Assessment of Effect of EcoShield™ on Erosion Protection

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1. **Background Information and Objective of Study**

Louisiana is in the forefront of a battle with land loss due to continuous erosion along the coast, particularly the barrier islands. About forty percent of the US wetland is in Louisiana and about 80% of the US land loss is from Louisiana. This is further complicated by the climate change that potentially brings higher sea level, leading to more exposure of the wetland to ocean forcing. As a result, an effective engineering approach of protecting the coast against the land loss is greatly needed. With the innovation of EcoShield™ (patent pending) by the Martin Ecosystems, such an approach is quickly becoming close to reality. This invention involves the use of layers of manmade nontoxic mats from recyclable plastics and the use of salt enduring plants to help the establishment of rooted coverage of vegetation protected by the mats from winds, waves, and related erosions. Our study is aimed at an independent investigation for an objective assessment of the approach and determine whether this will help to reduce waves and erosion. Our study involves the use of lab experiments, aerial photography, measurements of the topography and waves. The study is for 18 months. This report is compiled for internal use of the Martin Ecosystems who funded this study. It also serves as an internal self- report for the research group for future reference and not meant for public distribution.

Figure 1. Study Site.

2. Study Site

The study site (Figure 1) is at ~29°21'N, 89°32'W. It is about 90 km downstream of the city of New Orleans along the Mississippi River and 70 km from the southwest outlet of the Mississippi River delta to the Louisiana continental shelf. The study site is about 600 m from the Mississippi River over the south bank of the river. It is in a very shallow water (~0-8 ft), about 11 km from the Pelican Island which is further to the ocean side in the south. Beyond the Pelican Island it is the Louisiana Bight and coastal ocean. The Buras study site has been experiencing severe land loss. The barrier islands including Pelican Island had been eroded significantly.

3. Proposed Tasks

Task #1: A recon survey in the beginning of the project. The purpose of this is to get some first-hand information for the logistics of the surveys. We will be able to plan the detailed after the recon survey. This will take 2 days – we will have 2-3 people stay overnight for a full day survey the next day - at LSU it is considered a 2-day trip. One person will be a small boat driver. A second person and perhaps a third person (a student) will measure some water depth, record some flow data, examine the locations for the instrument deployment, taking some pictures, etc. in the area.

Task #2: RC Airplane photograph of the study area after the construction near the end of the project at the 18th month after the construction (a 2-day trip). During this work, one person will drive a small boat. A second person will fly the RC airplane to make sure a smooth and leveled flight with the assistance of another person for taking control of picture taking.

Task #3a: Area survey of bathymetry (water depth) around the construction area before the construction (a 2-day survey). The purpose of this is to measure water depth distribution prior to the construction so that we can quantify the change post construction.

Task #3b: Area survey of bathymetry (water depth) around the construction area after the construction (a 2-day survey). The purpose of this is to measure water depth distribution a few months after the construction so that we can quantify the change post construction.

Task #4a: Moored instrument data collection for waves and water level variations before the construction. This will gives us wave spectrum, including wave height under different conditions. Each deployment will be at least a few hours to a few days.

Task #4b: Moored instrument data collection for waves and water level variations after the construction. This will gives us wave spectrum, including wave height under different conditions. Each deployment will be at least a few hours to a few days. We will try to do this a few times during the project to cover different conditions.

Task #5a (optional) Land based LiDAR survey (we have the LiDAR) before the construction. This will provide a very high resolution land topography and coastline features, as well as the vegetation coverage (~ 2-3 day survey each time).

Task #5b (optional) Land based LiDAR survey (we have the LiDAR) after the construction. This will provide a quantification of the changes due to the construction.

Task #6 Data processing, analysis, and presentation (in visual format) for all the above data.

4. Modified Tasks

The above tasks were significantly modified with the verbal agreement between the two parties (LSU research team and Martin Ecosystems). The main modification was the change of measuring waves on site to that in the WAVCIS interior wave tank at LSU. We did measure actual depth and waves at the berm a couple of times but the results were tricky to interpret because the bottom was dredged after we did our first survey so that the results from tasks 3 and 4 would be contaminated. This was not foreseen when the project was proposed. The wave tank experiments were controlled experiments and can be used reliably to make quantitatively conclusions.

5. Discussion of work

5.1 bathymetric survey

On site surveys were done for water depth measurements and or RC Airplane photography on May 21, July 31, Aug 2, Dec. 2, 2014, Sep 2, 2015, and Oct. 1, 2015. Dozens of photos from the RC plan (drone) were obtained. The water depth in the area was measured. These are for the original tasks 1-3. Figures 2-3 shows the bathymetry (water depth) measured from the boat operated bathymetric survey.

