5	10:53am	Small	<10	South	No Scarp - T00
6	10:57am	Sailboat	22	South	No Scarp - T00
7	11:05am	Med	<10	South	No Scarp - T00
8	11:05am	Pontoon	<10?	North	No Scarp - T00
9	11:06am	Med	<10	South	No Scarp - T00
10	11:08am	Med lar	13	South	No Scarp - T00
11	11:10am	Small	24	North	No Scarp - T00
12	11:12am	Med	22	South	No Scarp - T00
13	11:12am	Med	21	South	No Scarp - T00
14	11:12am	Med	25	South	No Scarp - T00
15	11:13am	Jet Ski	19	North	No Scarp - T0
16	11:14am		<10	South	No Scarp - T0
17	11:14am	Small	12	South	No Scarp - T0
18	11:19am	Med	13	South	No Scarp - T0
19	11:19am	Jet Boat	16	South	No Scarp - T0
20	11:21am	Large	?	South	No Scarp - T0
21	11:22am	Large	?	North	No Scarp - T0
22	11:23am	Large	?	South	No Scarp - T0
23	11:24am	small	?	South	No Scarp - T0
24	11:29am	Large	?	North	No Scarp - T0
1	11:46am	Sailboat	<10	North	No Scarp - T0
2		small	<10	stops	No Scarp - T0
3	11:49am	Med	19	South	No Scarp - T0
4	11:49am	Small	15	South	No Scarp - T0
5	11:56am	Pontoon	14	South	No Scarp - T0
6	12:00pm	Large	<10	North	No Scarp - T0
7	12:00pm	Sailboat	<10	North	No Scarp - T0
8	12:01pm	Large	<10	North	No Scarp - T0
9	12:01pm	Med/L	<10	South	No Scarp - T0
10	12:03pm	Sailboat	<10	North	No Scarp - T1
11	12:08pm	Med	17	North	No Scarp - T1
12	12:08pm	Med	<10	North	No Scarp - T1
13	12:08pm	Jet Ski	29	North	No Scarp - T1
14	12:08pm	Jet Ski	29	North	No Scarp - T1

15	12:11pm	small	<10	South	No Scarp - T1
16	12:11am	Jet Ski	25	North	No Scarp - T1
17	12:11pm	Jet Ski	26	North	No Scarp - T1
18	12:12pm	Jet boat	16	North	No Scarp - T1
19	12:14pm	small	12	North	No Scarp - T1
20	12:16pm	Jet Ski	16	South	No Scarp - T1
21	12:20pm	Large	<10	North	No Scarp - T2
22	12:21pm	Large	<10	North	No Scarp - T2
23	12:21pm	small	<10	South	No Scarp - T2
24	12:23pm	Jet Ski	19	South	No Scarp - T2
25	12:23pm	Jet Ski	19	South	No Scarp - T2
26	12:23pm	Catamaran	<10	North	No Scarp - T2
27	12:23pm	small	?	North	No Scarp - T2
28	12:24pm	small	<10?	South	No Scarp - T2
29	12:25pm	Sailboat	<10	North	No Scarp - T2
30	12:28pm	Sailboat	<10	North	No Scarp - T2
31	12:28pm	small	21	South	No Scarp - T2
32	12:28pm	sailboat	<10	North	No Scarp - T2
33	12:28pm	small	12	North	No Scarp - T2
34	12:29pm	Jet Ski	26	South	No Scarp - T2
35	12:29pm	Jet Ski	27	South	No Scarp - T2
36	12:31pm	Jet Ski	27	North	No Scarp - T3
37	12:31pm	Jet Ski	23	North	No Scarp - T3
38	12:31pm	Jet Ski	28	South	No Scarp - T3
39	12:41pm	?	22	?	No Scarp - T3
40	12:41pm	Jet boat	18	South	No Scarp - T3
41	12:44pm	Sailboat	23		No Scarp - T3

