2-2008

New Point Comfort Lighthouse Mathews, Virginia Site Assessment Plan

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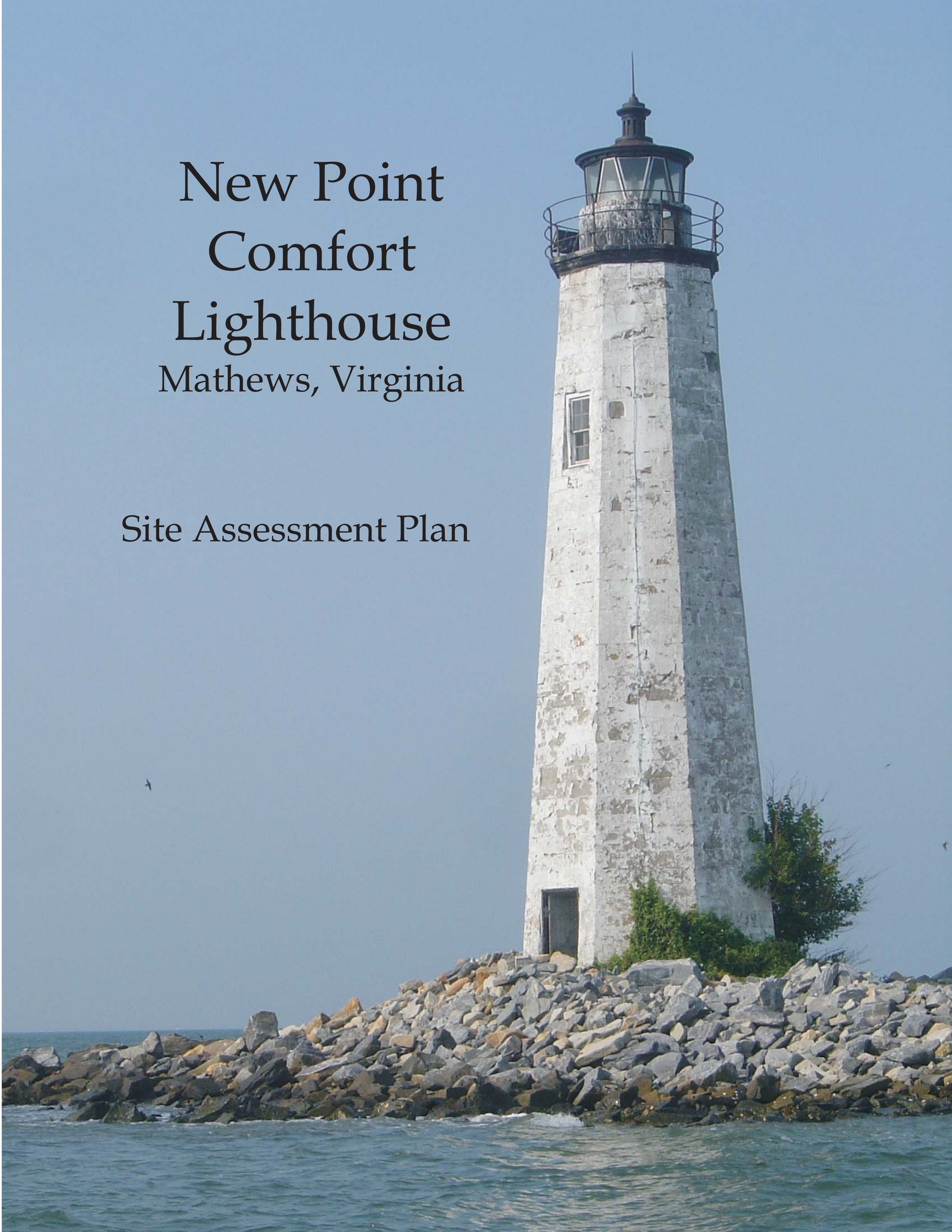

New Point Comfort Lighthouse
Mathews, Virginia

Site Assessment Report

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February 2008

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1 Introduction

1.1 Location and Purpose

New Point Comfort is located at the southern tip of Mathews County (Figure 1) between Chesapeake and Mobjack Bays. The New Point Comfort Lighthouse itself is on an island (Figure 2) that was once attached to the mainland but is now almost 0.6 miles from the mainland and only 0.33 acres in area above mean low water.

Previous studies have highlighted the problems which contribute to the instability of the island. McKay (2003) listed these factors which may allow continued erosion and potential damage up to and including the base of the lighthouse itself: rise in sea level, low base grade of the lighthouse, low crest of the existing rock revetment, not enough mass or numbers of rock in the revetment to fully dissipate the wave energy before it reaches the soil below, improper grading of the revetment rock where smaller rocks are inside and larger rocks on the outer layers, inadequately sized stone for the outer armor to combat the “design event”, inadequate lateral space between the crest of the revetment and the lighthouse to reduce the effects of wave run-up, wave overtopping and spray reaching the lighthouse structure. In fact, McKay (2003) rated the integrity and stability of the rock revetment around the lighthouse as poor to grave and would not remain intact after experiencing a large storm event.

This report will provide the necessary steps to be taken for immediate preservation of the lighthouse. A survey of existing conditions was performed as was a review of existing data. Storm surge levels were determined by analyzing data and models available from the U.S. Army Corps of Engineers (Corps), National Oceanic and Atmospheric Administration (NOAA), and the Virginia Institute of Marine Science (VIMS). Hydrodynamic modeling of storm events showed their environmental impact including the wave climate and water levels impacting the lighthouse under energetic conditions so that proper rock size, structure height, slope and toe size can be determined. The minimum stabilization solution consists of increasing the dimensions of the existing armor stone revetment that surrounds the light house.

1.2 Brief History of the Lighthouse

Construction began on the lighthouse in 1802 and completed in 1805 on two acres of the 75 acre New Point Comfort Peninsula. The keeper's house was completed in 1806. The design of the lighthouse called for it to be 50 feet in height, tapering from a diameter of 20 ft at the base to 12 ft at its top. The walls were to diminish in thickness from 5 ft to 2 ft, respectively. When built, the lighthouse including the light was 63 ft tall (NPC website, 2008).

The lighthouse was in service for over 150 years and the surrounding area was a popular recreational area from as early as 1820 to the beginning of the 20th century. Visitors came to the area for the day to fish, picnic, and sunbathe (Corps, 2007). A detailed assessment of this region’s cultural resources provides a history of the area from paleo-Indian period (9500 BC) to reconstruction and growth (1917) (Tidewater Atlantic Research, 2006). It documented that erosion has always been an issue at New Point Comfort. Only four years after the property was purchased, Keeper Elzy Burroughs reported that a storm had washed away “a considerable part of the beach” (Clifford, 2001). In October 1815, one observer noted that “the sand around the base of the Light House at New Point Comfort had washed away so much during the recent severe gales as imminently to endanger the safety of that building, the water every full tide entirely reaching it” (Clifford 2001). The earliest surviving survey of the island in 1833 showed the proximity of the lighthouse to the water. In fact, in 1839, a boat was requested for the lighthouse keeper as the facility was now separated from the mainland (Clifford, 2001). In November 1846, the lighthouse keeper called attention to the fact that the New Point Comfort “publik bildings was entirely surrounded by tidewater” (Clifford, 2001).

In order to protect the structure, riprap was deposited to the south and west of the lighthouse prior to 1925. In 1933, hurricane related flooding severely eroded the land upon which the lighthouse was located and damaged the light itself (Clifford, 2001). Extreme erosion has reduced the size of the island to less than 1/4 acre.

In 1963, the U.S. Coast Guard built a replacement structure, the New Point Comfort Spit Light, 1,050 yards southeast of the lighthouse. The old lighthouse was then abandoned, and later in 1976, the federal government deeded the lighthouse to Mathews County (Corps, 2007). Six hundred tons of rock were placed on the shoreline around the lighthouse in 1981. Although armored with riprap, the island, and the lighthouse itself, is still vulnerable to damage from storm generated wave action. This was the case during Hurricane Isabel in 2003.

In 2001, residents of the area formed the New Point Comfort Lighthouse Preservation Task Force to develop a master plan for preserving the lighthouse and making it accessible to the public. The next step for the County is to develop construction plans and specifications for the restoration plan and to provide the necessary dockage for access to the facility for restoration efforts.

2 Coastal Setting

2.1 Hydrodynamic Setting

With a location on the lower western shore of Chesapeake Bay, the effective fetch over which waves can form is large. The wind/wave climate impacting the Bay coast is defined by large fetch exposures in nearly all directions. Northeast, southeast, and south have the largest fetches across Chesapeake Bay – 24 miles, 26 miles, and 21 miles, respectively. The southeast fetch extends out the mouth of the Bay into the Atlantic Ocean. Fetches to the east, southwest, west and northwest are still significant at 17 miles, 9 miles, 8 miles, and 5 miles, respectively. Wind data from Norfolk International Airport reflect the frequency and speeds of wind occurrences in the region from 1960 to 1990 (Table 1). Winds from the North, South, Northeasters can be particularly significant in terms of the impacts of storm surge and waves on the lighthouse.

In addition to bay-generated waves, ocean waves impact New Point Comfort. Wave measurements were obtained and analyzed by Boon *et al.* (1992) from a directional wave gauge on Wolf Trap Light Tower which is farther north than New Point Comfort but is located off Mathews County shoreline. Boon *et al.* (1992) concluded that while the Wolf Trap site lies beyond the lower Chesapeake Bay region where ocean-generated waves are present in appreciable amounts, they are still evident and may modulate wave height and period during fair weather conditions. Figure 3 demonstrates one winter of wave data taken at Wolf Trap Light (1 Dec 1989-30 Apr 1990). Almost 13% of the wave data comes from the southwest or south-southwest which could indicate ocean generated swell. However being farther south than Wolf Trap, more ocean-generated swell will impact the site (Boon *et al.*, 1992).

The frequency and reach of storms impacting the lighthouse can be described the still water frequency for Yorktown (Table 2). These are used in modeling the impact of storms. Simply put, the 100 year storm has a 1% chance of occurring in any given year while the 50-year event has a 2% chance of occurring. Still water levels measured at Yorktown by the Shoreline Studies Program after Hurricane Isabel was 8.6 ft above mean lower low water (MLLW) and the high water/trash line was measured at 12.4 ft MLLW indicating 4 ft waves were impacting the site. These numbers indicate that this was a 100-year event for Yorktown.

In addition to storm surge, sea level is continuing to rise in the Tidewater Region. Understanding the long-term change in sea level is an essential part of coastal planning. In particular, knowing the projected rate of change in water levels is essential for determining coastal hazards from storms and flooding risks and designing long-term solutions. Tide data collected at Sewells Point in Norfolk show that sea level has risen 4.42 mm/yr (0.17 inches/yr) or 1.45 ft/century (http://www.co-ops.nos.noaa.gov/). Data from VIMS/Gloucester Point tide gauge indicates a rate of 1.3 ft/century based on data taken between 1950 and 1999 (http://www.co-ops.nos.noaa.gov/).

Table 1. Summary wind conditions at Norfolk International Airport from 1960-1990.

Wind Speed (mph)	Mid Range (mph)	South	South west	West	North west	North	North east	East	South east	Total
		WIND DIRECTION								
< 5	3	5497* 2.12+	3316 1.28	2156 0.83	1221 0.47	35748 13.78	2050 0.79	3611 1.39	2995 1.15	56594 21.81
5-11	8	21083 8.13	15229 5.87	9260 3.57	6432 2.48	11019 4.25	13139 5.06	9957 3.84	9195 3.54	95314 36.74
11-21	16	14790 5.70	17834 6.87	10966 4.23	8404 3.24	21816 8.41	16736 6.45	5720 2.20	4306 1.66	100572 38.77
21-31	26	594 0.23	994 0.38	896 0.35	751 0.29	1941 0.75	1103 0.43	148 0.06	60 0.02	6487 2.5
31-41	36	25 0.01	73 0.03	46 0.02	25 0.01	162 0.06	101 0.04	10 0.00	8 0.00	450 0.17
41-51	46	0 0.00	0 0.00	0 0.00	1 0.00	4 0.00	4 0.00	1 0.00	0 0.00	10 0.00
Total		41989 16.19	37446 14.43	23324 8.99	16834 6.49	70690 27.25	33133 12.77	19447 7.50	16564 6.38	259427 100.00

*Number of occurrences +Percent

This rise in sea level directly effects the reach of storms and their impact on shorelines. Anecdotal evidence of storm surge during Hurricane Isabel, which impacted North Carolina and Virginia on September 18, 2003, put it on par with the storm surge from the "storm of the century" which impacted the lower Chesapeake Bay in August 1993. Boon (2003) showed that even though the tides during the storms were very similar, the difference being only 1.5 inches, the amount of surge was different. The 1933 storm produced a storm surge that was greater than Isabel's by slightly more than a foot. However, analysis of the mean water levels for the months of both August 1933 and September 2003 showed that sea level has risen by 1.35 ft at Hampton Roads in the seventy years between these two storms (Boon, 2003).

Table 2. Still-water frequency levels for Yorktown, Virginia.

Exceedance Frequency		Stillwater Level (ft MLW)
(Percent)	(Years)	U.S. COE, 1989
10	10	6.3
2	50	7.8
1	100	8.5
0.2	500	10.3
1	100+waves	12.0

The mean tide range is 2.3 ft with an average spring tide of 2.8 ft. A database of monthly high tide levels recorded between May 1950 and January 2008 in the VIMS/Gloucester Point/Yorktown vicinity was analyzed to determine how often tides exceed mean higher high water. Data came from NOAA's website (2008) from the Gloucester Point tide gage at VIMS (1950-2003) and U.S. Coast Guard tide gauge (2004-2008). The Gloucester Point tide gauge at VIMS was destroyed during Hurricane Isabel and replaced just downstream at the U.S. Coast Guard Station pier in June 2004. These data do not account for multiple high water events in each month since only the highest tide in each month was available for analysis before 1996. Table 3 shows that most months exceeded mean higher high water by up to 1 ft. Thirty percent of the months since 1950 exceeded the MHHW by 2 ft. Five months during that time frame had tides greater than +4 ft MHHW. It is interesting to note that of the highest seven tides, three occurred September, October, and November 2006. In fact, five out of the seven highest water levels in the last 58 years occurred in the last ten years (Table 4).

Table 3. Analysis of monthly high tide levels (1950-2008) at Gloucester Point/USCG.

Elevation	Number of Months Exceeded	Total Number of Months Analyzed	Percent Exceeded
> MHHW or +2.8 ft MLLW	625	665	94%
> 1 ft MHHW or +3.8 ft MLLW	200	665	30%
> 2 ft MHHW or +4.8 ft MLLW	32	665	5%
> 3 ft MHHW or +5.8 MLLW	5	665	1%

Table 4. Seven highest monthly tides.