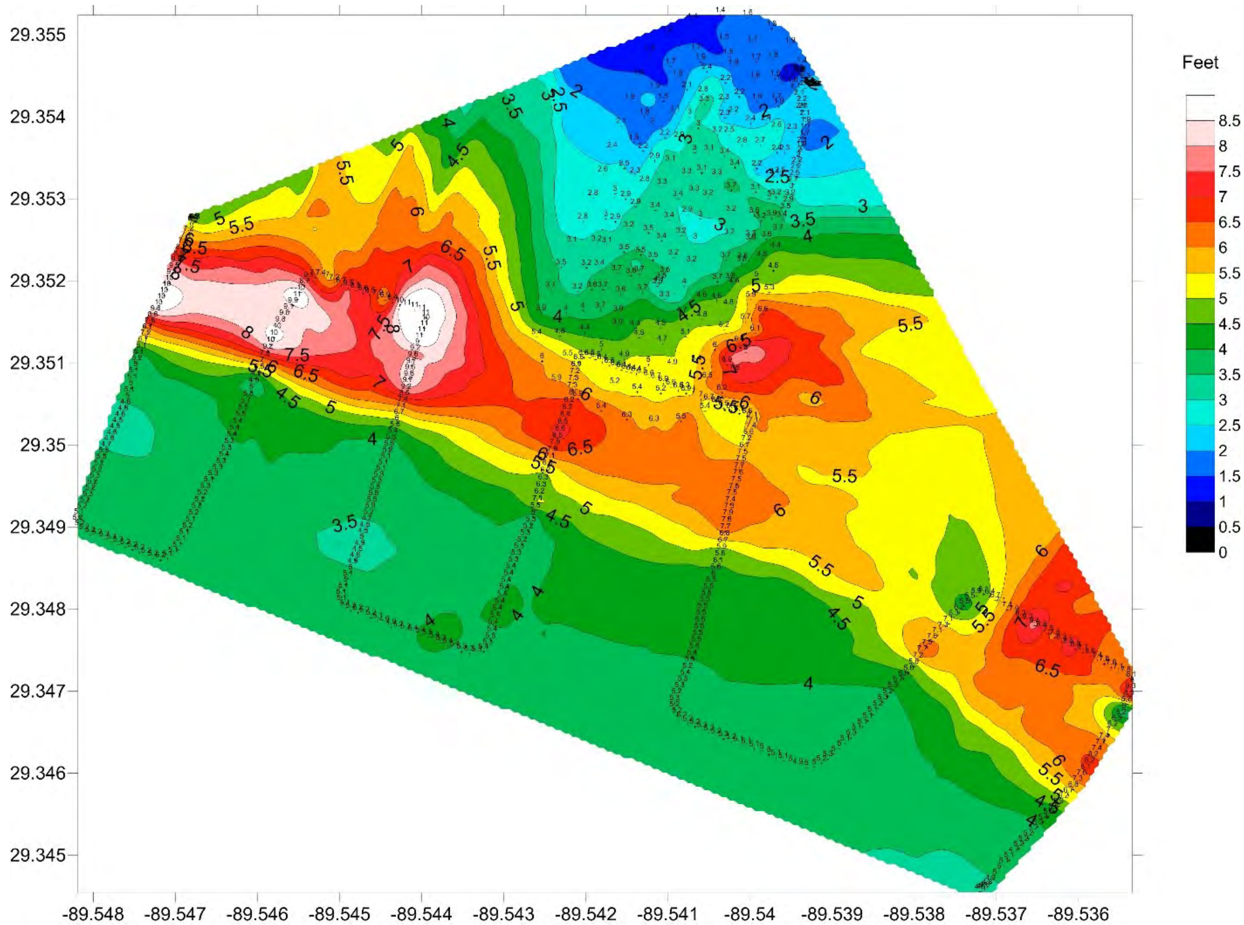


Figure 2. Water depth measured from a single beam echo sounder fathometer with GPS on May 21, 2014.

The area is very shallow – up to ~ 8 feet deep as shown in Figures 2-3. The photos taken show the variation of the area before and after the installation of the EcoShield™. Some vegetation behind the berm can be seen over time (e.g. Figure 14, 15, 17). The later pictures from 2015 and 2016 showed extensive development of the vegetation particularly around the EcoShield™ (Figures 25-37). The installation of the EcoShield™ apparently had rooted very well that helped to keep the sediment, allowing them to grow more and spread.

To better utilize the aerial photos, we applied some 3D photo processing techniques for terrain mapping for half of the earthen berm. Some additional oblique pictures were collected for an overview of the site. We made ten black-and-white chess board targets and evenly distributed them in the mapping area before the flight of the drone. There were two flight lines at a height between 100 and 150 meters. The targets were surveyed using RTK GPS and used to register the photo-based DSM together with those form LiDAR for potential comparison. Figure 38 shows the collected images, flight paths, and the DSM mapping results based on the drone. Figure 39 is the perspective view of the earthen berm DSM based on the results. We used Pixel4D software to conduct the data process and image registration.

5.2 LIDAR survey

In this project, we also used a terrestrial LiDAR and RTK GPS to map earthen berm terrain and terrain change. Terrestrial LiDAR, also referred to as terrestrial laser scanning device (TLS), is one with laser scanning sensors mounted on a tripod. The system has potential to achieve high-accuracy topographic mapping and capable of quick and frequent responds to mapping needs because of its portability and ease of use. The system used in this project is Riegl VZ-1000. This laser scanner uses eye-safe near infrared wavelength and is capable of long-range dense measurement (122,000 measurement/second) for a distance up to 1400 meters. The range measurement accuracy is eight millimeter based on a hundred meter range. At one single scan, the system scans the surrounding environment with 360° horizontally and 100° (+60°/-40°) vertically. To map a larger area, users can scan at multiple positions and angles and register point clouds through “multi station adjustment”. With the aid of high accuracy RTK GPS, the positioning accuracy can be improved from 1 meter to a few centimeters. The DTMs before and after one year of construction were used to analyze terrain changes at the earthen berm.

As planned, we conducted terrestrial LiDAR scan at the Buras wetland restoration site on July 30, 2014. Figure 40 illustrates the LiDAR point clouds rendered in true color. The outlined area in red box is the targeted area for detailed mapping and is 380 meters long and 25 meters wide. We conducted five evenly distributed LiDAR scanning on the berm and collected additional scans on the levee in the north and along the road in the west for an overall coverage of surrounding environment demonstrated in Figure 40. Figure 41 is the land topographic mapping result of the earthen berm based on the LiDAR survey. Figure 42 shows super high resolution view of the earthen berm where fixing grid and planted grass are visible.

One year after the construction, the planted vegetation and a few locally grown vegetation species successfully colonized on the earthen berm, exposing only a narrow zone of soil along the berm center. The dense vegetation presented a challenge to terrain mapping as they block the laser light. This is an unsolved issue for coastal terrain mapping and we made additional effort to collect data more than proposed to map the terrain as accurate as possible. Therefore, we conducted denser LiDAR scan (eleven scan positions) on the earthen berm with integrated RTK GPS, collected 11 evenly distributed cross-berm elevation transacts (extended into water) for sediment change analysis, and 65 cross-berm elevation transacts in the vegetated area for terrain correction. Figure 43 illustrates the digital surface model (DSM) of the earthen berm from terrestrial LiDAR scanning and Figure 44 is the surface change model before and after one year construction of the earthen berm. Figure 45 is the cross section comparison of the surface model before and after one year construction.

To further improve the terrain mapping under dense vegetation, we plan to develop new methods by integrating LiDAR data with the GPS survey. The expected results and improved products will be available later when the peer-reviewed papers for journals are accepted.

5.3 Wave tank experiments

In order to test the effectiveness of the protective mat in wave attenuation, we conducted wave tank experiment with a comparison with and without mat. Figure 46 shows the results of the pre- and after-wave simulation with (a) being the initial elevation distribution and (b) as the elevation change after a 30-minutes wave simulation. This result indicates that the mat successfully contained sediment under the mat. Relatively more sediment erosions in the mat area occurred on the edges when the edge is not secured from wave.

Wave Tank dimension is as follows: Total Length: 28’8” (8.74 m)

Length from the wave maker front surface: 22’5” (6.83 m)

Width: 18’8.5” (5.70 m)

Depth at the wave maker front: 30.1 cm

Distance of sand front to the wave maker front (~ 10ft)

Time of experiment #1: afternoon of Feb. 20, 2015. Participant: Baozhu Liu, Shelley Meng, Chunyan Li

Time of experiment #2: morning of Feb. 21, 2015. Participant: Baozhu Liu, Shelley Meng, Chunyan Li

Instrument Used: three pressure sensors that measure the wave height.