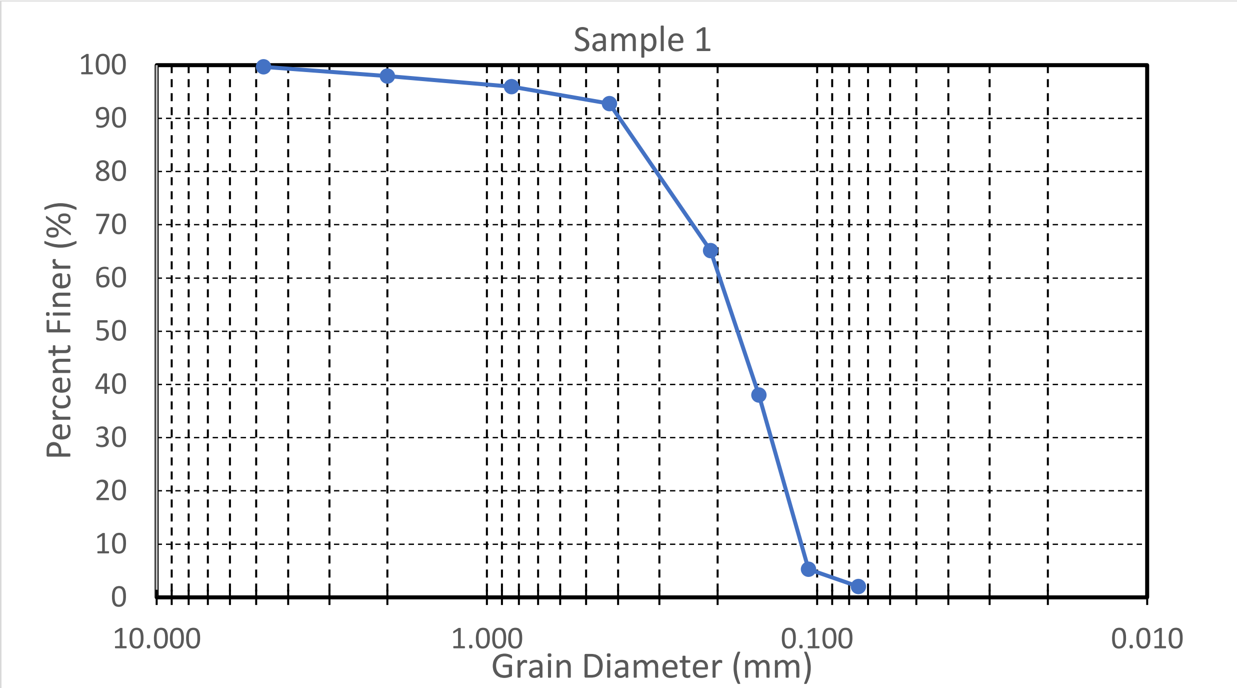

Figure 12: Above is the grain size distribution of the sediment sample that was taken nearest to the channel (where the sensors were placed).