Year	Month	Tide Height (ft MLLW)	Storm
2006	11	5.7	November 22, 2006 Northeaster
1978	4	5.77	April 15, 1978 Northeaster
1998	2	5.86	Twin Northeasters
2006	9	5.91	Tropical Storm Ernesto
2006	10	6.1	October 10, 2006 Northeaster
1962	3	6.26	Ash Wednesday Storm
2003	9	7.83*	Hurricane Isabel

*This was the maximum water level recorded, however, the water level was increasing when the gage was destroyed by the storm.

2.2 Physical Setting

The coastal geomorphology of the County is a function of the underlying geology and the hydrodynamic forces operating across the land/water interface, the shoreline. The last low stand found the ocean coast about 60 miles to the east when sea level about 300 feet lower than today and the coastal plain was broad and low. The current estuarine system was a meandering series of rivers working their way to the coast. About 15,000 years ago, sea level began to rise and the coastal plain watersheds began to flood. Shorelines began to recede. The slow rise in sea level is one of two primary long-term processes which cause the shoreline to recede; the other is wave action, particularly during storms. As shorelines recede or erode the bank material provides the sands for the offshore bars, beaches and dunes.

As seen in the shoreline change summary shown in Figures 4 through 7, the southern most part of Mathews County has had dramatic shifts in shore position. The sand has subsequently shifted into its current position by wave and current forces operating at this confluence of Mobjack Bay and Chesapeake Bay. As early as 1815, concerns over the proximity of the lighthouse to the water had emerged. While the main island was still relatively intact by 1853, a tidal drainage is visible on the chart at the position of the lighthouse. This drainage, as well as a notch on the back side of the island, could have brought tidal waters close to the lighthouse. New Point Comfort Lighthouse became an island by at least 1839 when Deep Creek breached. The island has since receded leaving the lighthouse completely stranded in Chesapeake Bay. The northern section of the mainland has been more stable over the years, and the coast has evolved to a semi-equilibrium shore form. The long term shore change rate (1937-2002) of the mainland north of the lighthouse is -5.5 ft/yr (Hardaway *et al.*, 2005). Extreme fluctuations in shore change are seen at the southern end of New Point Comfort where wave and current dynamics interact and significantly influence alongshore sand movement.

A bathymetric survey conducted by the U.S. Army Corps of Engineers in 2004 of the area surrounding the lighthouse showed that depths varied from less than 1 ft MLW new the New Point Comfort peninsula to 5 ft MLW south of the lighthouse. In general, depths to the north of the island tend to be shallower than those south of it (Corps, 2007).

The immediate vicinity of the lighthouse consists of sediments that are primarily sands and clays with traces of silts of mostly marine origin. Sediment borings made by the Corps of Engineers show mostly fine to medium grained sand at the surface with small amounts of silts incorporated. The borings are shown in Appendix A. Generally, they show that from 4 to 14 ft below the surface of the sediment/water interface, the material was mostly fine to coarse silty sand with some shell fragments. Below the depth of 14 ft, the sediment/water interface, the sediments consisted of mostly clays and/or silty sands with some shell fragments (Corps, 2007).

3 Methods

3.1 Site Surveying

A shoreline and nearshore survey was performed at the New Point Comfort Lighthouse on 26 June and 25 July 2007. A Trimble 4700 Real-Time Kinematic Global Positioning System (RTK-GPS) was used to set site control and acquire shore data. The 4700 receiver utilizes dual-frequency, real-time technology to obtain centimeter accuracy in surveying applications. In addition, a Trimble 5600 Robotic Total Station was used to acquire data in the nearshore.

Base station benchmarks were at the site with a 2-hour occupation. These data were processed through the National Geodetic Survey's On-line Positioning User Service (OPUS) (http://www.ngs.noaa.gov/OPUS/). All the survey data were based on these benchmarks. In addition, 3-minute occupations were taken at secondary benchmarks in order to determine survey error. The horizontal datum is UTM, Zone 18 North, NAD83, international feet. The vertical datum is feet MLLW, geoid03, as determined from nearby benchmarks publishing both NAVD88 and MLLW for the 1980-2001 tidal epoch (http://www.co-ops.nos.noaa.gov/bench_mark.shtml?region=va).

Generally, the surveys included the following elements:

1. Dimensions of the project structures such as the revetment and pier;
2. Mean High Water (MHW) and Mean Low Water (MLW); survey extends to approximately the -3 ft MLW contour;
3. Base of rock, top of rock, and the base of the lighthouse.

3.2 Photo Geo-referencing

Recent color aerial photography was acquired by Shoreline Studies Program to show the state of the lighthouse's island. The images were scanned as tiff files at 600 dpi. The reference mosaic, the 2002 Digital Orthophotos from the Virginia Base Mapping Program (VBMP), is divided into a series of orthophoto tiles and is stored in a Virginia south, state plane projection, in feet. The aerial photo tiles from VBMP for the lighthouse was re-projected to a UTM zone 18 North, NAD83 projection, in meters.

Rectifying requires the use of ground control points to register the aerial photography to the reference images. Ground control points were limited on the island; GPS points from the survey were used to help ensure accurate registration without excessive amounts of warp and twist in the images. The standard in this project was to achieve a root mean square (RMS) error under six for the aerial photo. Georeferencing was done by using the Georeferencing Tool in ArcMap. First the reference image and the scanned aerial photograph are roughly aligned so that common points can be identified. Then, with the aid of the Georeferencing tool, ground control points are added until the overall RMS error is less than six and the location of the aerial photograph closely matches the location of the reference image. When an acceptable correspondence is achieved, the aerial photograph is saved as a rectified image.

3.3 Hydrodynamic Modeling

In order to model the wave height and period associated with specific storm events, the Nearshore Evolution MOdeling System was used. NEMOS, as it is called, is a set of codes that operates as a system to simulate the long-term planform evolution of the beach in response to imposed wave conditions, coastal structures, and other engineering activity. NEMOS is part of the Coastal Engineering Design and Analysis System (CEDAS) (Veritech, Inc., 2008). Specifically, the grid generator was used to develop a bathymetric grid over which, wave conditions could be modeled.

In order to create a bathymetric grid to model storm impacts (Figure 8), three datasets were formated and merged. All data was reprojected to UTM zone18, NAD83, meters. Vertical data were not altered except to convert to meters. The U.S. Army Corps of Engineers performed a bathymetric survey of the lighthouse in 2004 (State Plane, VA South, ft, MLW). The Shoreline Studies Program at VIMS surveyed the island and nearshore in the summer of 2006 (UTM, NAD83, ift, MLLW). Geo-referenced soundings and depth contour information were obtained from NOAA's Electronic Navigational Charts (NOAA ENC) database. They provide fully integrated vector base maps for GIS that are used for coastal management and other purposes (UTM, NAD83, m, MLLW).

STWAVE uses a finite-difference representation of a simplified form of the spectral balance equation to simulate near-coast, time-independent spectral wave energy propagation. This model was used to generate wind-driven storm waves from the northeast and southeast resulting only from a persistent high winds. Two model runs were performed:

Run 1: Input wind, 72 mph from the northeast, with an increased water level of 8.5 ft
Run 2: Input wind, 72 mph from the southeast, with an increased water level of 10.5 ft

4 Results and Discussion

4.1 Survey

The topographic and nearshore survey showed the scattering of the original revetment's rock around the island as indicated by the blue "Rock Sand" line on the survey (Figure 9). In general, the rock extends to the northeast indicating that larger waves which can move the rock impact this side of the island. The water is shallower on the south and west and deeper on the north and east sides of the island which allows larger waves closer to the shore. Figures 10-12 show cross-sections of the survey data at each corner of the lighthouse. They show the extent of the rock along the profile. Along most of the profiles, the rocks of the old revetment have been rearranged so that they extend from below MLW to the base of the lighthouse. Only profiles 1 and 2 on the west and northwest side of the lighthouse have not had the rocks pushed up against the base of the lighthouse.

The lighthouse, itself, is being impacted by the elements. Being exposed to the elements due to peeling paint and broken windows and doors, the sandstone structure is eroding. Figure 13 shows that all sides of the lighthouse are in need of repair. The door to the structure is open (Figure 14) allowing the elements to cause interior deterioration (Figure 15). Figure 16 depicts the state of the outside of the lighthouse. Peeling paint threatens the integrity of the sandstone structure. The sandstone is being worn away and mortar between the joints is being eroded.

4.2 Hydrodynamic Modeling

Hydrodynamic modeling of the lower Bay in the vicinity of the lighthouse was performed for several storm scenarios. The goal of these model runs was to determine the sizing of rock that will be necessary for the revetment. In addition, the elevation of the revetment must withstand a certain level event. The most recent large storm event was Hurricane Isabel which made landfall along the southeast coast of North Carolina on September 18, 2003. At one time, the storm was a Category 5 on the Safir-Simpson scale but had been downgraded to a Category 2 before it made landfall. By the time it impacted the Chesapeake Bay, it was a minimal Category 1. However, in addition to being in the "right-front" quadrant of the advancing hurricane, southeastern Virginia experienced east and east-southeast winds which are known to have the greatest potential to transport water into Chesapeake Bay.

Storm data was obtained by an Acoustic Doppler Current Profiler (ADCP) which was deployed in 28 ft of water offshore of VIMS at Gloucester Point. The instrument provided a quantitative record of the hurricane's impact on lower Chesapeake Bay. Data from the ADCP showed that Isabel created a 7-foot storm tide topped by 6-foot waves. At the height of the storm, wave crests were passing over the instrument once every 5 seconds, and the storm was forcing the entire flow of the York River upstream at a rate of 2 knots. Because Isabel was so large, its winds, waves, and surge effected the Bay for an abnormally long time. The ADCP data showed that storm conditions persisted in the Bay for nearly 12 hours (VIMS, 2003). Hovis *et* *al.* (2004) showed that the Hurricane Isabel tide levels exceeded the historical maximum water levels at the Chesapeake Bay Bridge Tunnel, one of the handful of gauges still operating after the storm. Prior to Isabel, the previous storm of record at this site was the Twin Northeasters in January/February 1998 (Hovis *et al.*, 2004). However, as shown in a previous section, two additional large storms occurred in 2006 that had a larger storm surge than the Twin Northeasters at Gloucester Point.

Weather data provided by instruments atop VIMS' Byrd Hall during Hurricane Isabel showed that maximum sustained winds on the campus reached 65 mph, with 90-mph gusts. The barometer bottomed out at 29.2 inches, with a rainfall accumulation of about 2.2 inches (VIMS, 2003).

These factors were taken into consideration when determining the storm scenarios to model. The initial model run used 72 mph winds which was slightly higher than those experienced at VIMS to simulate a more open bay condition. Storm surge was 8.5 ft MLLW which was consistent with the surge experienced at Yorktown. Figures 17 and 18 show the results of the first design model run. Northeast winds generated a maximum wave of 4.6 ft MLLW and 5.6 sec mostly coming from the east-northeast. Considering these conditions have already been experienced during Isabel, the second model run used a larger surge (Figure 19 and 20). Southeast winds generated a maximum wave of 6.9 ft MLLW and 6.1 sec from the southeast.

5 Preliminary Plan

Previous research has identified the causes of instability of the island on which New Point Comfort Lighthouse sits as well as provided plans for it's stabilization. In general, McKay (2003) rated the present rock revetment around the lighthouse as "poor to grave" and susceptible to a large storm event (Figure 21). He predicted that a large storm event would push the undersized rocks at the crest of the revetment into the walls of the lighthouse. This occurred during Hurricane Isabel which impacted the region on September 18, 2003 (Figure 21) as a minimal category 1 storm. As part of his report, McKay (2003) developed several alternative plans but also made a recommended core course of action (Figure 22). His plan consists of a 50 ft level, open surface around the base of the lighthouse, a proper rock revetment 50 ft wide and a crest elevation of +10.5 ft with at least two grades of rock, geotextile fabric, and an embedded toe to guard against undermining, a parapet wall cast into the crest of the revetment, and a new pier. McKay (2003) noted that this core plan, which was estimated to cost just over $1 million, would stand alone as primary protection for the lighthouse but will also be compatible with future phases, should they occur.

The Corps (2007) developed several different alternative plans at the New Point Comfort site. These plans generally had a combination of rock breakwaters and rock revetments to create an artificial island around the lighthouse. The cost of these alternatives ranged from $21.6 to $55.8 million (Corps, 2007). One of the most three most cost-effective plans is shown in Figure 23. It consists of a revetment protecting the northern side of a manmade island and breakwaters holding the southern side of the island. The focus of the Corps (2007) study was ecosystem restoration, not necessarily protection of the lighthouse, although stabilization is a primary component of all their plans. However, due to the different report focus, the implementation of the ecosystem restoration plan was not recommended as the designs were too costly.

The plan that resulted from our research efforts are similar to those proposed by McKay (2003). Several variations resulted from a new wave climate information (Hurricane Isabel) and modeling. Figure 24 shows the revetment that will surround the island, and its dimensions are shown in Figure 25. The revetment is proposed to follow the outline of the lighthouse itself being an octagon rather than round. This is mostly for aesthetic reasons and visual interest. The footpath or open level surface around the entire perimeter of the lighthouse is 20 ft wide, reduced in width from McKay's (2003) plan, but sand fill is required. The revetment will be built on a 2:1 slope and is 46 ft wide, extending 66 ft out from the lighthouse. The crest elevation is +12.5 ft MLLW. The rock size for the armor layer needs to have a D_{50} of 3,700 lbs. The rocks from the existing revetment can be reused in the bedding and armor layers of the proposed revetment.

This plan results from new understanding of wave climate due to recent storm activity. A storm surge of over 8 ft MLLW was documented during what's been called a 100-yr event (Hurricane Isabel). However, Isabel was only a minimal category 1 hurricane and since it occurred, three additional storm events caused surges of around 6 ft MLLW. In addition, sea level rise is continuing in the lower portion of the Bay. In order to maintain long-term protection, it was deemed necessary to raise the elevation of the revetment. The final design may modify this plan and will include a new access pier.