Procedure for experiment #1: (1) move the sand to the top of the back of tank where water cannot reach (make room for the waves in the front), (2) smooth the surface so that it is symmetric on both sides of the tank; (3) position the three pressure sensors such that one in the center, one on each side of the tank (sensor #1 is ~ 4ft from the wall, the second sensor is along the center line of the wave maker, while the third sensor was about 3ft10in from the wall, the sensors are about 5ft7in from the wave maker front); (4) cut a piece of the EcoShield™ the size of ~ 2.85 m x 2 m and lay it over the right hand side of the wave tank facing the direction of the wave propagation; (5) fill the tank with water to the depth of 30.1 cm; (6) start making the waves with the following parameters: (1) sine wave, (2) frequency of 1.4719 Hz, (3) span of 2.007 in; after running about 5 minutes, we started recording of the wave data for 2048 data points at 10 Hz sampling frequency; (7) we recorded the data twice and then changed the setting to be (1) sine wave, (2) frequency of 0.4999 Hz, (3) span of 4.449 in (i.e. increased the amplitude and decreased the frequency, making larger waves); we recorded the 3rd set of data.

Our first experiment has shown that (1) the side with the EcoShield™ has a significantly smaller wave height, (2) the EcoShield™ can absorb the incoming wave energy to reduce the wave breaking and reduce the impact from the waves for re-suspension; (3) the EcoShield™ provides a cover that protects the sand from the pounding waves; (4) on the side with EcoShield™, the wave run up is reduced in height; (5) the top portion under the EcoShield™ is best protected compared to the other side.

As an example, we subtracted the instantaneous wave height between the two sides for 2048 continuous measurements (measured at 0.1 second intervals), we found that the majority of the time (1110 of 2048) the bare side had a higher wave by an average of 1.2990 cm (with a standard deviation of 0.7066 cm), while the rest (938 of the 2048) of the times the bare side had a lower wave by an average of just 0.4465 cm (with a much smaller standard deviation of 0.2138 cm). This is because the EcoShield™ can reduce the wave height by absorbing the incoming wave energy.

6. Summary of finding

In summary, our aerial photography, LIDAR surveys, and wave tank experiments were carried out with great success. The aerial photos over time showed clear trend of development of vegetation around the EcoShield™, suggesting deep rooted plants developed successfully in the area. The LIDAR measurements onsite also confirmed that and helped to quantify the terrain change over time. This work can continue even after the end of this project – we do plan to return to the site and remap the area repeatedly in the next few years, pending availability of funding. Since we have the boat, equipment, and trained personnel, the cost of future work is minimal and therefore is not a significant obstacle. The LIDAR was also used in the wave tank experiments which helped to quantify the sediment change after application of waves. The wave tank experiments recorded wave height in front of the bare beach and that in front of the covered beach respectively and we conclude that one layer of the EcoShield™ can reduce wave height by ~ 40%. With multiple layers, we expect the effect to be even more significant. An onsite experiment of similar nature would have helped even more. However, the onsite wave experiment would require different weather conditions that would produce small and significant waves at various magnitude in front of the berm and control site. The selection of control site can be challenging as there are no two places that are identical to all combined conditions. While the lab experiment can have precise control. Even though there are lot more can be done especially the follow up surveys, which are indeed what we plan to do, we are still working on the large dataset and presentations at local and regional conferences, such as the State of the Coast in June of this year. We are also currently working on some manuscripts and a student is working on his PhD dissertation using the data from this project. We therefore anticipate that more results will come from this project and some peer reviewed journal articles are expected to be published in the next year or two, pending successful reviews and revisions.

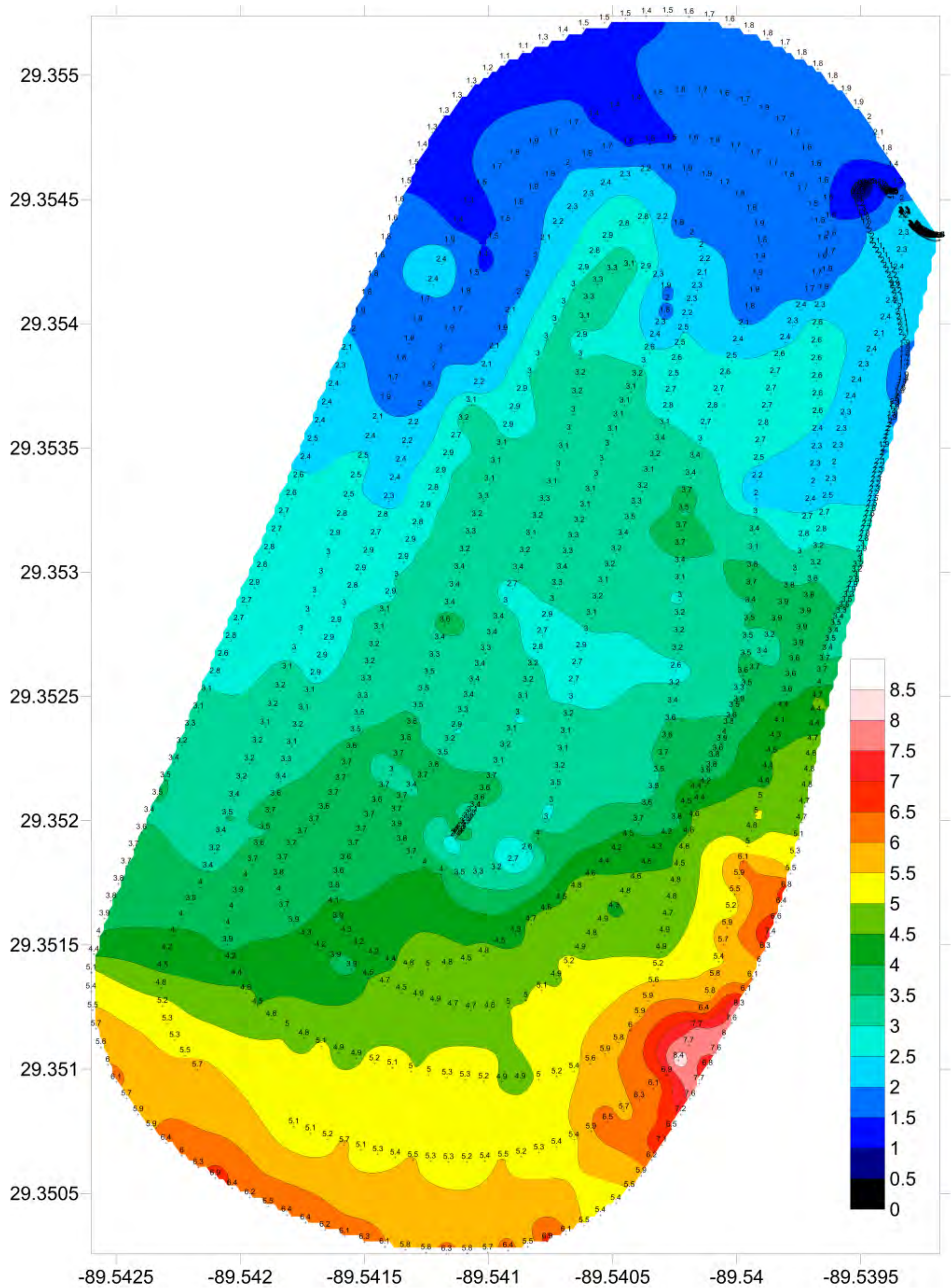


Figure 3. Water depth measured from a single beam echo sounder fathometer with GPS on July 31, 2014.