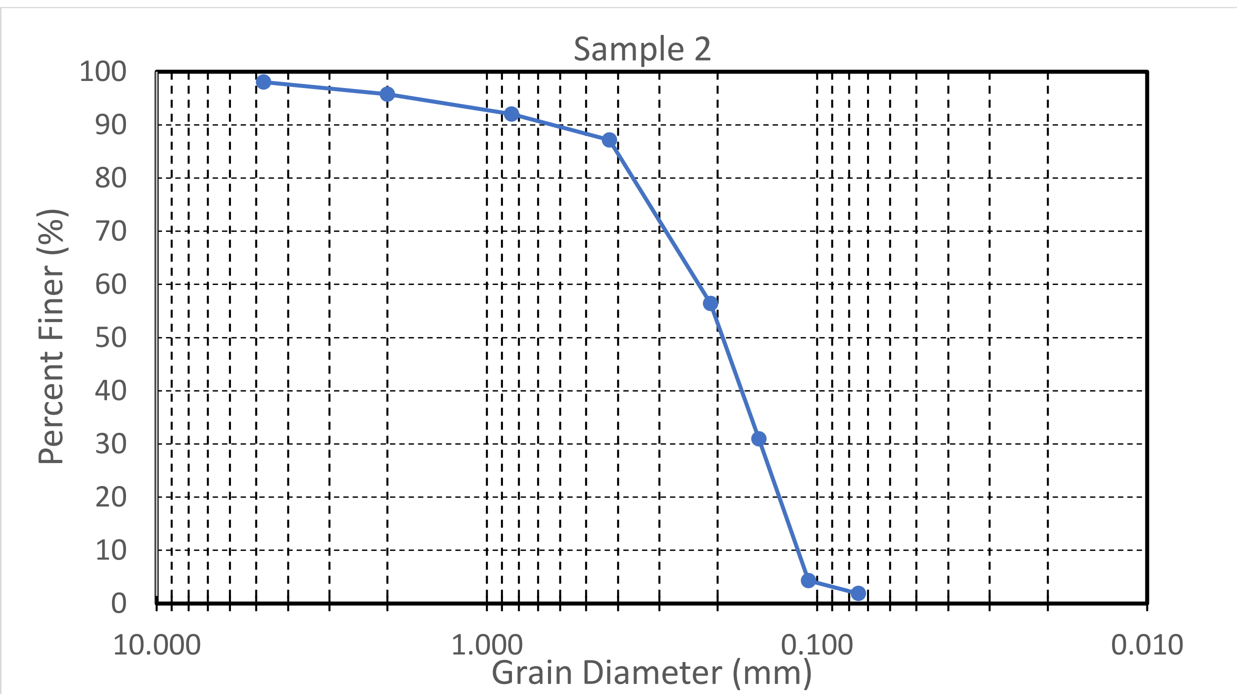

Figure 13: Above is the grain size distribution of the sediment sample that was taken about 10 feet shoreland from where the sensors were placed.

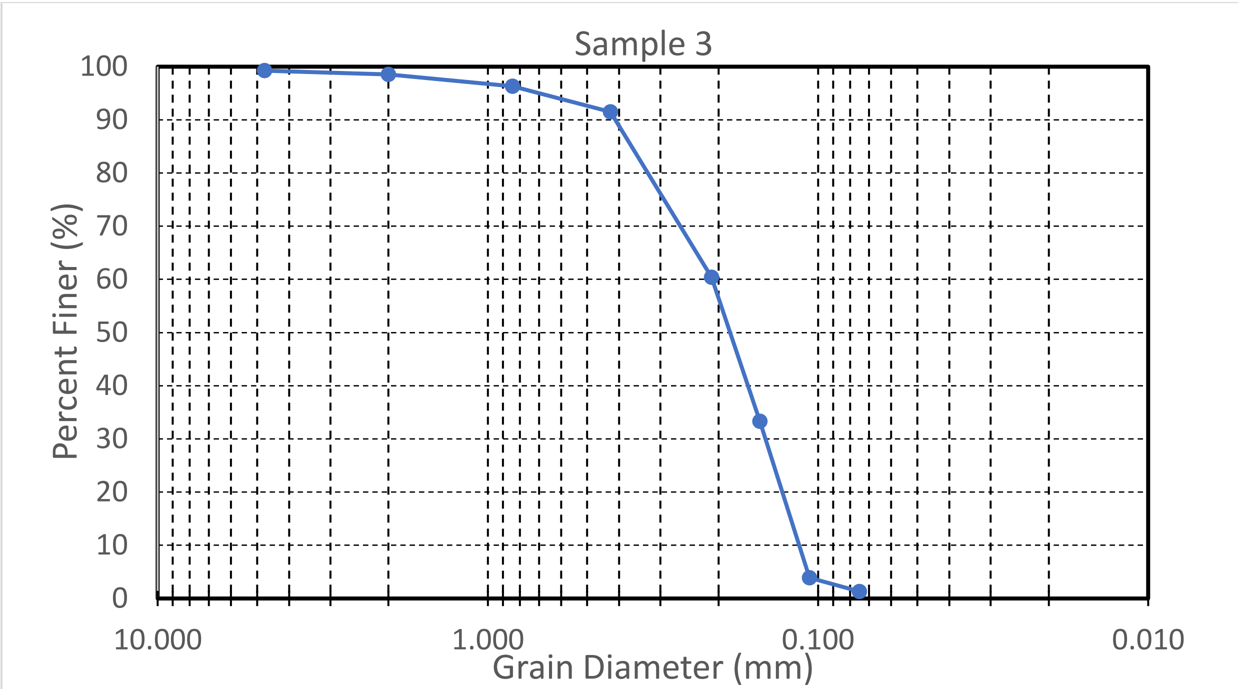

Figure 14: Above is the grain size distribution of the sediment sample that was taken about 20 feet shoreland from where the sensors were placed.