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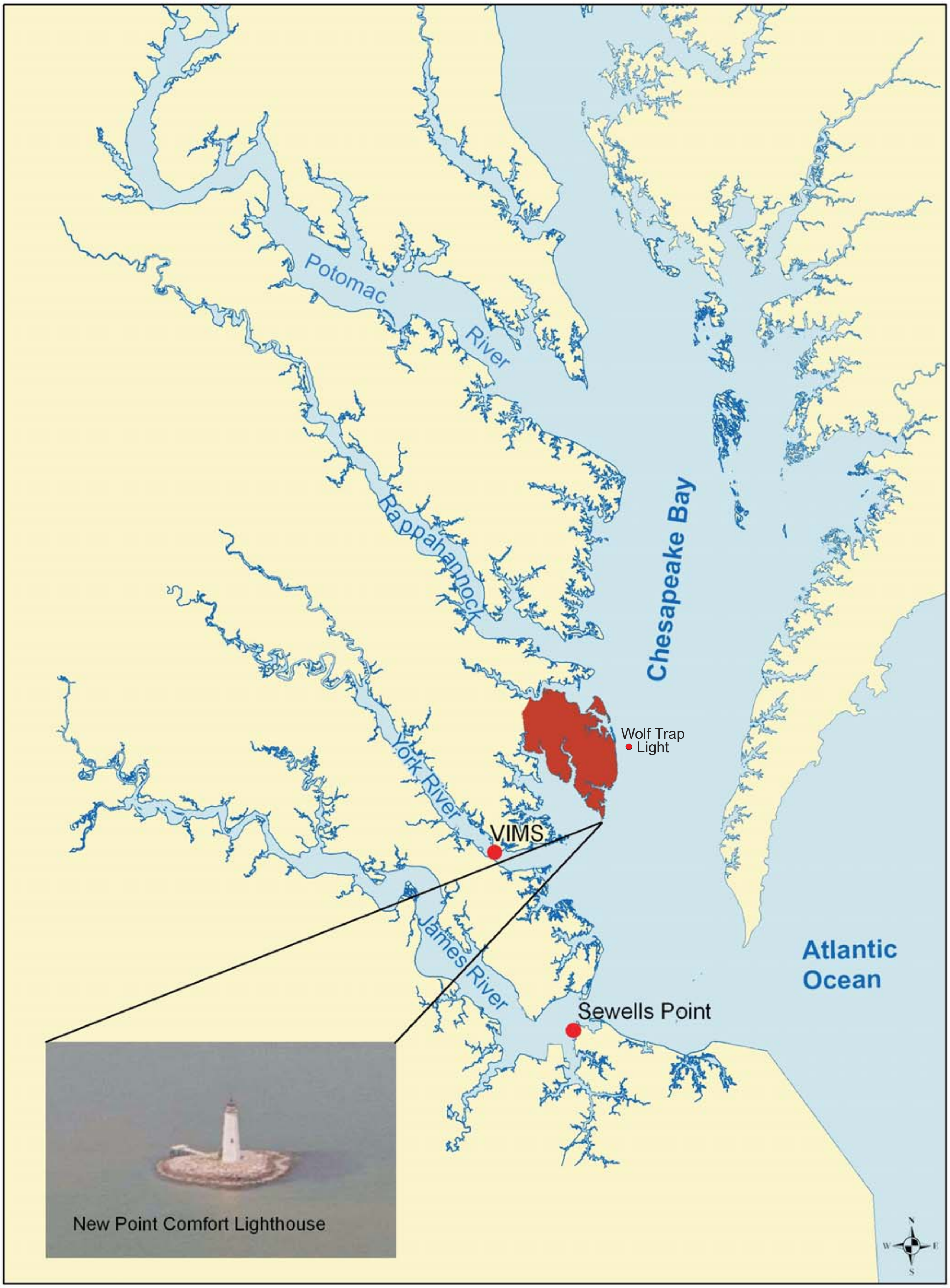


Figure 1. Location of New Point Comfort Lighthouse and Mathews, Virginia within the Chesapeake Bay estuarine system. The VIMS location is at Gloucester Point and just across the river from Yorktown.

Figure 2. Aerial view of New Point Comfort Lighthouse taken on 9 August 2007.

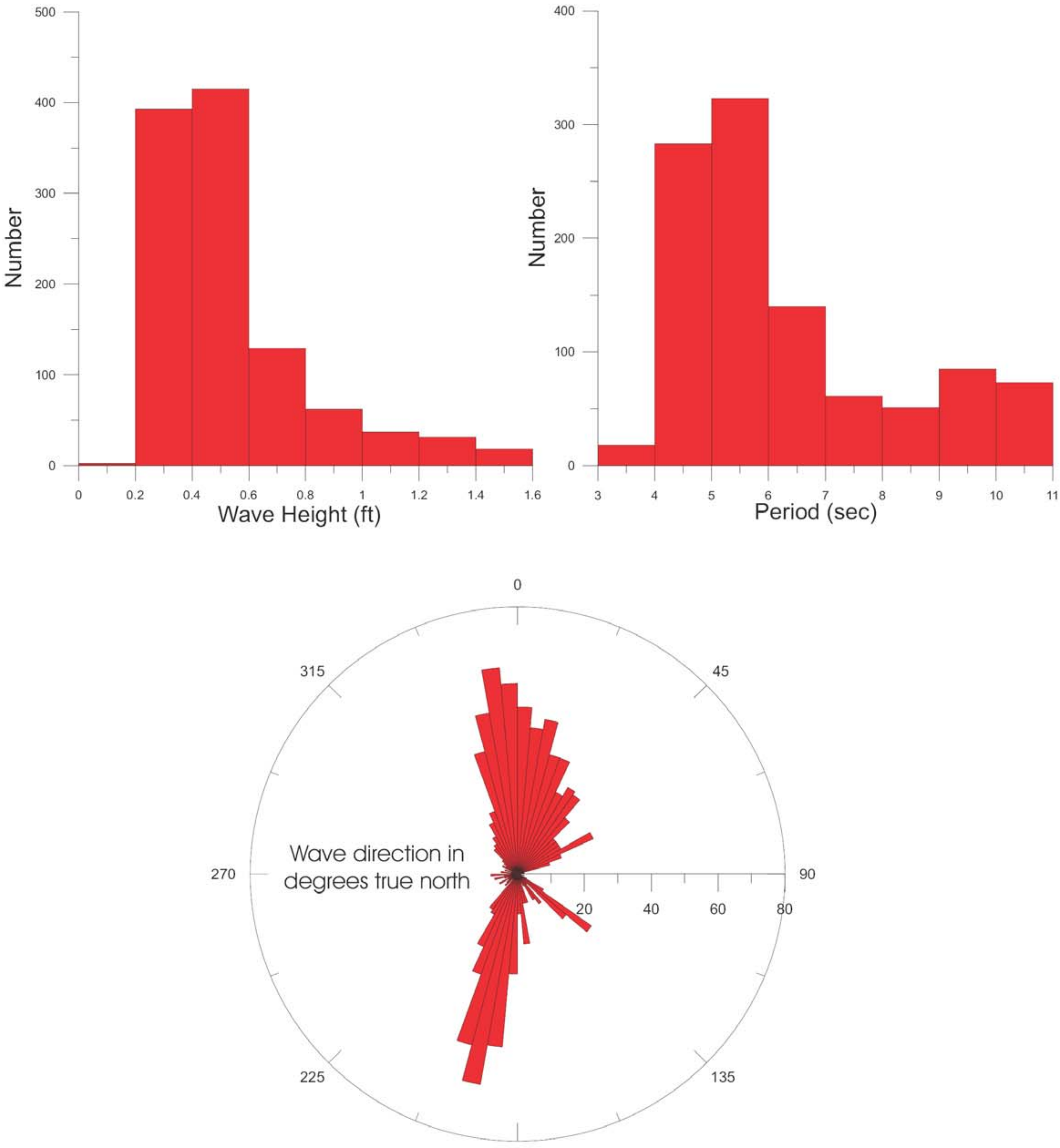


Figure 3. Parameters of wave data collected at the Wolf Trap Light wave guage between 1 Dec 1989 and 30 Apr 1990. Data from VIMS website http://www.vims.edu/physical/research/VIMSWAVE/VIMSWAVE.htm.

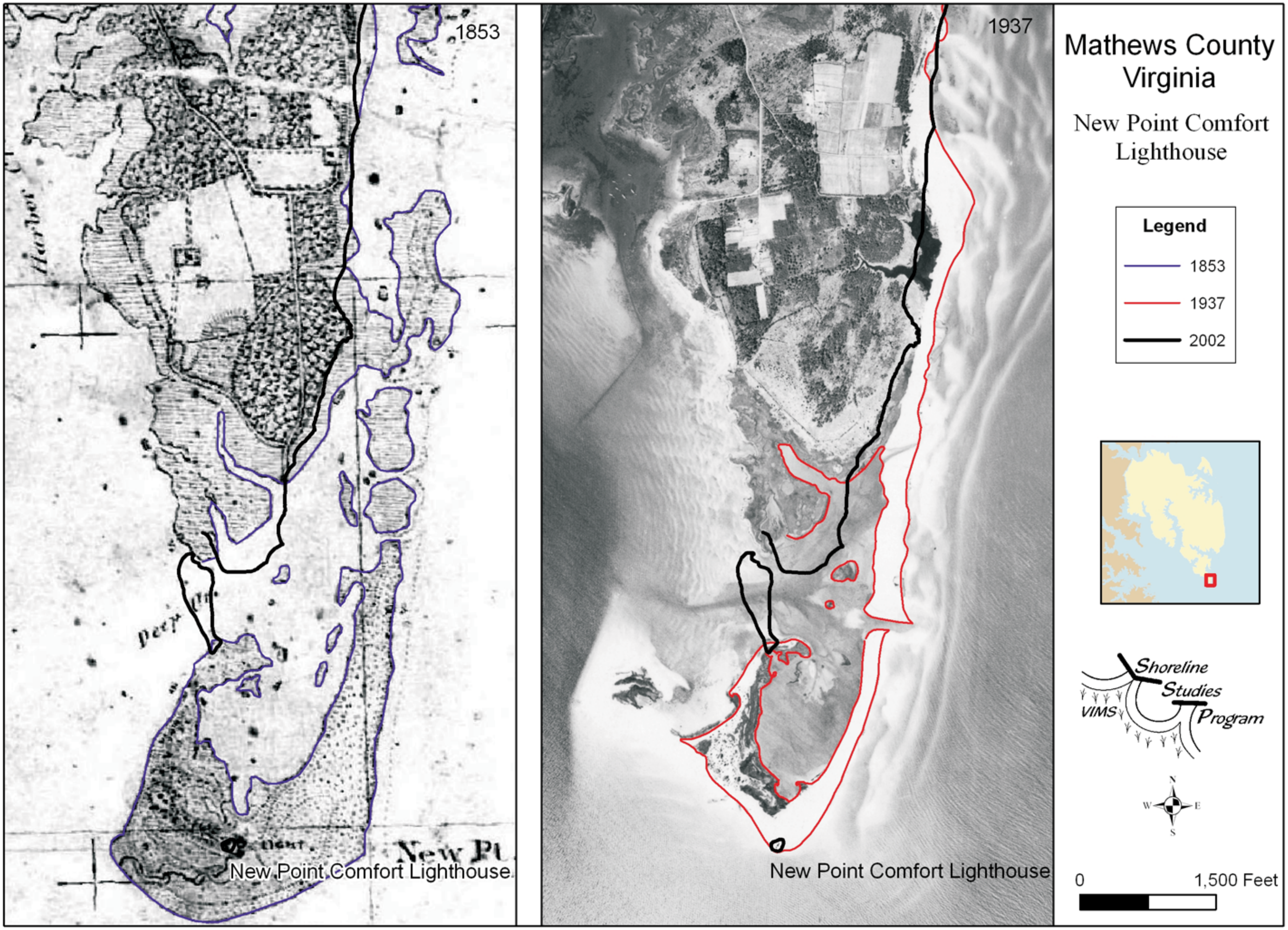


Figure 4. Orthorectified 1853 map and 1937 photo showing the location of New Point Comfort Lighthouse and the 2002 digitized shoreline.

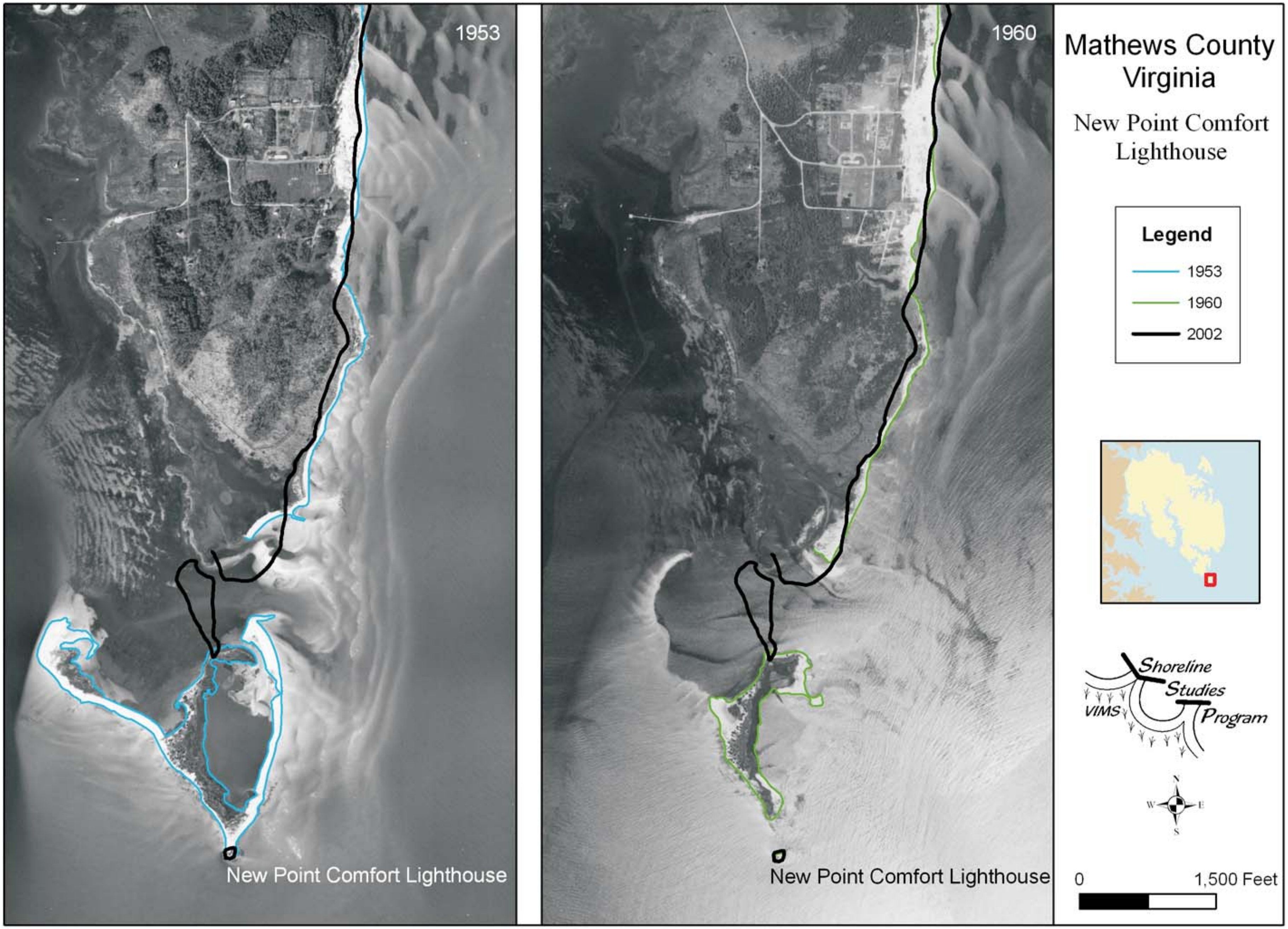


Figure 5. Orthorectified 1953 and 1960 aerial photos showing the location of New Point Comfort Lighthouse and the 2002 digitized shoreline.