Figure 4. One of the photos from the RC airplane taken on May 21, 2014.

Figure 5. One of the photos from the RC airplane taken on May 21, 2014.

Figure 6. One of the photos from the RC airplane taken on May 21, 2014.

Figure 7. One of the photos from the RC airplane taken on May 21, 2014.

Figure 8. One of the photos from the RC airplane taken on May 21, 2014.

Figure 9. One of the photos from the RC airplane taken on May 21, 2014.

Figure 10. One of the photos from the RC airplane taken on May 21, 2014.

Figure 11. One of the photos from the RC airplane taken on May 21, 2014.

Figure 12. One of the photos from the RC airplane taken on May 21, 2014.

Figure 13. One of the photos from the RC airplane taken on May 21, 2014.

Figure 14. One of the photos from the RC airplane taken on Dec. 2, 2014.

Figure 15. One of the photos from the RC airplane taken on Dec. 2, 2014.

Figure 16. One of the photos from the RC airplane taken on Dec. 2, 2014.

Figure 17. One of the photos from the RC airplane taken on Dec. 2, 2014.

Figure 18. One of the photos from the RC airplane taken on Dec. 2, 2014.

Figure 19. One of the photos from the RC airplane taken on Dec. 2, 2014.

Figure 20. One of the photos from the RC airplane taken on Dec. 2, 2014.

Figure 21. One of the photos from the RC airplane taken on Dec. 2, 2014.

Figure 22. One of the photos from the RC airplane taken on Dec. 2, 2014.

Figure 23. One of the photos from the RC airplane taken on Dec. 2, 2014.

Figure 24. One of the photos from the RC airplane taken on Dec. 2, 2014.

Figure 25. One of the photos from the RC airplane taken on Sep. 2, 2015.

Figure 26. One of the photos from the RC airplane taken on Sep. 2, 2015.

Figure 27. One of the photos from the RC airplane taken on Sep. 2, 2015.

Figure 28. One of the photos from the RC airplane taken on Sep. 2, 2015.

Figure 29. One of the photos from the RC airplane taken on Sep. 2, 2015.

Figure 30. One of the photos from the RC airplane taken on Sep. 2, 2015.

Figure 31. One of the photos from the RC airplane taken on Sep. 2, 2015.

Figure 32. One of the photos from the RC airplane taken on Sep. 2, 2015.

Figure 33. One of the photos from the RC airplane taken on Sep. 2, 2015.

Figure 34. One of the photos from the RC airplane taken on Sep. 2, 2015.

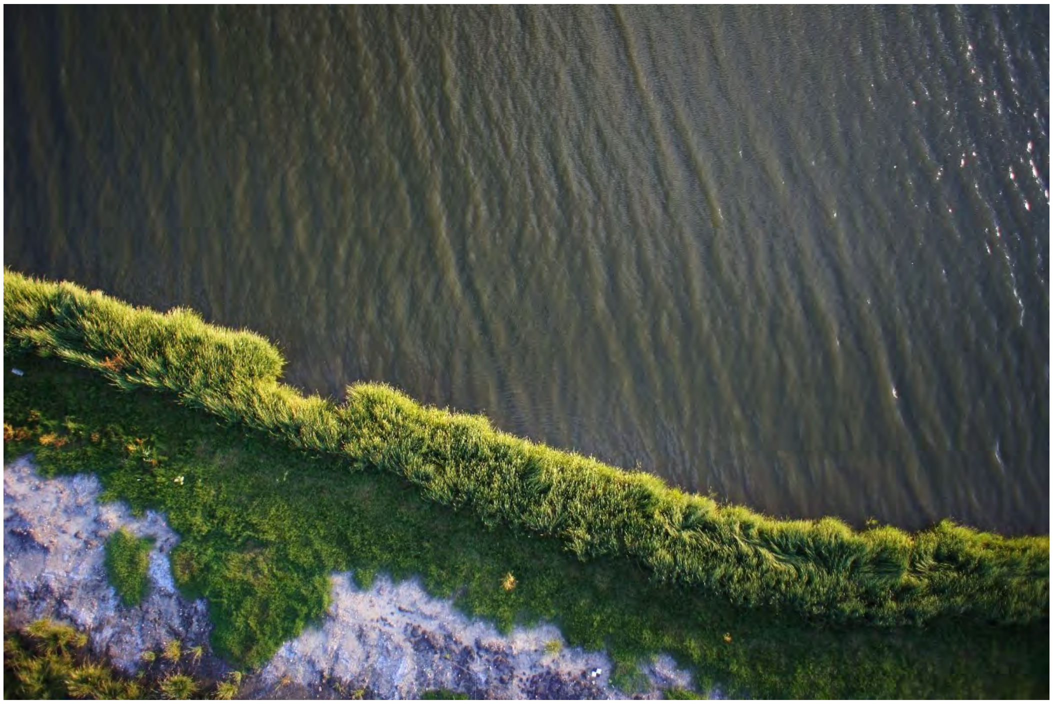


Figure 35. One of the photos from the RC airplane taken on Oct. 1, 2015.