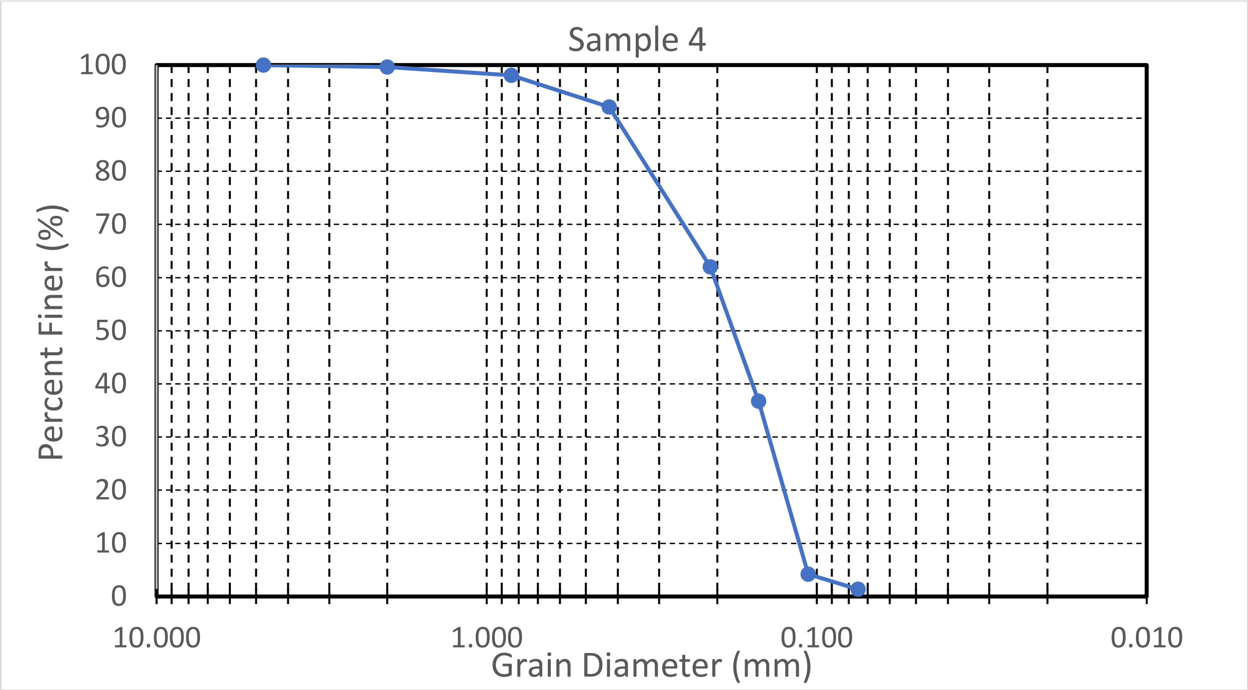

Figure 15: Above is the grain size distribution of the sediment sample that was taken at the PVC pipe on the shoreline (about 30 feet shoreland from where the sensors were placed).