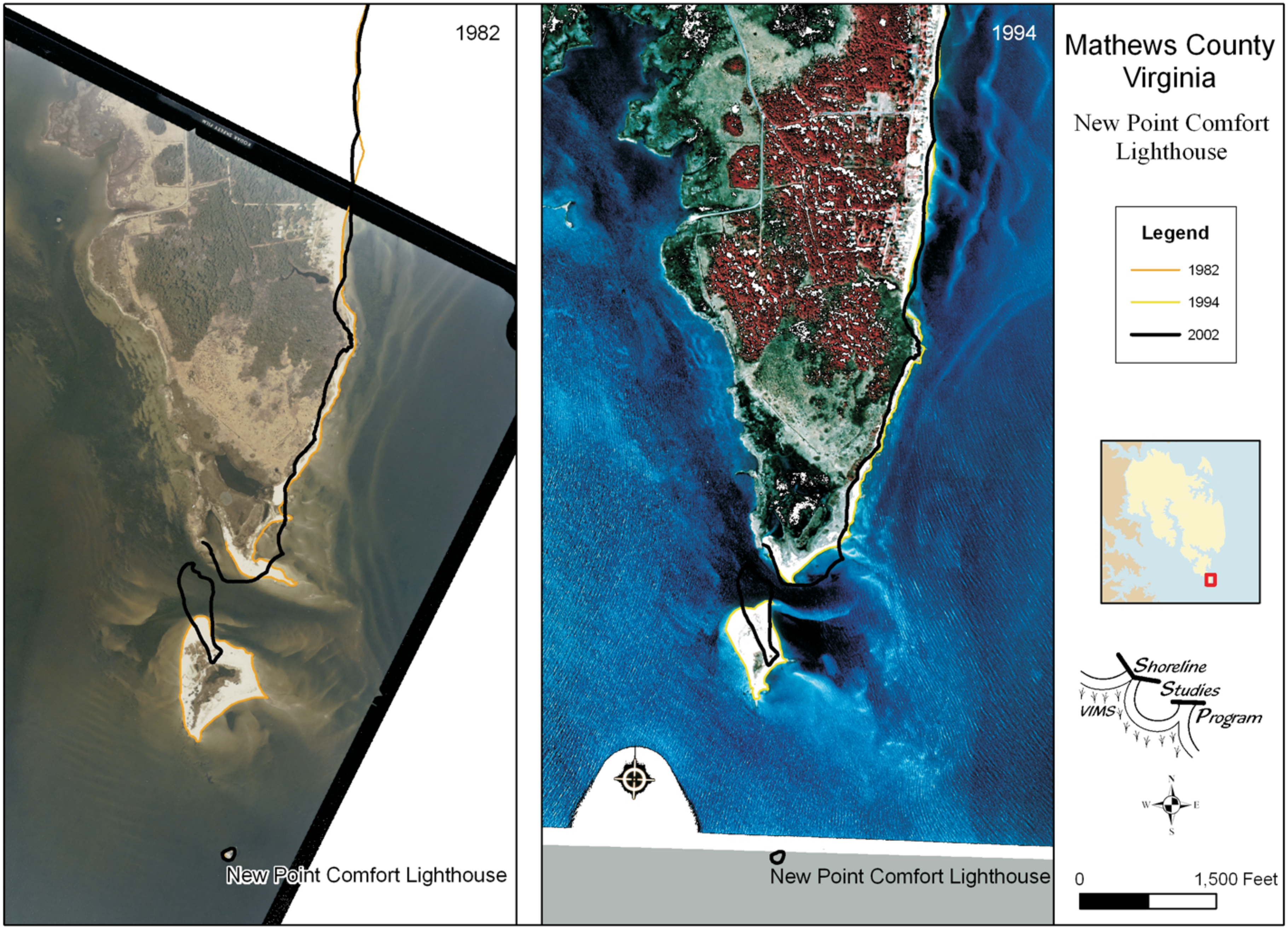


Figure 6. Orthorectified 1982 and 1994 aerial photos showing the location of New Point Comfort Lighthouse and the 2002 digitized shoreline.

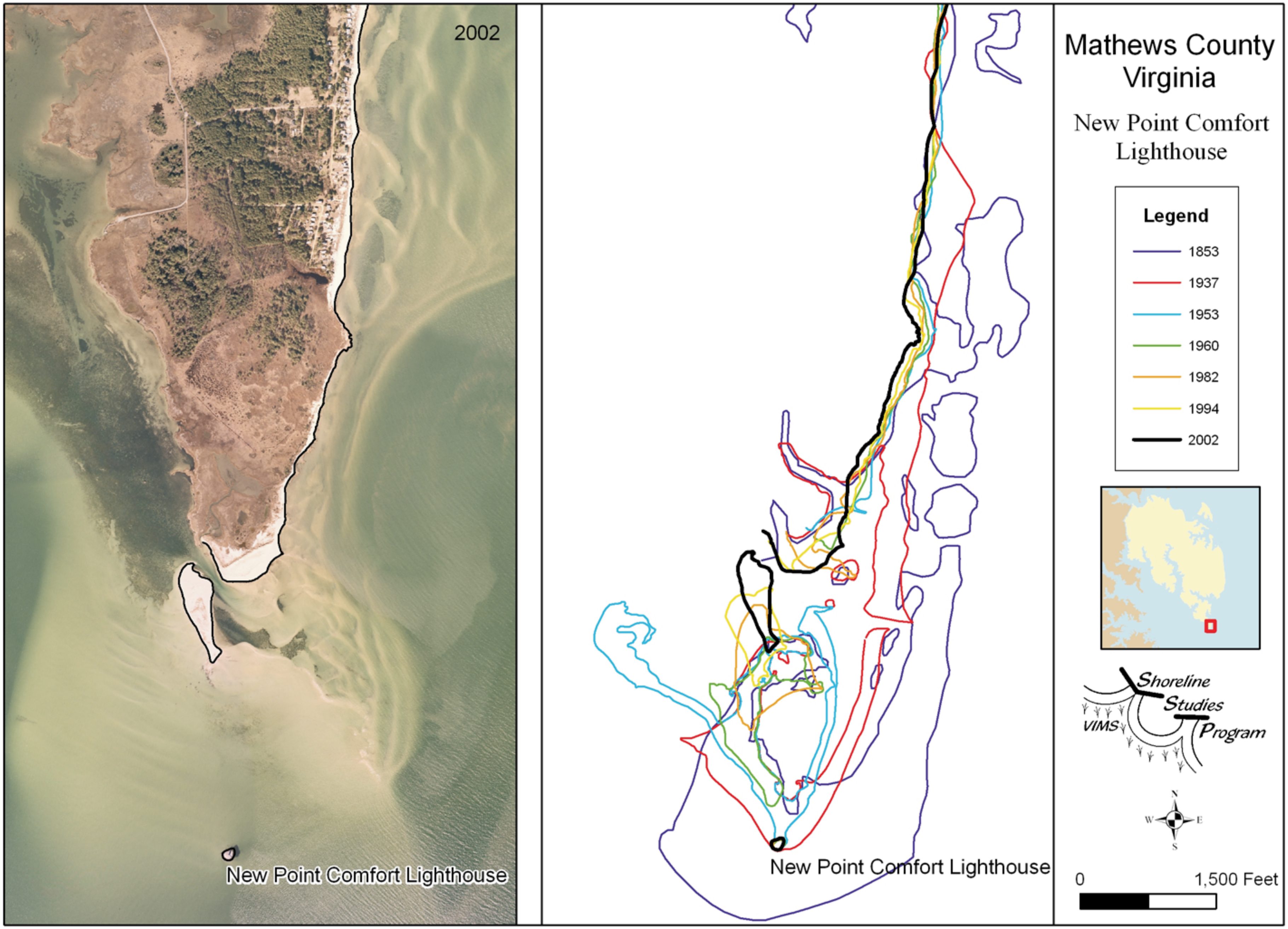


Figure 7. Orthorectified 2002 aerial photo showing the location of New Point Comfort Lighthouse and the shoreline change that has occurred its vicinity since 1853.

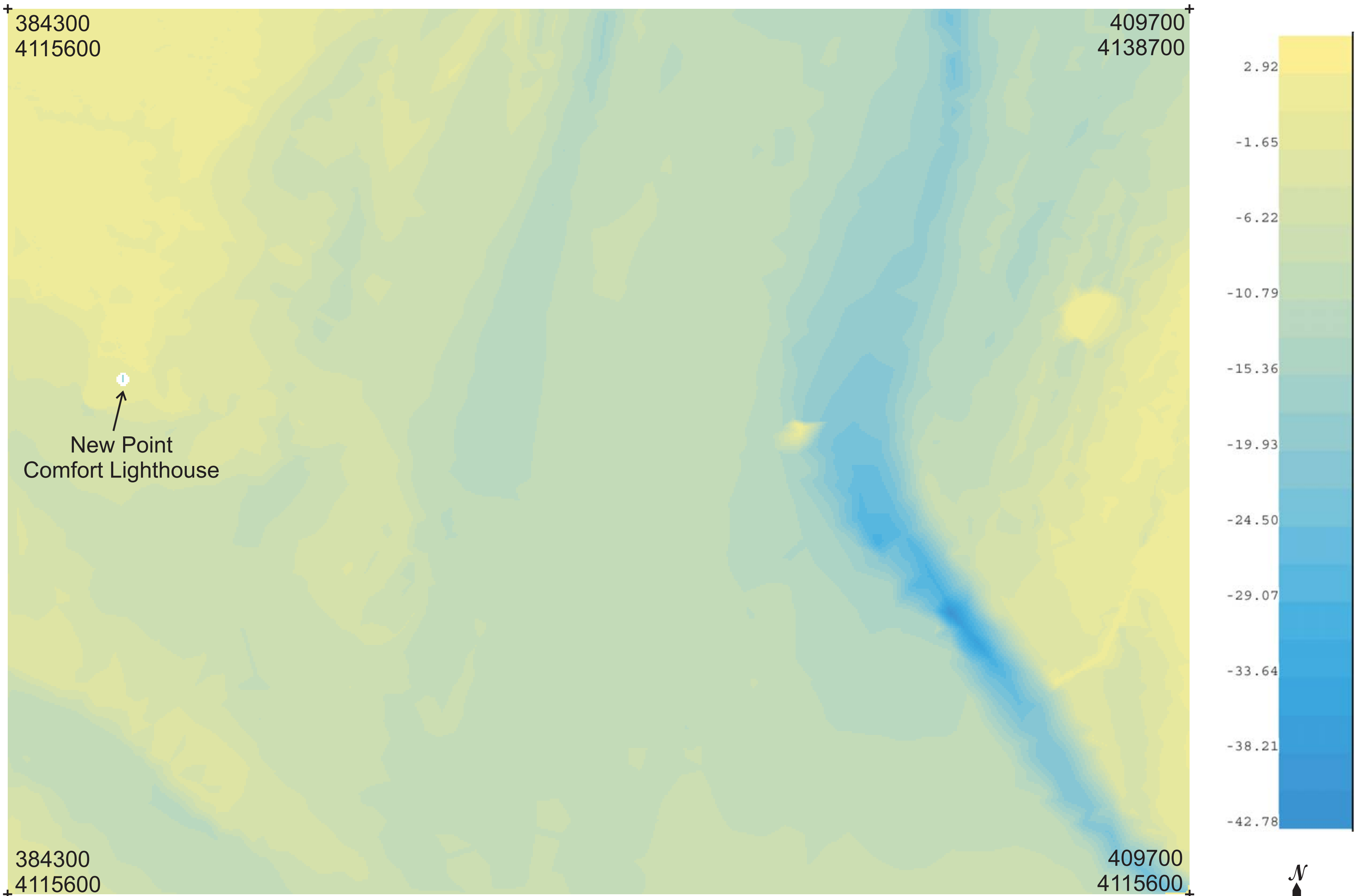


Figure 8. Bathymetric grid of the lighthouse area and the lower Chesapeake Bay in general used in the hydrodynamic modeling. Grid is in UTM Zone 18, NAD83, meters.

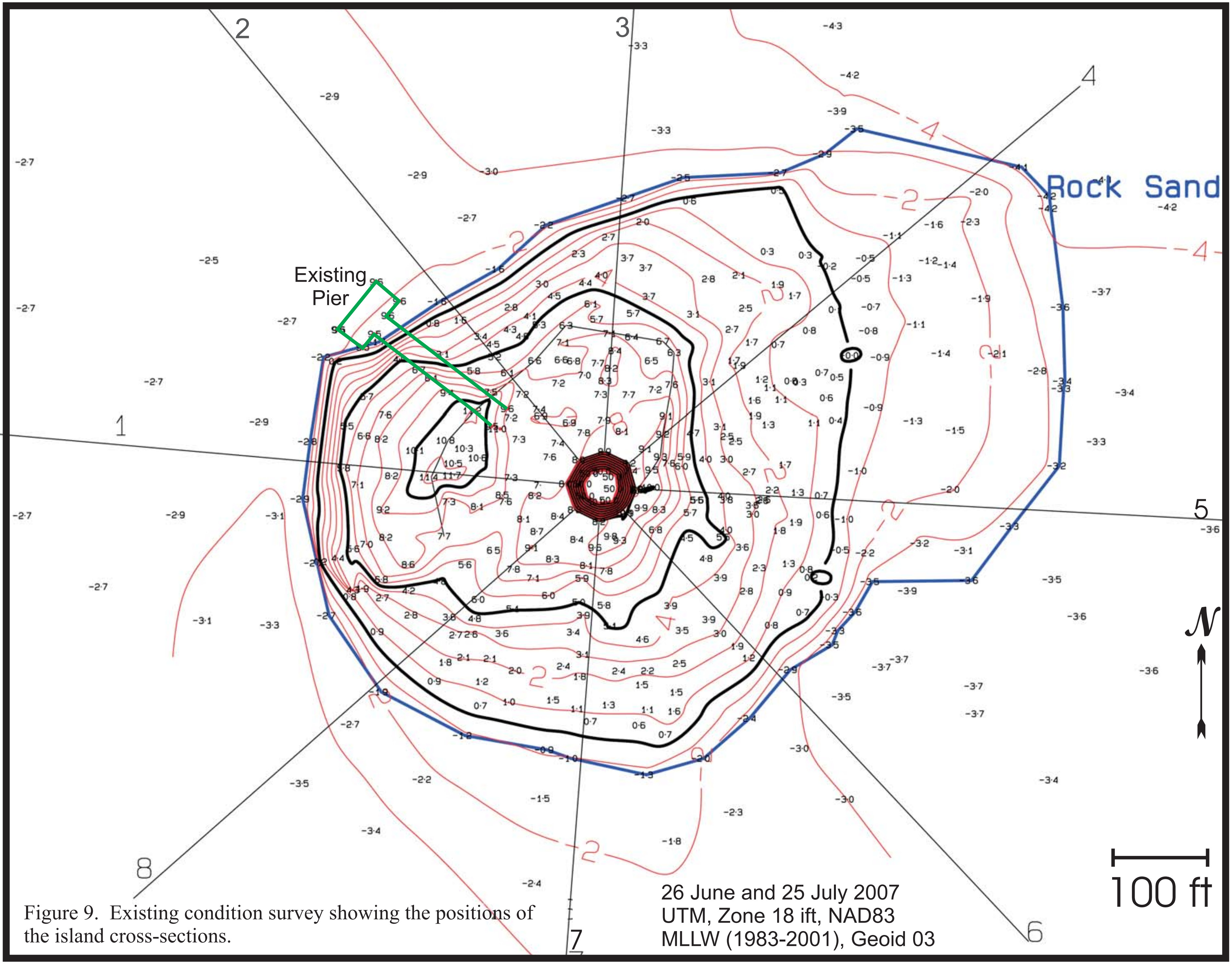


Figure 9. Existing condition survey showing the positions of the island cross-sections.