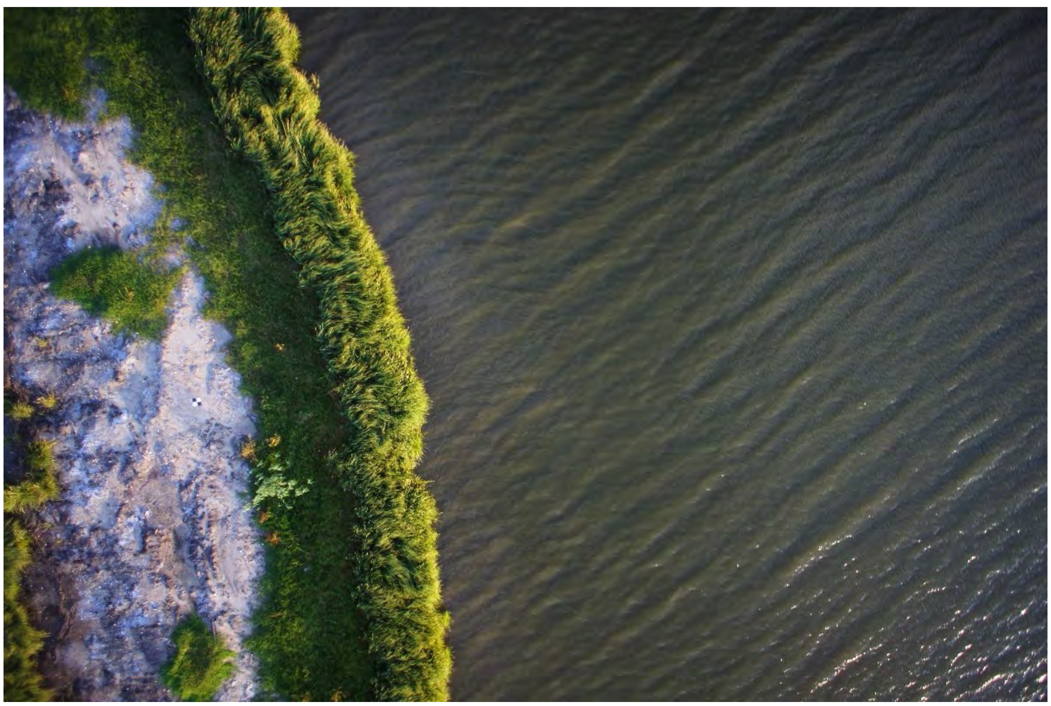


Figure 36. One of the photos from the RC airplane taken on Oct. 1, 2015.

Figure 37. One of the photos from the RC airplane taken on Oct. 1, 2015.

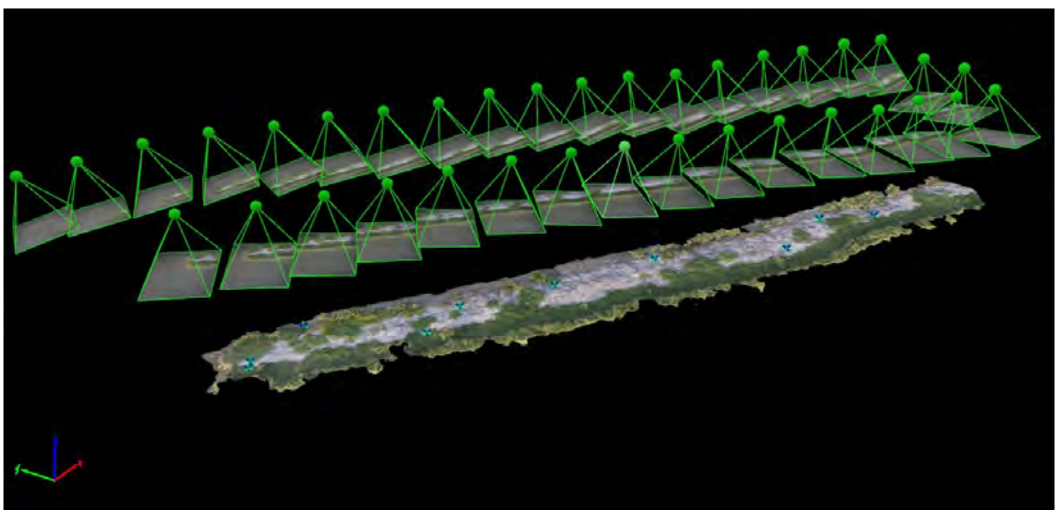


Figure 38. Demonstration of the flight paths and images illustrated above the digital surface model (DSM) of the drone mapping results. The ten targets are shown on the DSM.

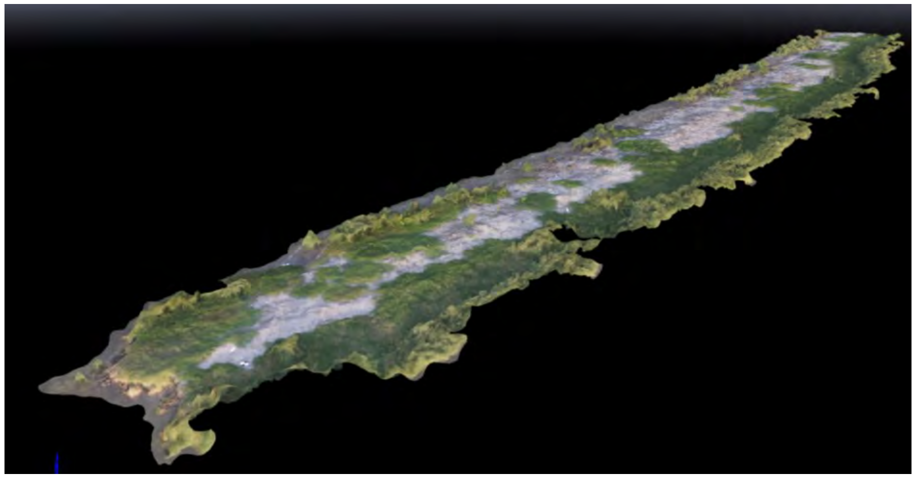


Figure 39. The DSM model of the earthen berm derived from the drone images.

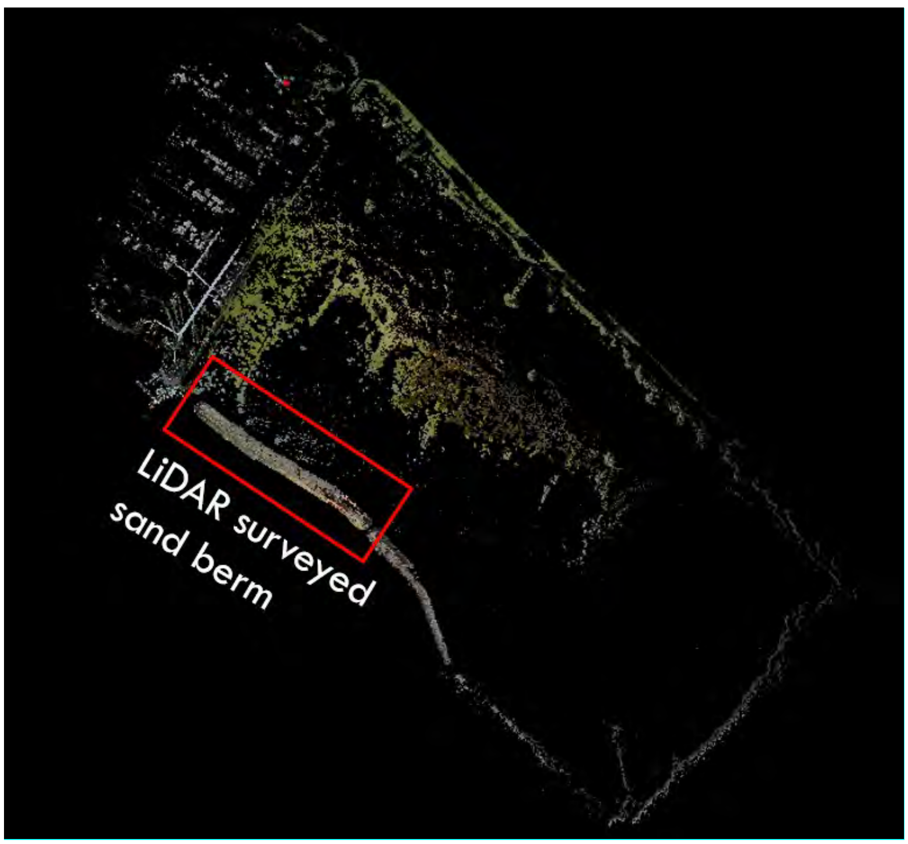


Figure 40. LiDAR point cloud data for the Buras wetland restoration site. The outlined earthen berm is the site with high resolution terrestrial LiDAR survey.