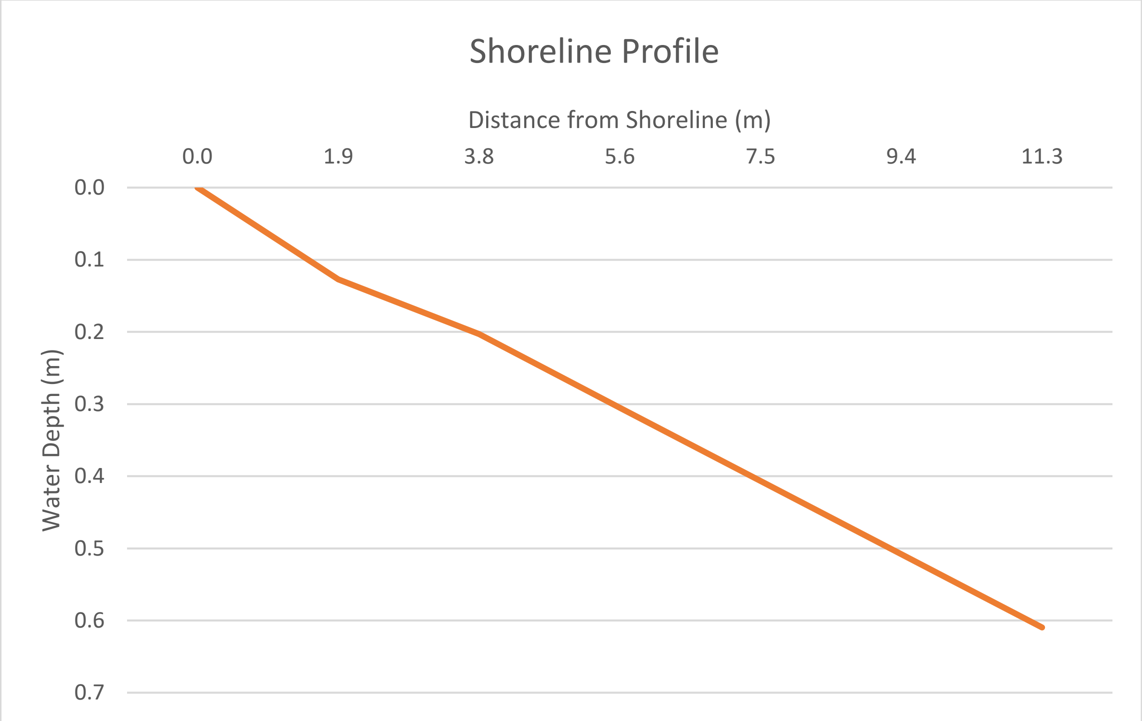

Figure 16: Profile of the shoreline at the site location.

APPENDIX B

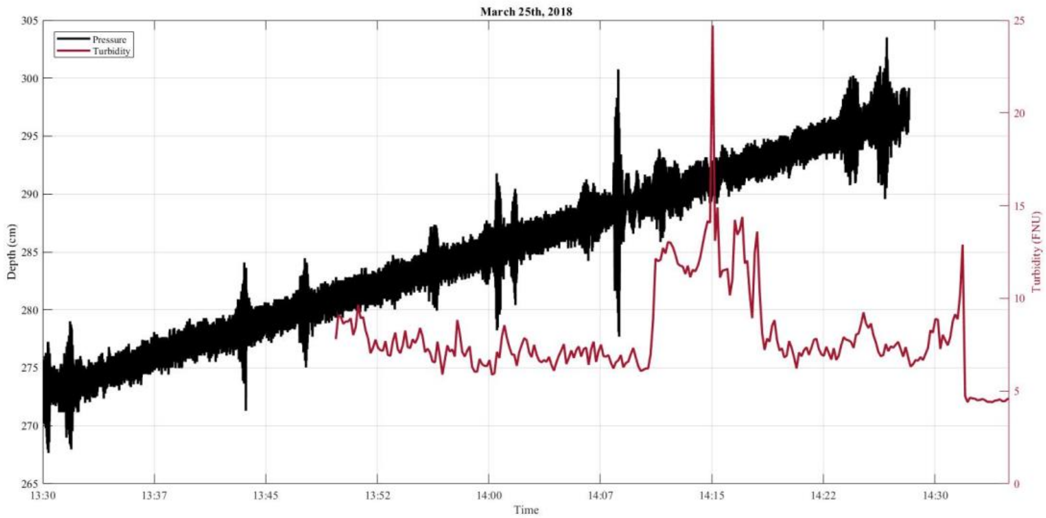

Figure 17: MatLab plot of March 25th, 2018 pressure and turbidity versus time. Turbidity was started after pressure sensors, creating the large delay.