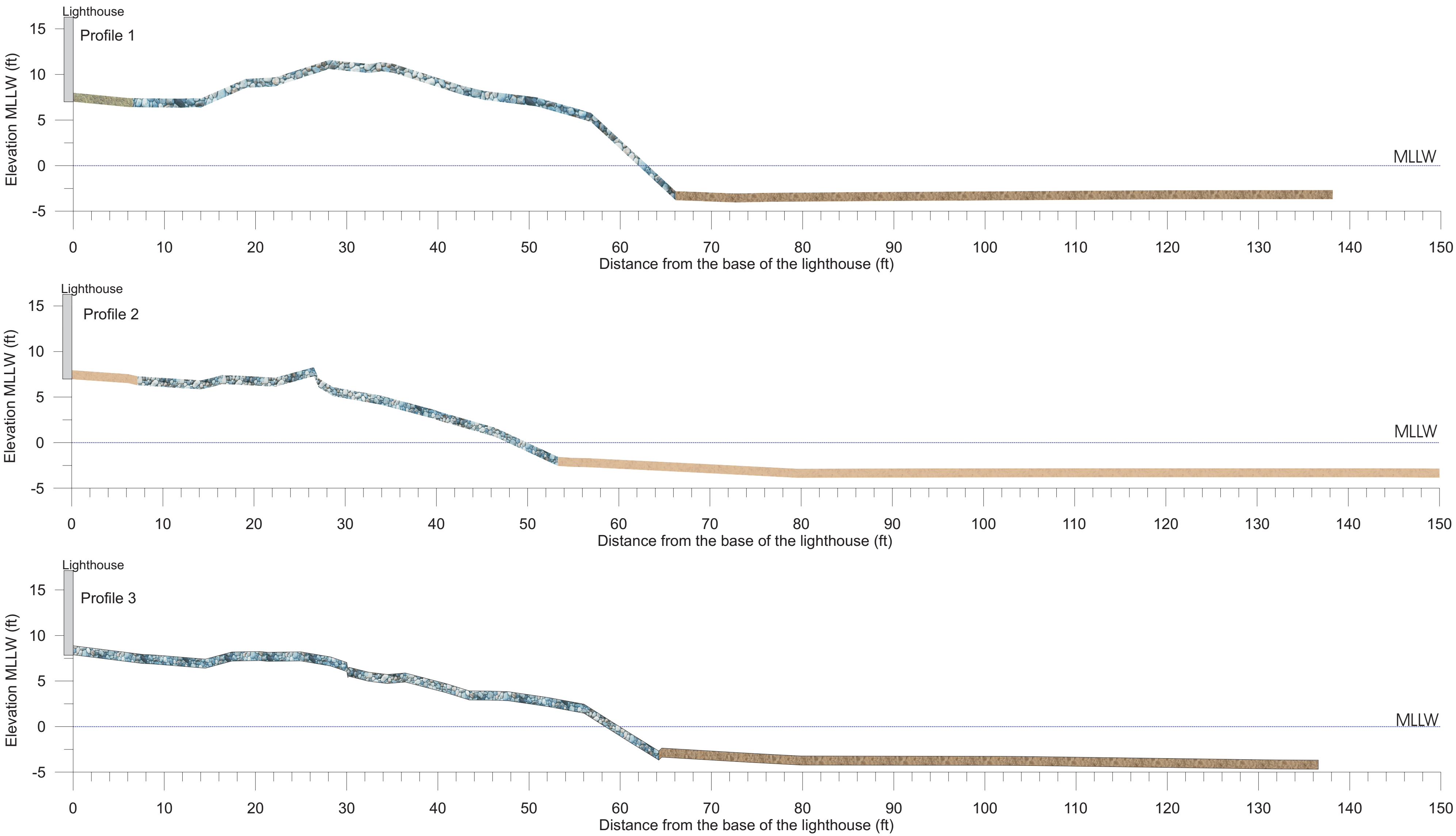


Figure 10. Cross-sections 1 through 3 of the island using the survey data taken in the summer of 2007. The extent of the rock is shown on the profile. Cross-section location is shown on Figure 9.

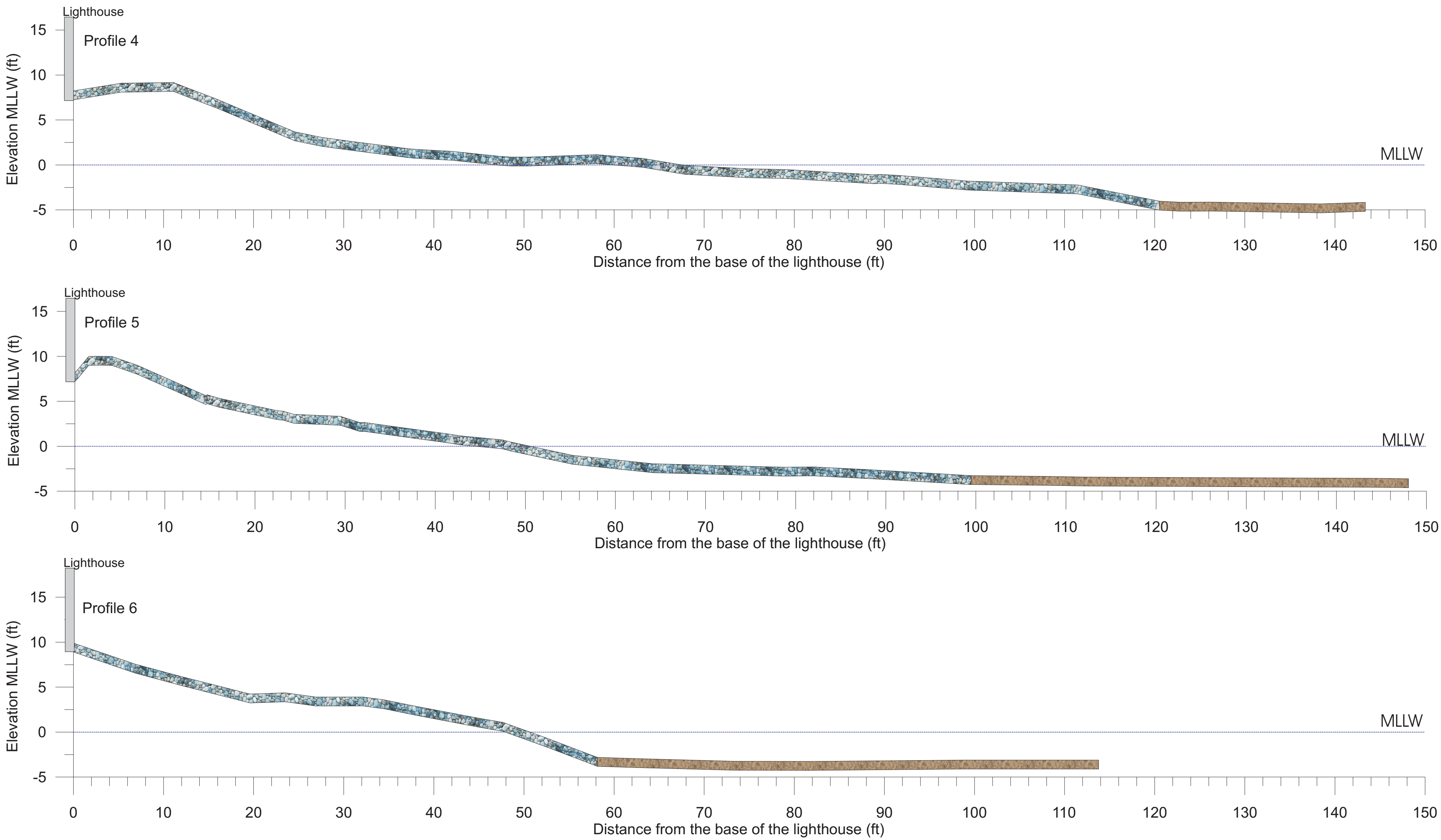


Figure 11. Cross-sections 4 through 6 of the island using the survey data taken in the summer of 2007. The extent of the rock is shown on the profile. Cross-section location is shown on Figure 9.

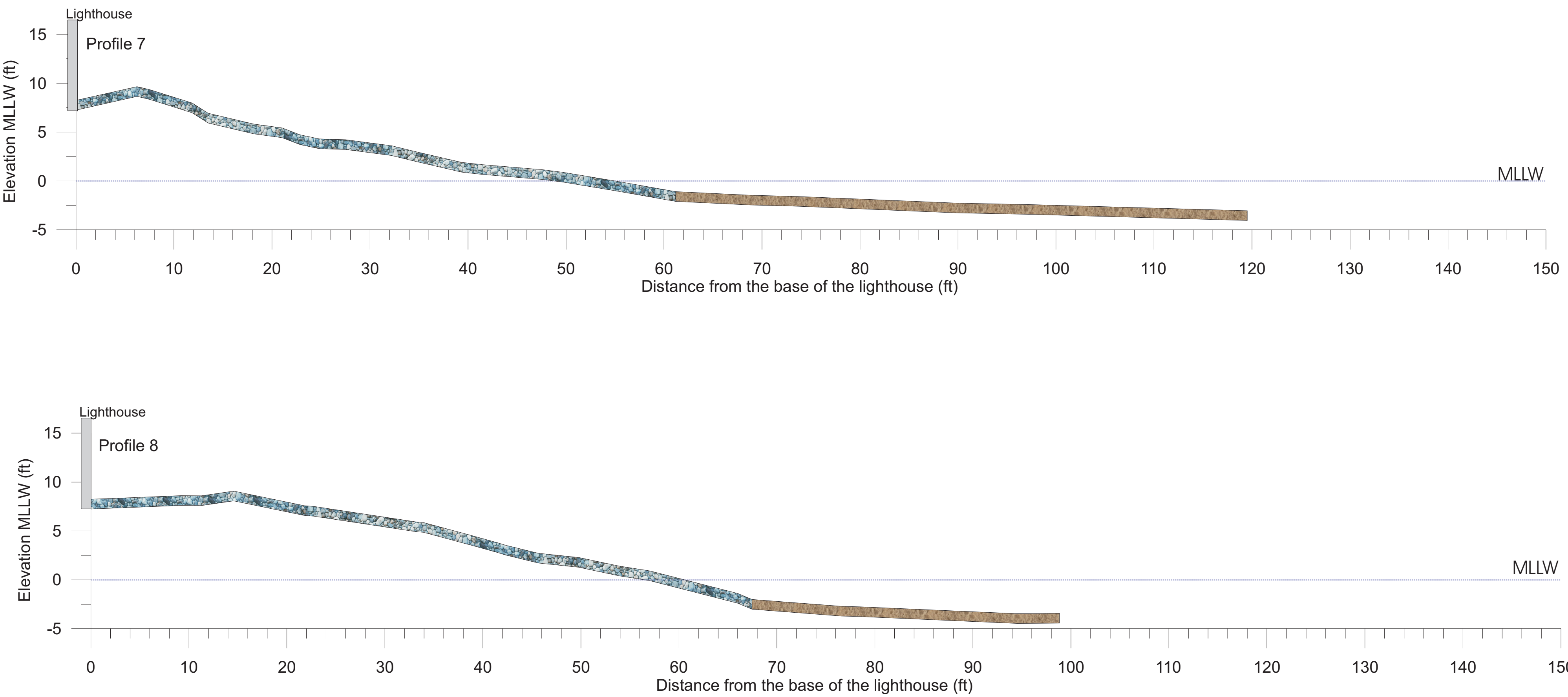


Figure 12. Cross-sections 7 and 8 of the island using the survey data taken in the summer of 2007. The extent of the rock is shown on the profile. Cross-section location is shown on Figure 9.