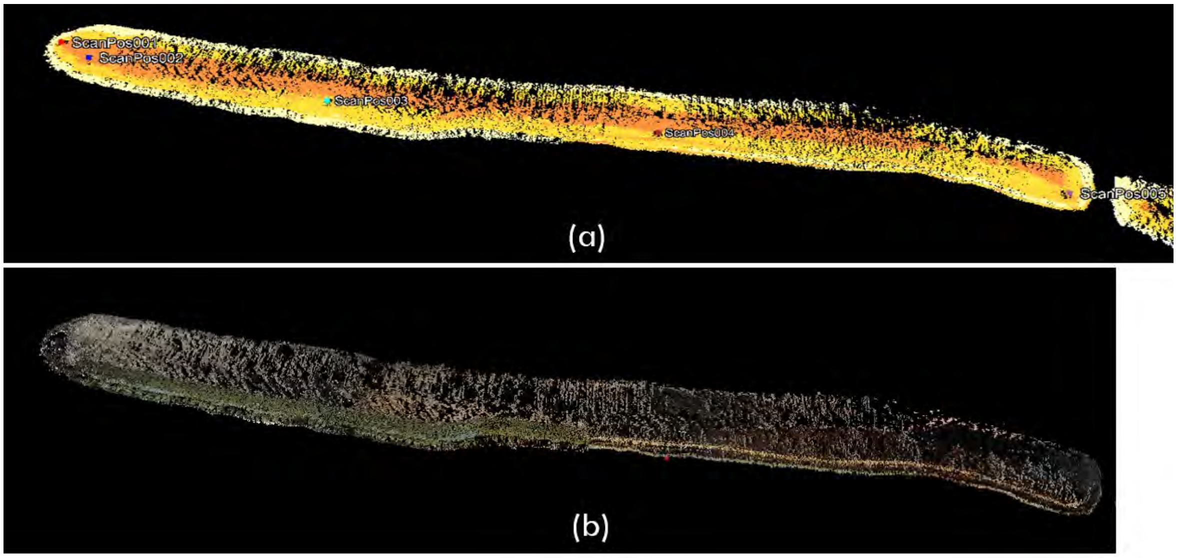


Figure 41. Earthen berm topographic maps from terrestrial LiDAR scan. (a) illustrates the berm topography based elevation and (b) is rendered in true color.

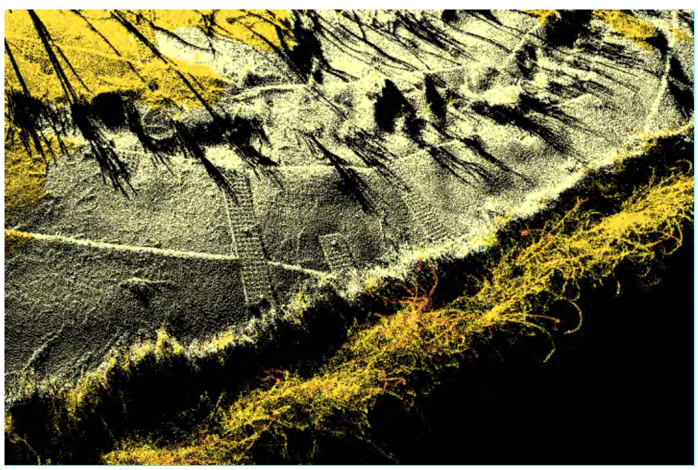


Figure 42. Detailed view of the LiDAR point clouds with fixing grid and grass presented on the berm. Black are shadow areas blocked by above ground features.

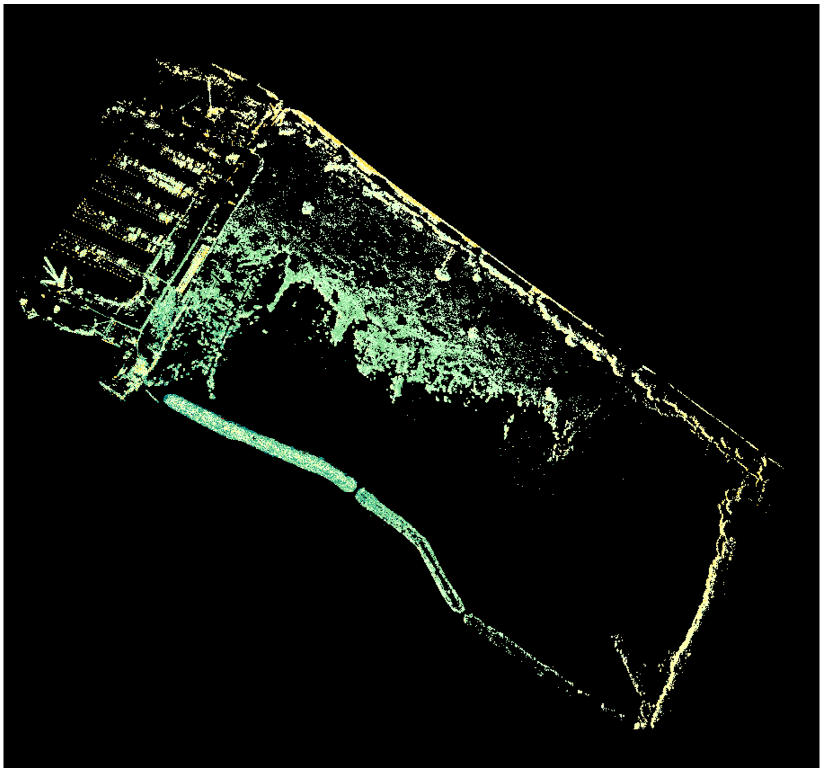


Figure 43. DSM model of the study site in October 2015 after one year construction. LiDAR point clouds are rendered in signal intensity for clear visual effect.