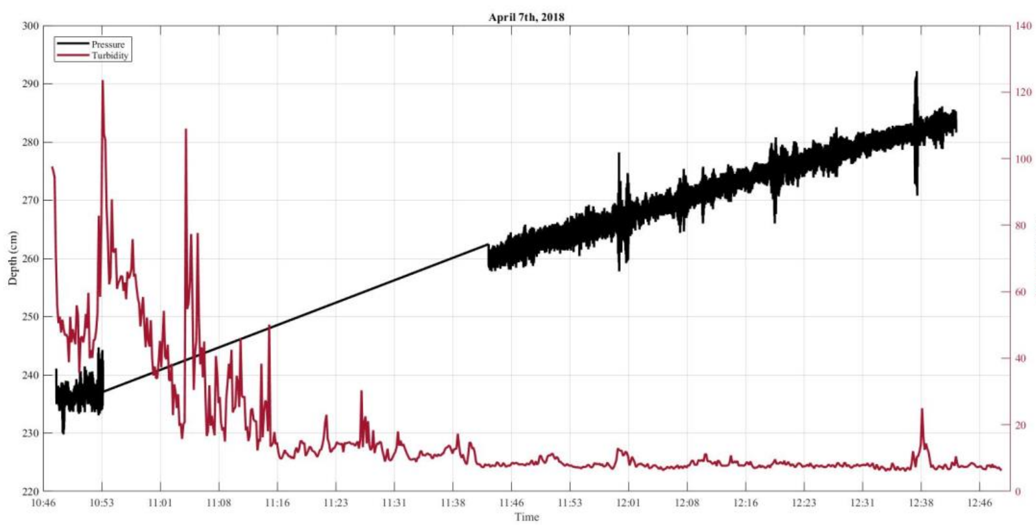

Figure 18: MatLab plot of April 7th, 2018 pressure and turbidity versus time. Pressure sensors stopped recording after a few minutes and then was restarted at 11:47PM for the full hour of data collection.

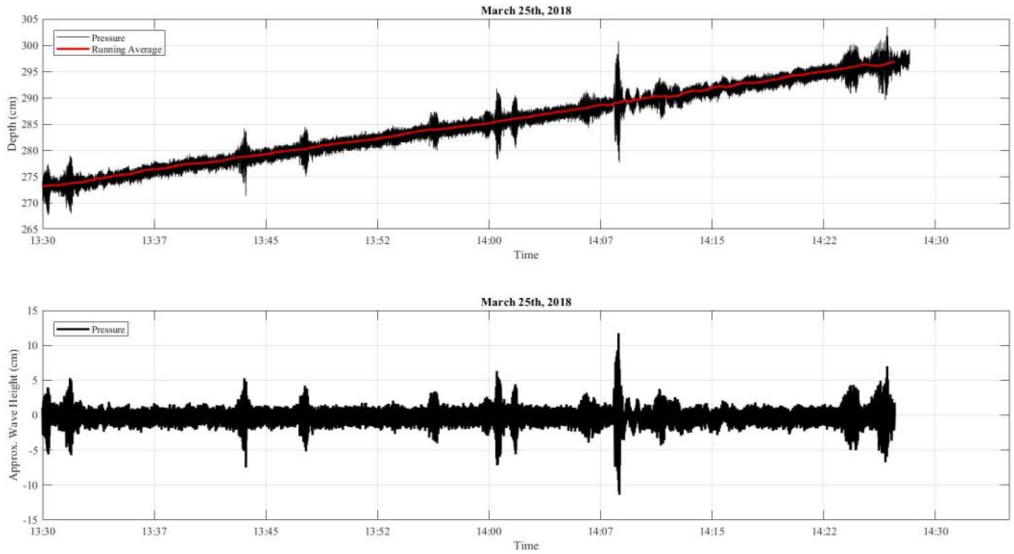

Figure 19: A running average was calculated and subtracted from the original pressure data from March 25th, 2018 to provide approximate wave heights.