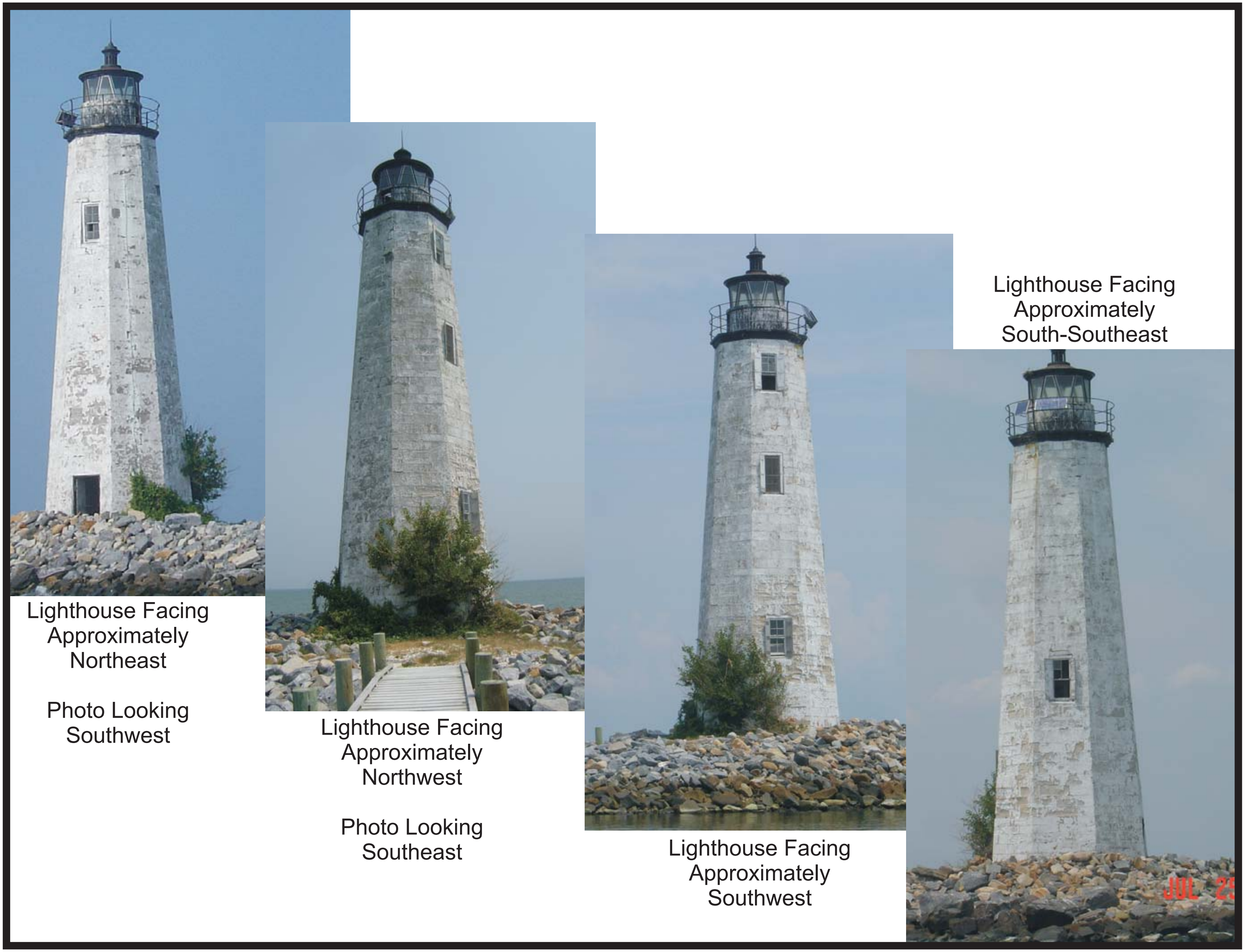


Figure 13. Photos of the lighthouse from all sides. The photo in the upper left is dated 26 June 2007. The others were taken on 25 July 2007.

Figure 14. The door to the lighthouse is open exposing the interior to the elements and wildlife.

Figure 15. Photos depicting the present state of the interior of the lighthouse. The sandstone steps are exposed to the elements and eroding. The upper level platform is only being held up by a 2x4.

Figure 16. Damage to the structure is occurring due to the elements. Peeling and chipping paint, vegetation, and broken windows is exposing the soft sandstone structure and damaging the mortar joints.

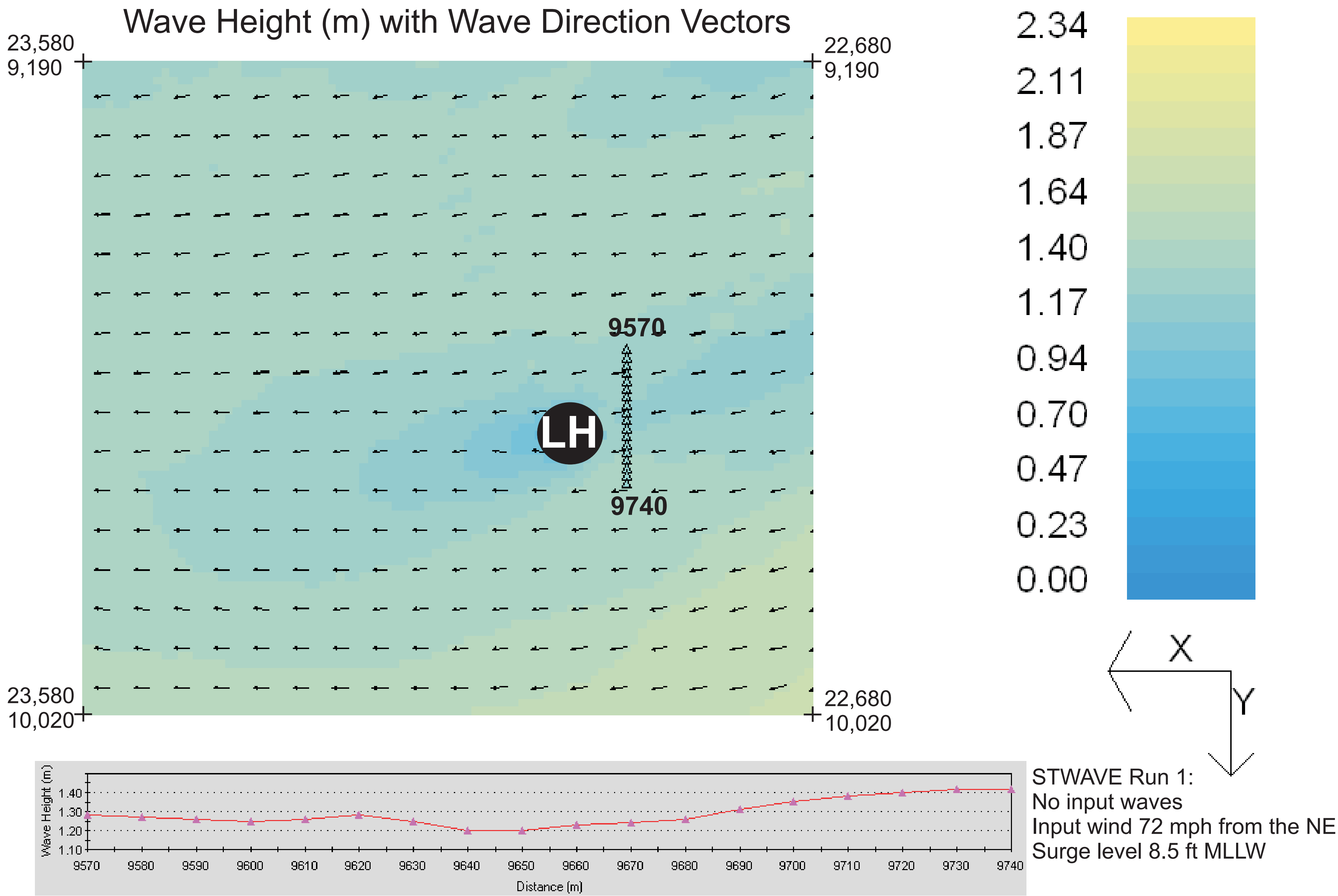


Figure 17. Results from STWAVE model run 1. Lighthouse position is approximate.

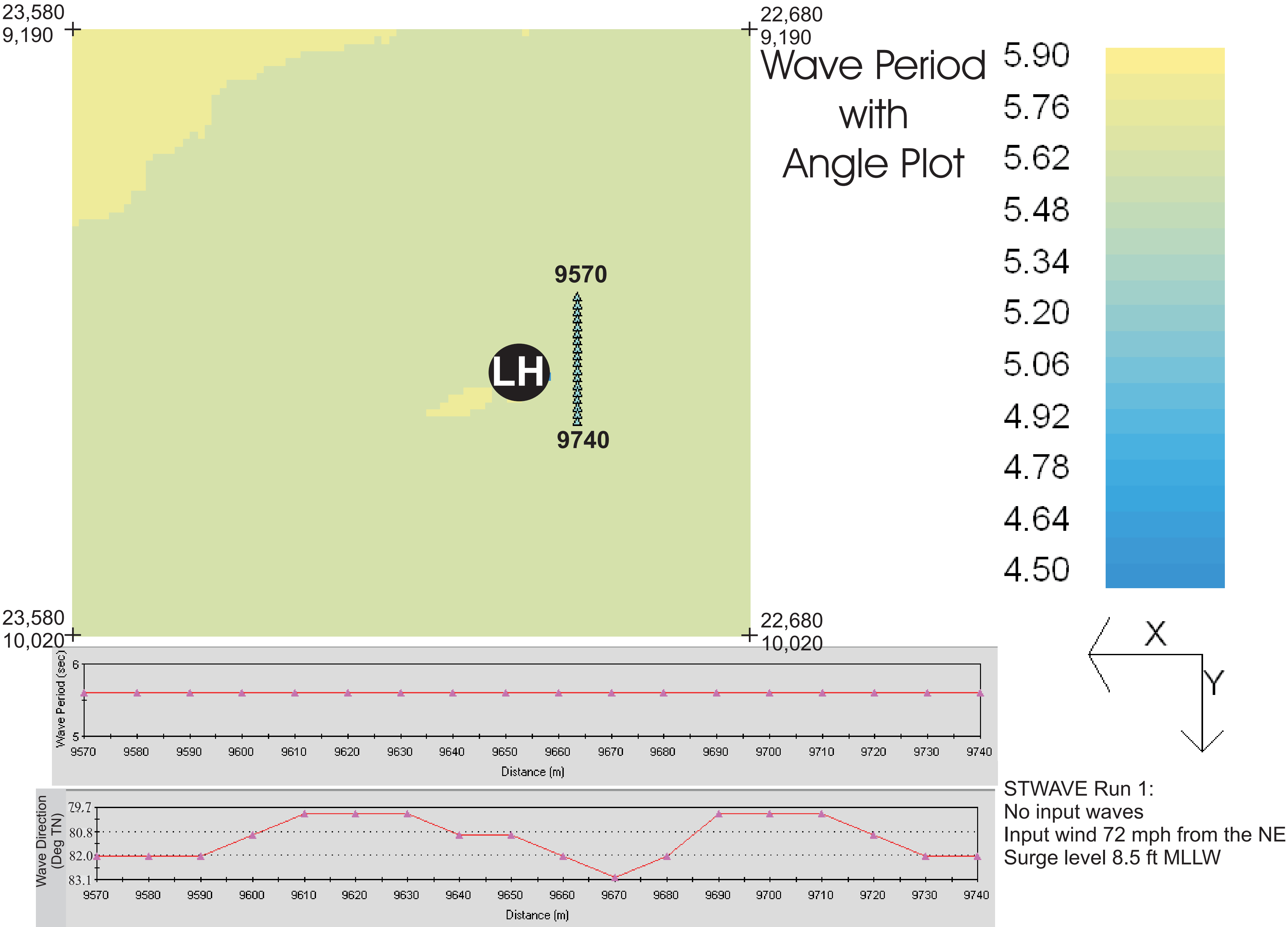


Figure 18. Results from STWAVE model run 1. Lighthouse position is approximate.

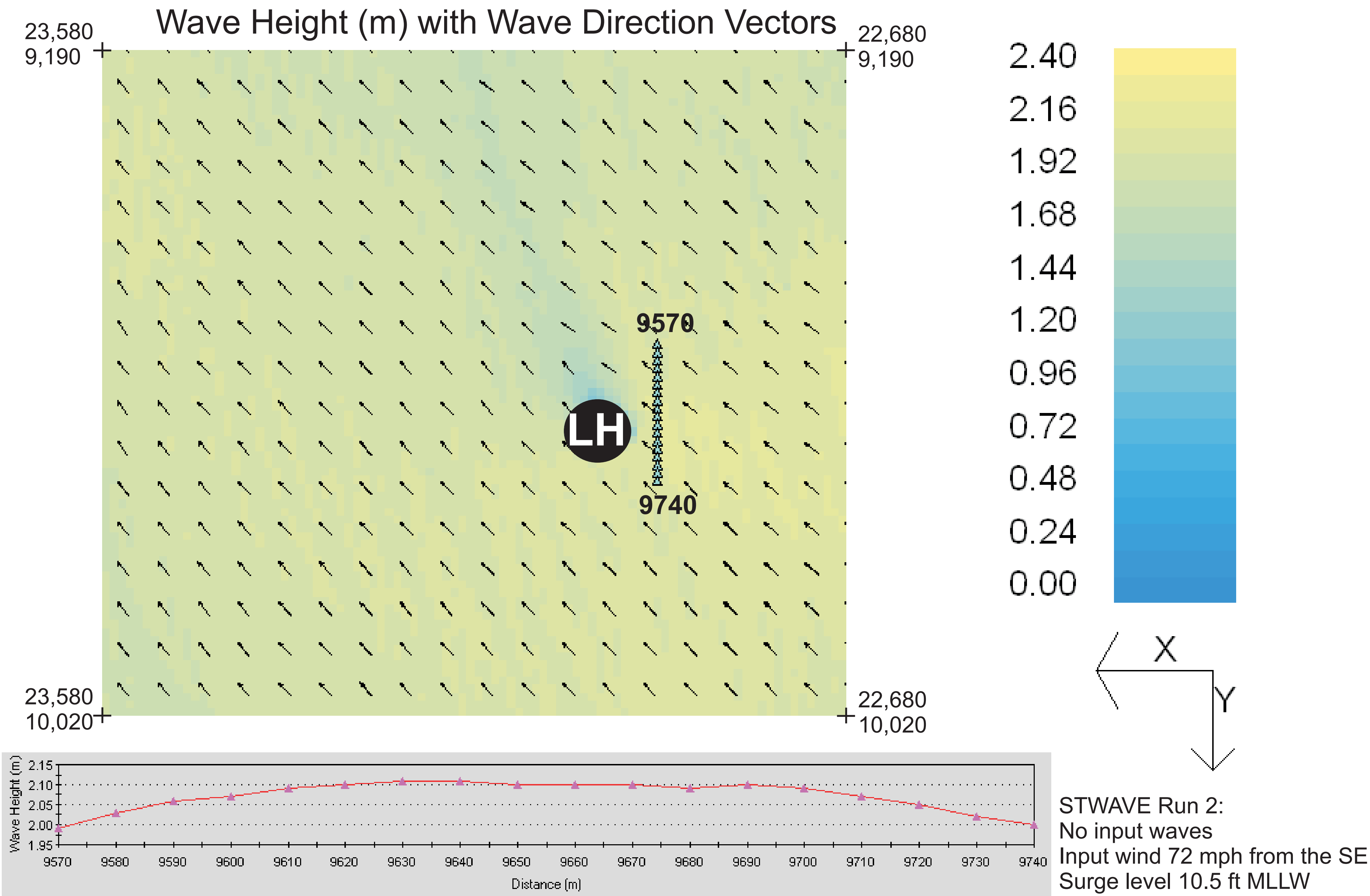


Figure 19. Results from STWAVE model run 2. Lighthouse position is approximate.