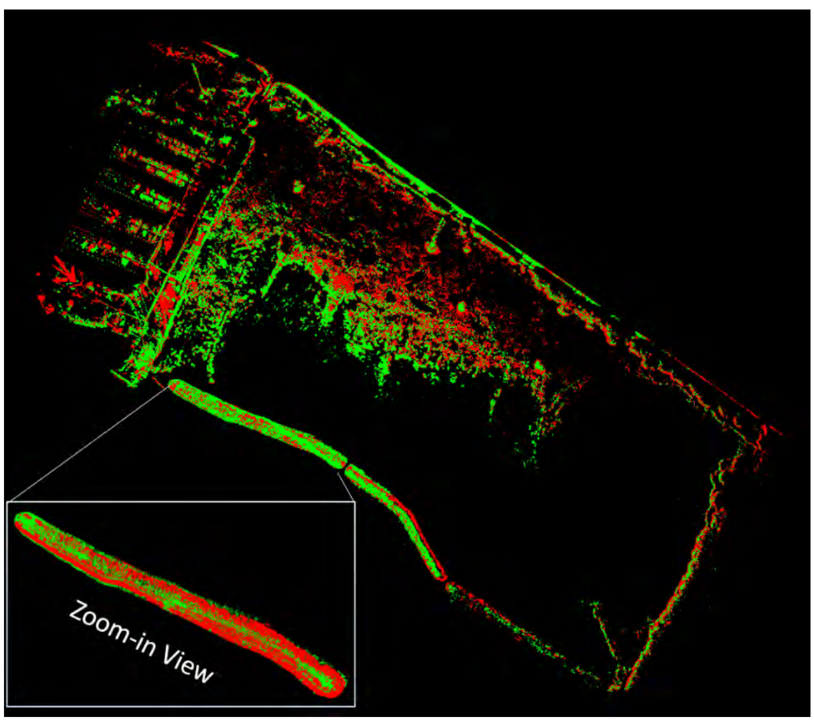


Figure 44. The surface model difference between 2014 (green) and 2015 (red).

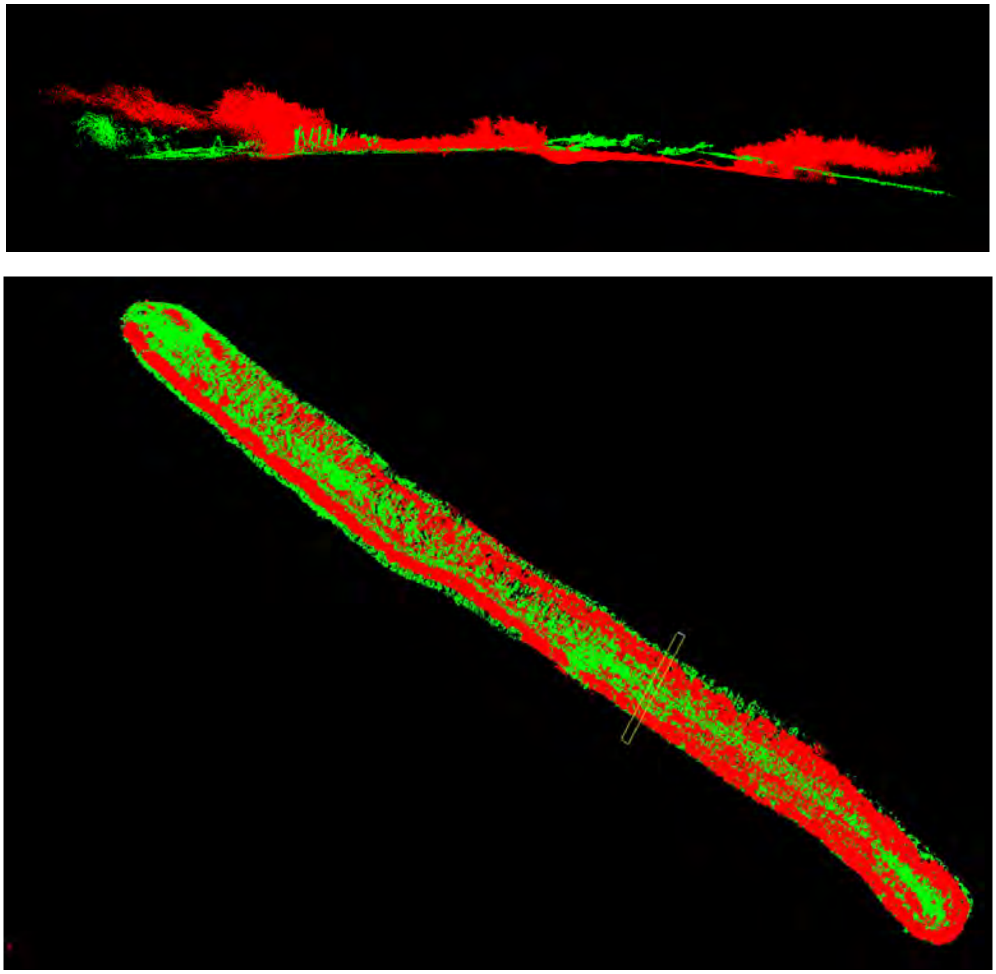
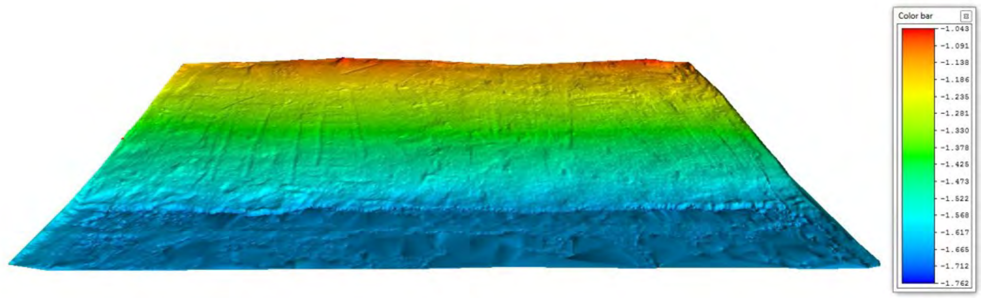
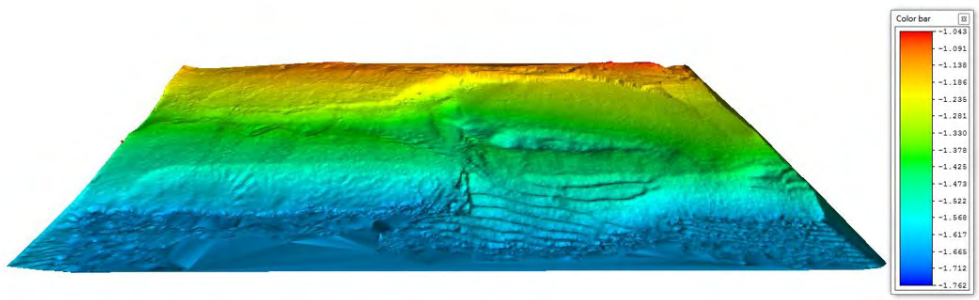


Figure 45. Cross transacts of the surface models in 2014 (green) and 2015 (red). The upper panel shows the zoomed in cross section which is marked in the lower panel.