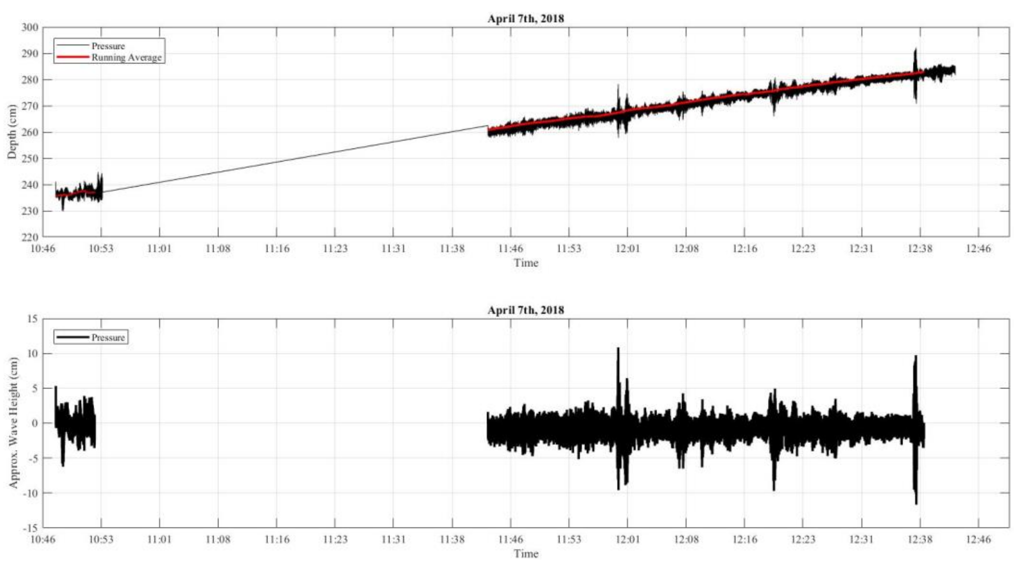

Figure 20: A running average was calculated and subtracted from the original pressure data from April 7th, 2018 to provide approximate wave heights.

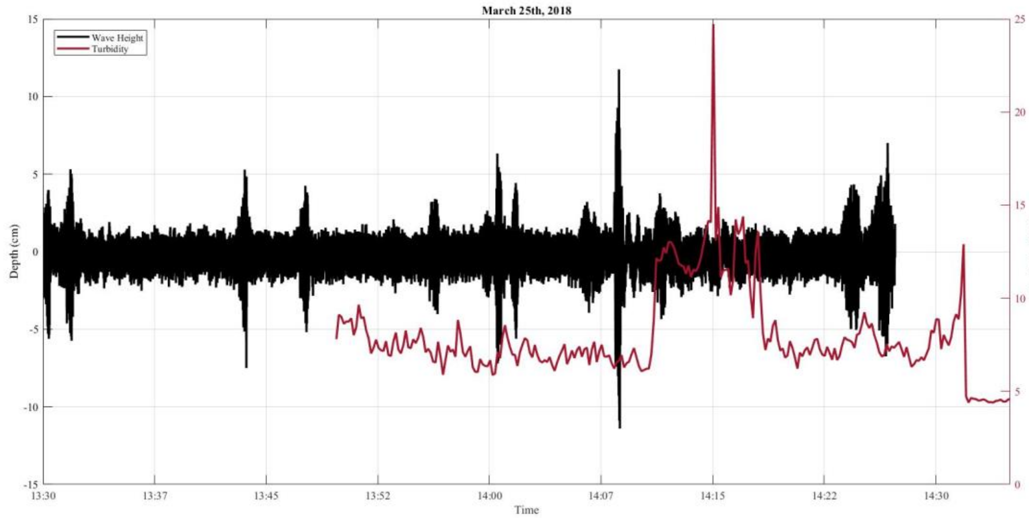

Figure 21: Turbidity plotted over approximate wave heights versus time on March 25th, 2018.

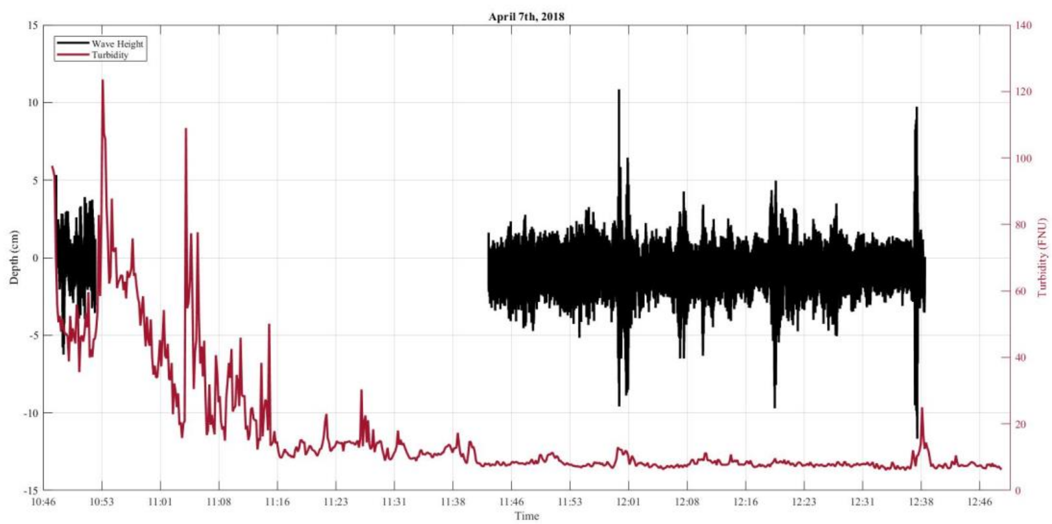

Figure 22: Turbidity plotted over approximate wave heights versus time on April 7th, 2018.