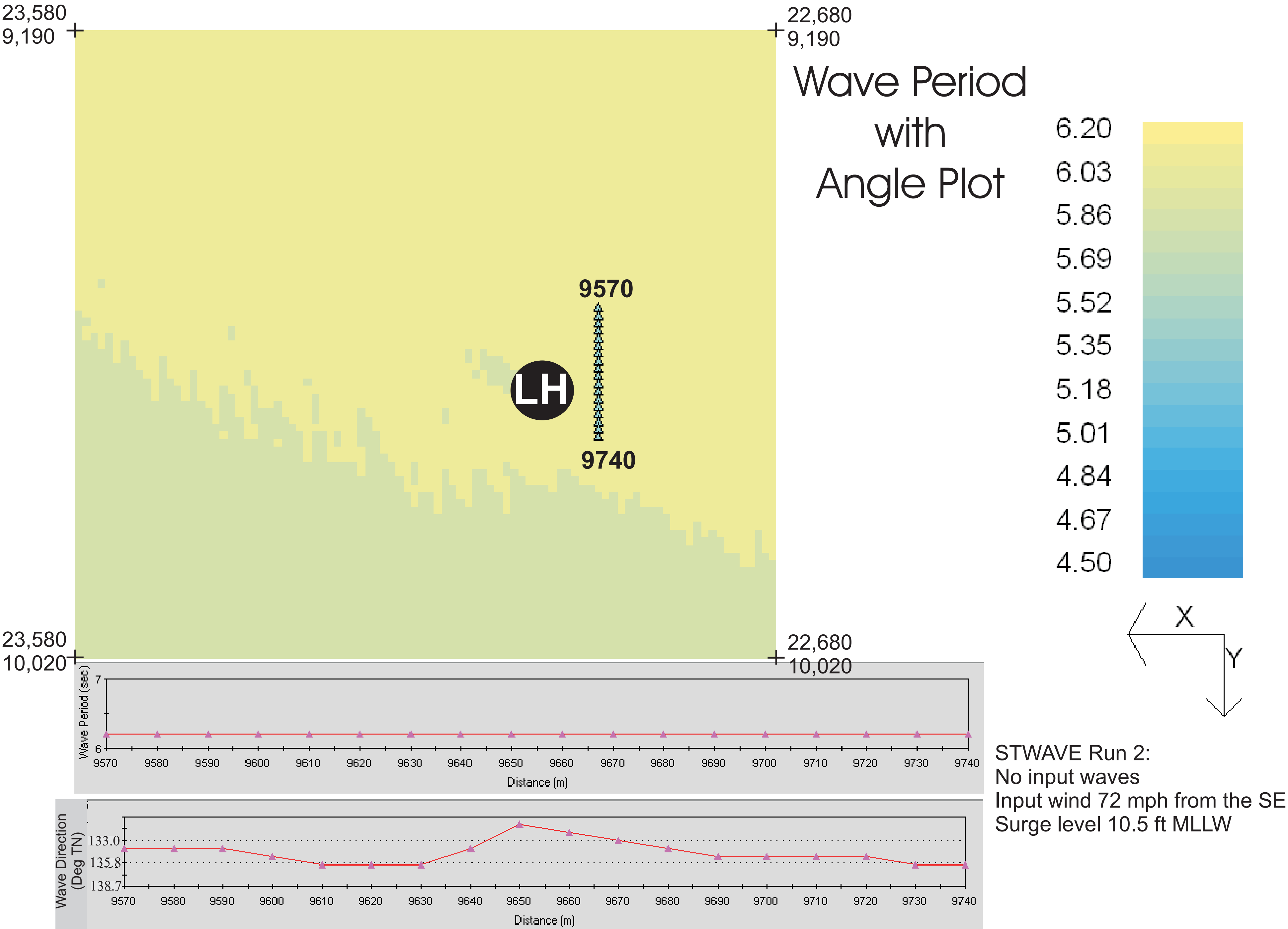


 Figure 20. Results from STWAVE model run 2. Lighthouse position is approximate.

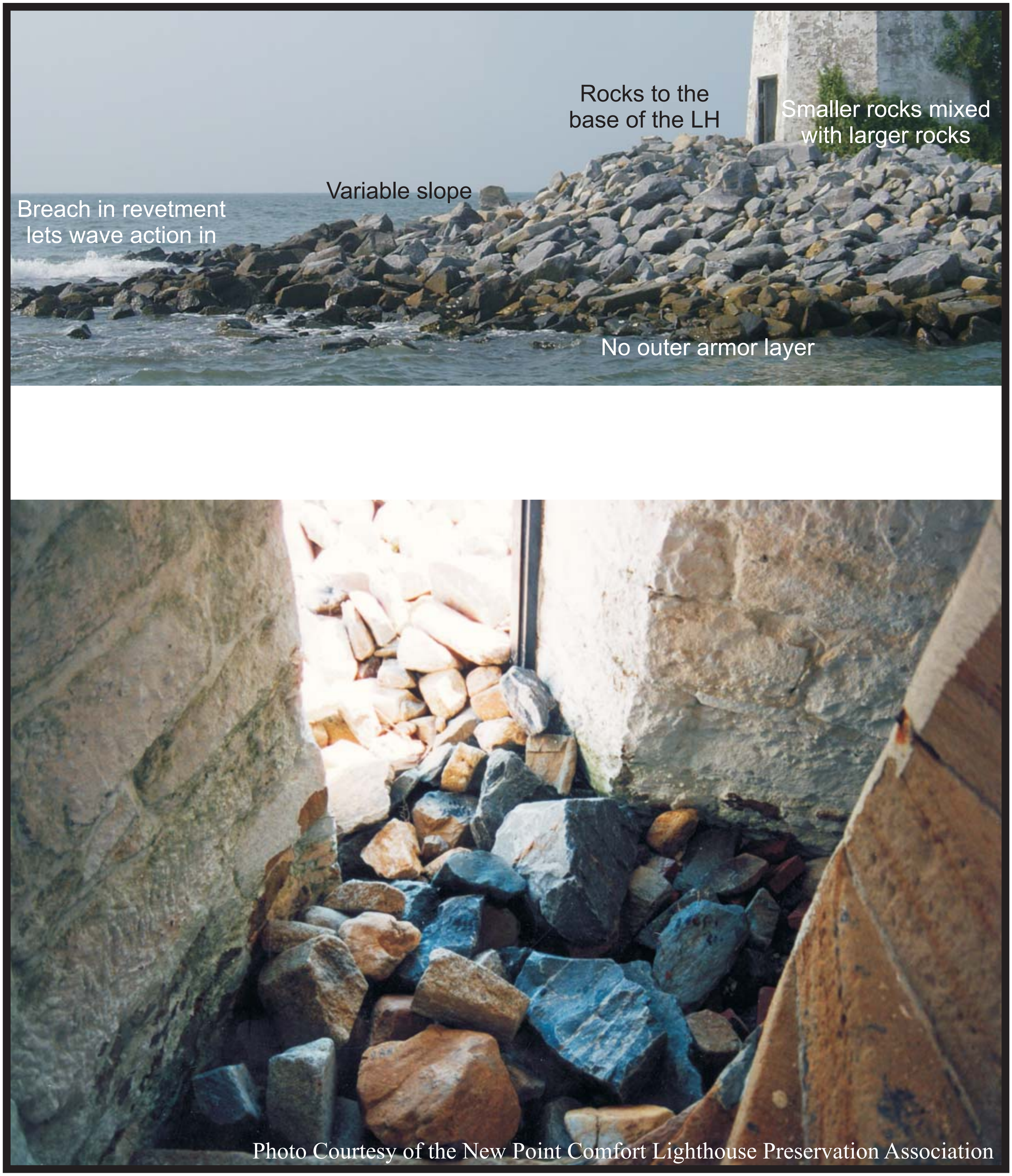


Figure 21. Photo illustrating the present rock revetment's deficiency's and a photo showing how many of the smaller rocks on the island were pushed into the lighthouse during Hurricane Isabel (18 Sep 2003).

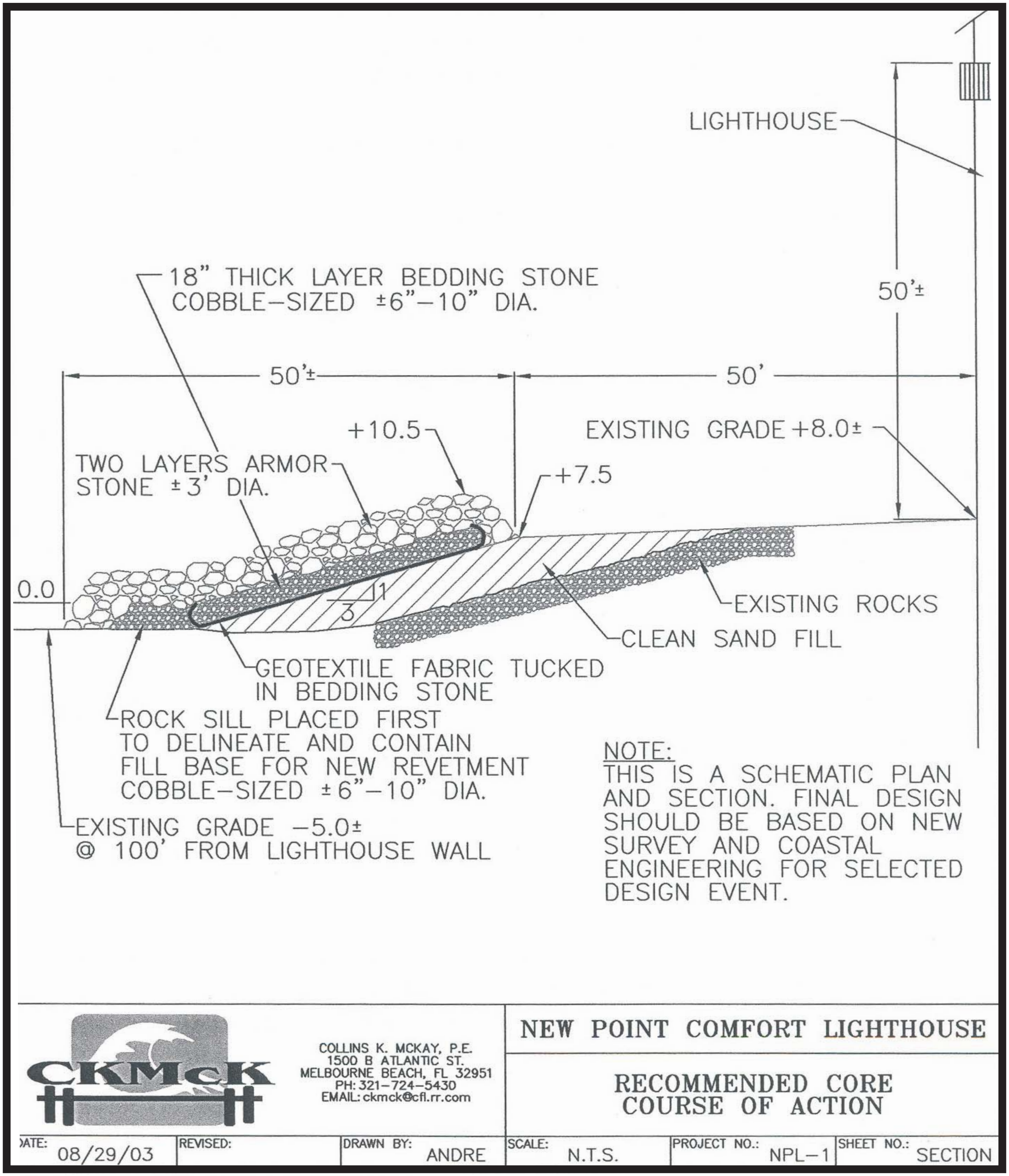


Figure 22. Typical cross-section of the core course of action recommended by McKay (2003).

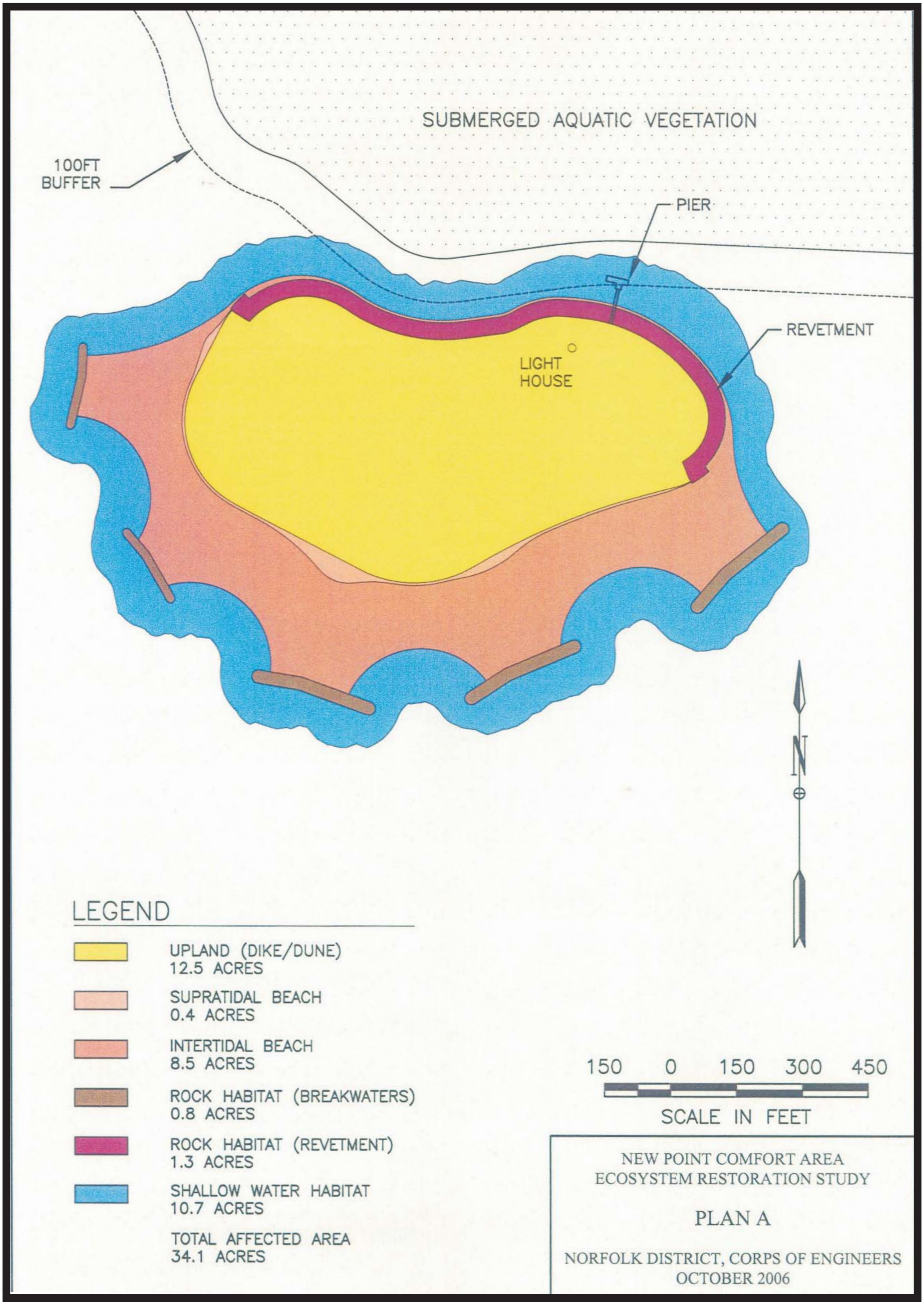


Figure 23. One of the three most cost-effective plans included in the Corps (2007) ecosystem restoration study.