(a)



(b)

Figure 46. Wave tank experiment results with mat protection on the left side. (a) shows the initial earthen berm status and (b) demonstrates the results after a 30-minutes wave simulation.

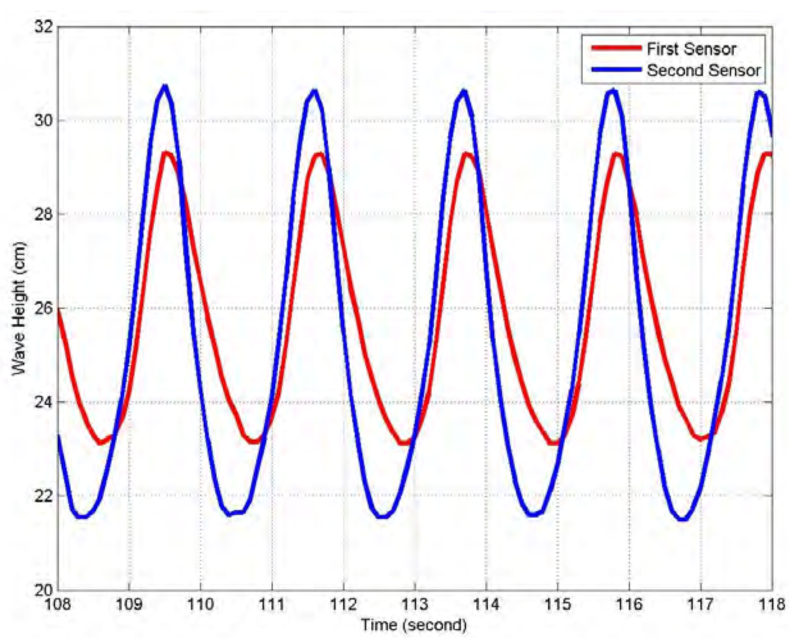


Figure 47. Wave height comparison: red colored curve – from the left most sensor which was in front of the EcoShield™; blue colored curve – from the right most sensor. The reduction in wave height by the EcoShield™ reached ~30-40%.

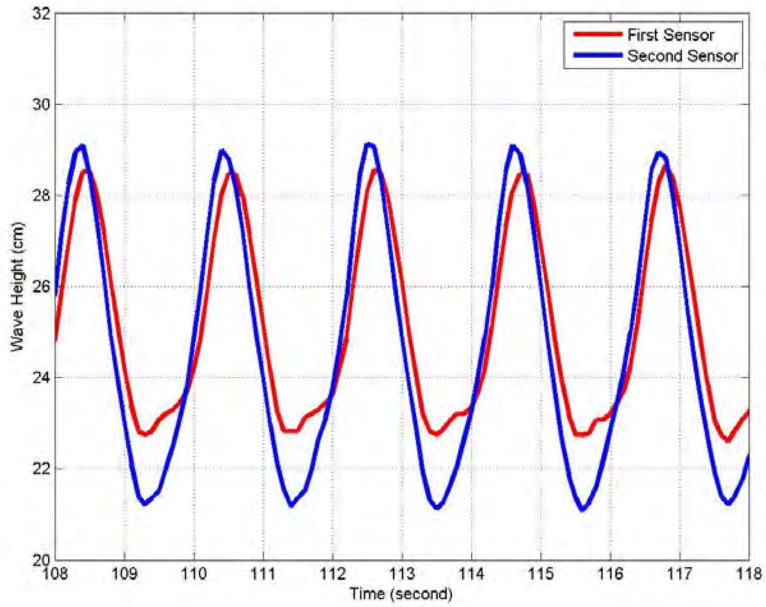


Figure 48. Wave height comparison: red colored curve – from the left most sensor which was in front of the EcoShield™; blue colored curve – from the right most sensor. The reduction in wave height by the EcoShield™ reached ~20-25%.

Photo 1. *before cutting the mat*: The sensors are numbered from left to right. The first sensor is at the end of the left most line with the pressure sensor tied to a lead weight, with a red band around the cable near the end of the cable. The second sensor tied to a lead weight is in the middle with two red

bands around the cable near the end of the cable. The third sensor is at the end of the right hand side line tied to a lead weight, with three red bands around the cable near the end of the cable.

Photo 2: The first set of wave parameters.

Photo 3: The second set of wave parameters.

Photo 4: The third set of wave parameters.

Photo 5: The fourth set of wave parameters.

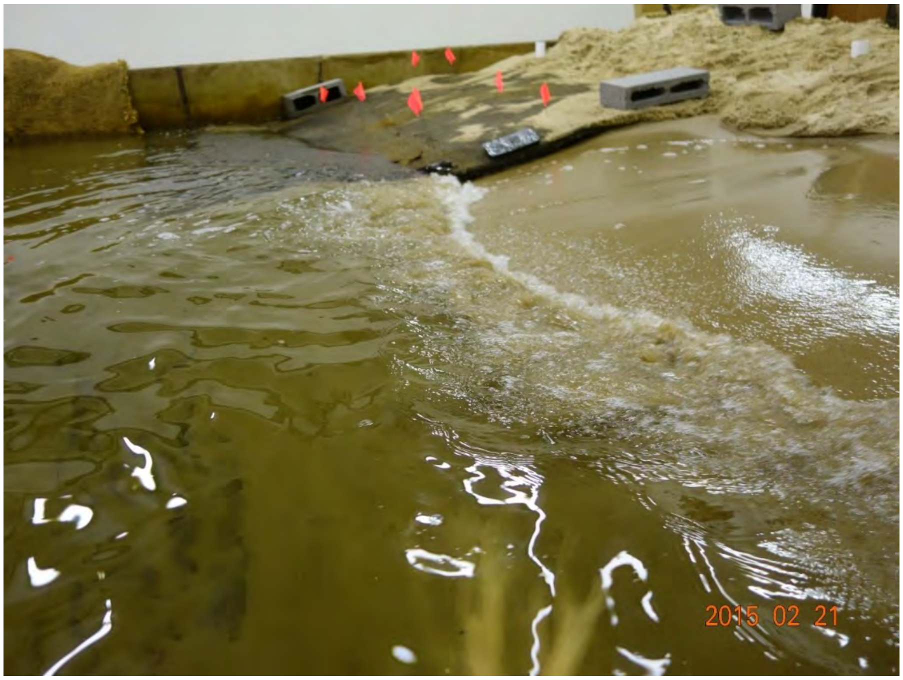


Photo 6: Showing the wave breaking in front of the bare side but wave height suppressed in front of the EcoShield™ mat.

Photo 7: Showing the wave reaching further on beach in front of the bare side than that of the EcoShield™ mat.

Photo 8: Showing the wave breaking in front of the bare side but wave height suppressed in front of the EcoShield™ mat.

Photo 9: Showing the wave breaking in front of the bare side but wave height suppressed in front of the EcoShield™ mat.