APPENDIX C

Figure 23: Image of site near low tide conditions on February 6th, 2018

Figure 24: Image of site near peak high tide conditions on February 15th, 2018.

Figure 25: Image of site near peak low tide conditions on February 27th, 2018

Figure 260: Image of site near low tide conditions on March 7th, 2018 at 11:14AM.

VITA – MACKENZIE SANCHEZ

Educational

Master of Science in Civil Engineering
(Port and Coastal) August 2016-April 2018

College of Computing, Engineering and Construction
University of North Florida, Jacksonville, FL

Academic Performance
Anticipated graduation: April 2018

Bachelor of Science in Civil Engineering August 2014-December 2016

College of Computing, Engineering and Construction
University of North Florida, Jacksonville, FL

Academic Performance
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Bachelor of Art in Biology August 2011-December 2016

College of Arts and Sciences
Jacksonville University, Jacksonville, FL

Academic Performance
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Bachelor of Science in Marine Science August 2011-April 2015

College of Arts and Sciences
Jacksonville University, Jacksonville, FL

Academic Performance
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Employment

Graduate Research Assistant May 2014 – April 2018

Taylor Engineering Research Institute
College of Engineering and Computer Science
University of North Florida, Jacksonville, FL

The Haskell Company Internship January 2016-March 2018

Worked as Assistant Project Manager with Water Division and Pre-Construction and Estimating Division
Transportation and Infrastructure Department
Jacksonville, FL

JEA Summer Internship May-August 2014

Worked with DEP and formatting Discharge Monitoring Reports
JEA, Environmental Department
Jacksonville, FL

Jacksonville University Student Alliance August 2014-April 2015

Director of Student Affairs
Jacksonville University
Jacksonville, FL

Conferences

ASCE Leadership Conference January 2017

Workshop for Student Chapter Leaders (WSCL) in Newark, NJ

FSPBA Conference February 2016

Florida Shore and Beach Protection Association - Tech Conference

14th International Workshop
Wave Hindcasting and Forecasting November 2015

Sponsored by Dr. Don Resio in Key West, FL

Academic Honors and Awards

Green Key National Honors Society Spring 2015-Present

Awarded to the top 1% of Jacksonville University student body

Women's Transportation Society
Northeastern Florida Spring 2013

Outstanding Woman Award (for academic achievement and merit)
2013 Women in Transportation National Scholarship Nominee

Presidential Advisory Council Fall 2013-Spring 2015

Discussion board between students and University President

NFAPE Spring 2013-Spring 2015

$750 Environmental Scholarship

Jacksonville University

$21,000 Academic and Art Scholarship — Fall 2012-Spring 2015

Dean's List
(achieved 3.5 or higher semester GPA) — Fall 2011- Fall 2012

Theodore Johnson Foundation — Fall 2011-Spring 2015

$2,000 Scholarship

Relevant Experience

Study Abroad courses in Santander, Spain — July 2015

Marine Construction and Introduction to Port and Coastal Engineering
University of Cantabria, Spain

Study Abroad courses in San Salvador — May 2014

Coral Reef Ecology and Marine Caribbean Geology - Conducted and presented blue hole research

Coastal Reef Analysis — Spring 2014

Natural versus Artificial reef survey at Riviera Beach

Jacksonville University Leadership Retreat — Fall 2013

Leadership Development program for students at Jacksonville University

Aerial Manatee Survey — Spring 2012-Summer 2012

Jacksonville University – Dr. Pinto – Manatee population data collection in the St. Johns River

Dolphin Boat Surveys — Spring 2012-Summer 2012

Jacksonville University – Dr. Borkowski – Dolphin population data collection in the St. Johns River

Organizations

Coastal, Oceans, Ports and Rivers Institute — August 2016-April 2018

University of North Florida Chapter President

American Society of Civil Engineers August 2014-April 2018

University of North Florida Member

Society of Women Engineers August 2015-April 2018

University of North Florida Member

Jacksonville University Student Alliance Fall 2012- Spring 2015

Held Positions – Director of Student Affairs, Commuter Representative, Activities Chair, Campus Liaison

National Society of Professional Engineers Fall 2012- Spring 2015

Jacksonville University Member