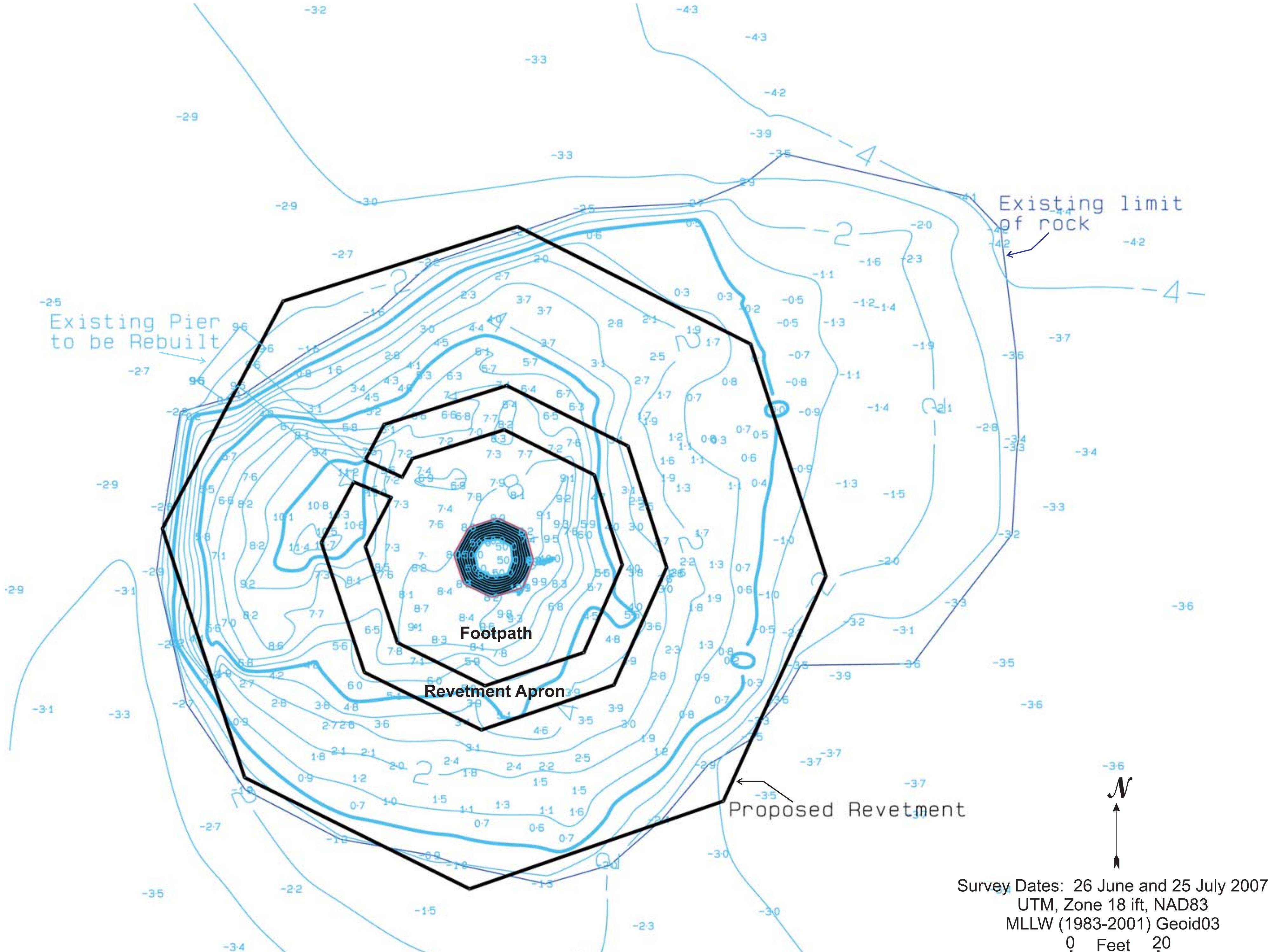


Figure 24. Existing conditions survey with the proposed revetment.

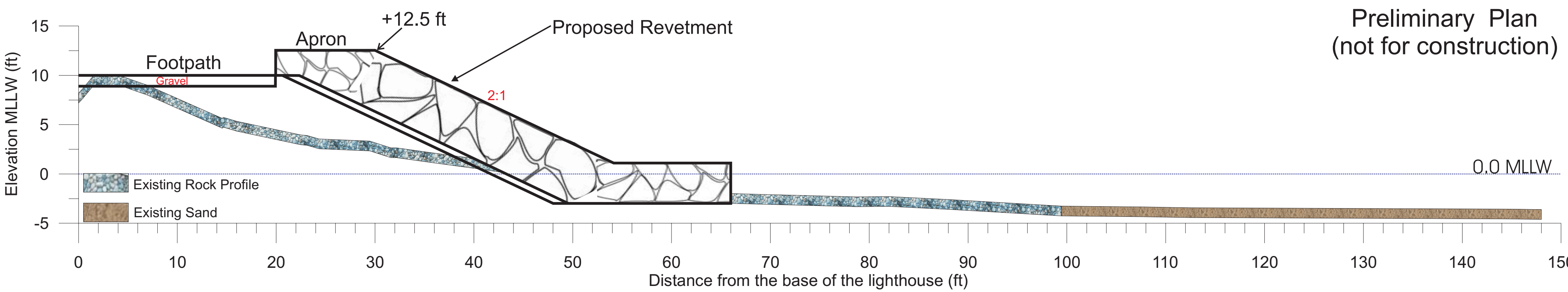


Figure 25. Typical cross-section with existing conditions and proposed revetment.

Appendix A

Boring Logs

from

Schnabel Engineering South, LLC
Offshore SPT Drilling
New Point Comfort Lighthouse
Mathews County, Virginia
Project 04131286
April 6, 2005

BORING COORDINATES

	PLANNED LOCATIONS		GPS LOCATIONS		OFFSETS		
BORING	NORTH	EAST	NORTH	EAST	NORTH	EAST	DISTANCE
WB1	3641011.4	12129474.4	3641009.5	12129497.5	1.8	-23.1	23.2
WB2	3640834.2	12128950.7	3640891.2	12129114.9	-57.0	-164.3	173.9
WB3	3640776.7	12129339.3	3640756.1	12129381.7	20.7	-42.4	47.2
WB4	3640529.2	12128932.7	3640644.2	12128993.9	-115.1	-61.2	130.3
WB5	3640555.0	12129445.5	3640574.9	12129359.1	-19.9	86.4	88.6

SCHNABEL ENGINEERING SOUTH, LLC

GENERAL NOTES FOR SUBSURFACE EXPLORATION LOGS

1. Numbers in sampling data column next to Standard Penetration Test (SPT) symbols indicate blows required to drive a 2 inch O.D., 1-3/8 inch I.D. sampling spoon 6 inches using a 140 pound hammer falling 30 inches. The Standard Penetration Test (SPT) N value is the number of blows required to drive the sampler 12 inches, after a 6 inch seating interval. The Standard Penetration Test is performed in accordance with ASTM-1586.

2. Visual classification of soil is in accordance with terminology set forth in "Identification of Soil." The ASTM D-2487 group symbols (e.g. CL) shown in the classification column are based on visual observations.

3. Estimated ground water levels indicated by ▼; these levels are only estimates from available data and may vary with precipitation, porosity of the soil, site topography, etc.

4. Refusal at the surface of rock, boulder, or obstruction is defined as an SPT resistance of 100 blows for 2 inches or less of penetration.

5. The logs and related information depict subsurface conditions only at the specific locations and at the particular time when drilled or excavated. Soil conditions at other locations may differ from conditions occurring at these locations. Also, the passage of time may result in a change in the subsurface soil and ground water conditions at the test boring, test pit and/or hand auger locations.

6. The stratification lines represent the approximate boundary between soil and rock types as obtained from the subsurface exploration. Some variation may also be expected vertically between samples taken. The soil profile, water level observations and penetration resistances presented on these logs have been made with reasonable care and accuracy and must be considered only an approximate representation of subsurface conditions to be encountered at the particular location.

7. Key to symbols and abbreviations:

5+10+1	- Standard Penetration Test
24/18	- Length Pushed/Recovery (in inches)
3T	- 2" or 3" Undisturbed Tube Sample
	Rock Core Sample
NX	- Core Diameter Size
REC	- Recovery %
RQD	- RQD%
W	- Water Content
do	- Ditto
WOW	- Water Observation Well
PP	- Pocket Penetrometer Reading (tsf)
FID	- Flame Ionization Detector Reading (ppm)
PID	- Photoionization Detector Reading (ppm)
GP	- Geostick Penetration Reading (inches)
LL	- Liquid Limit
PL	- Plastic Limit
TPH	- Total Petroleum Hydrocarbons

SCHNABEL ENGINEERING SOUTH, LLC
Consulting Geotechnical Engineers
IDENTIFICATION OF SOILS

I. DEFINITION OF SOIL GROUP NAMES (ASTM D-2487-83)

			SYMBOL	GROUP NAME
Coarse-Grained Soils More than 50% retained on No. 200 sieve	Gravels – More than 50% of coarse fraction retained on No. 4 sieve Coarse, ¾" to 3" Fine, No. 4 to ¾"	Clean Gravels Less than 5% fines	GW	Well graded gravel
			GP	Poorly graded gravel
		Gravels with fines More than 12% fines	GM	Silty gravel
			GC	Clayey gravel
	Sands – 50% or more of coarse Fraction passes No. 4 sieve Coarse, No. 40 to No. 4 Medium, No. 40 to No. 10 Fine, No. 200 to No. 40	Clean Sands Less than 5% fines	SW	Well-graded sand
			SP	Poorly graded sand
		Sands with fines More than 12% fines	SM	Silty sand
			SC	Clayey sand
Fine-Grained Soils 50% or more passes the No. 200 sieve	Silts and Clays – Liquid Limit less than 50 Low to medium plasticity	Inorganic	CL	Lean clay
			ML	Silt
		Organic	OL	Organic clay
				Organic silt
	Silts and Clays – Liquid Limit 50 or more Medium to high plasticity	Inorganic	CH	Fat clay
			MH	Elastic silt
		Organic	OH	Organic clay
				Organic silt
Highly Organic Soils	Primarily organic matter, dark in color and organic odor		PT	Peat

II. DEFINITION OF MINOR SOIL COMPONENT PROPORTIONS

			Examples
Adjective Form	Gravelly Sandy	30% or more coarse grained	Gravelly lean clay
"With"	With gravel With sand	15% or more coarse grained	Fat clay with gravel
	With silt With clay	5% to 12% fine grained	Poorly graded sand with silt
"Trace"	Trace gravel Trace sand	1% to 15% coarse grained	Silty sand, trace gravel
	Trace clay Trace silt	1% to 5% fine grained	Poorly graded sand, trace clay

III. GLOSSARY OF MISCELLANEOUS TERMS

SYMBOLS .... Unified Soil Classification Symbols are shown above as group symbols. Dual symbols are used for borderline classifications.

BOULDERS & COBBLES .... Boulders are considered rounded pieces of rock larger than 12 inches, while cobbles range from 3 to 12 inch size.

DISINTEGRATED ROCK .... Residual rock materials with a standard penetration resistance (SPT) between 60 blows per foot and refusal. Refusal is defined as a SPT of 100 blows for 2" or less penetration.

ROCK FRAGMENTS .... Angular pieces of rock, distinguished from transported gravel, which have separated from original vein or strata and are present in a soil matrix.

QUARTZ .... A hard silica mineral often found in residual soils.

IRONITE .... Iron oxide deposited within a soil layer forming cemented deposits.

CEMENTED SAND .... Usually localized rock-like deposits within a soil stratum composed of sand grains cemented by calcium carbonate or other materials.

MICA .... A soft plate of silica mineral found in many rocks, and in residual or transported soil derived therefrom.

ORGANIC MATERIALS .... (Excluding Peat)
- Topsoil .... Surface soils that support plant life and which contain considerable amounts of organic matter;
- Organic Matter .... Soil containing organic colloids throughout its structure;
- Lignite .... Hard, brittle decomposed organic matter with low fixed carbon content (a low grade of coal).

FILL .... Man-made deposit containing soil, rock and often foreign matter.

PROBABLE FILL .... Soils which contain no visually detected foreign matter but which are suspect with regard to origin.

LENSES .... 0 to ½ inch seam of minor soil component.

LAYERS .... ½ to 12 inch seam of minor soil component.

POCKET .... Discontinuous body of minor soil component.

COLOR SHADES .... Light to dark to indicate substantial difference in color.

MOISTURE CONDITIONS .... Wet, moist or dry to indicate visual appearance of specimen.

Schnabel Engineering South, LLC	TEST BORING LOG	Project: New Point Comfort Lighthouse, Matthews County, Virginia	Boring Number: **WB-1** Contract Number: 04131286 Sheet: 1 of 1

Boring Contractor: Fishburne Drilling, Inc.
Chesapeake, Virginia

Boring Foreman: M. Young

Drilling Method: 3-1/4" Mud Rotary

Drilling Equipment: CME-45C (Automatic Hammer)

SEA Representative: S. Price

Dates Started: 3/22/05 **Finished:** 3/22/05

Location: See Location Plan, Figure A1

Mudline Elevation: **-4.0± (feet)**

Water Depth Observations

	Date	Time	Depth	Casing	Caved
Completion	3/22	1:10	3.0'	---	---

DEPTH (ft)	STRATA DESCRIPTION	CLASS.	ELEV. (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	Fine to medium poorly gaded sand, trace silt, moist - gray	SP		B1		4+5+13+4 SPT	W=23.1%	TABB FORMATION
4.0	Fine to coarse silty sand, contains shell fragments, moist - brown	SM	-8.0	C1	5	WOH/6"+1+1 +1 SPT		YORKTOWN FORMATION
					10	4+13+10+15 SPT		
14.0	Fat clay with sand, contains shell fragments, wet - brown	CH	-18.0	C2	15	2+3+3+4 SPT	PP=1.0tsf	
	do, dark gray				20	2+3+3+4 SPT	PP=1.0tsf W=35.3%	
					25	2+3+4+4 SPT	PP=1.0tsf	
29.0	Fine to coarse clayey sand, contains shell fragments, wet - dark gray	SC	-33.0	C1	30	5+5+6+14 SPT		
32.0	Boring Terminated at 32.0 ft		-36.0					

Comments:
1. Elevations referenced to estimated mean sea level.
2. Depths referenced to mudine.

TEST BORING LOG 04131286 (RICHMOND).GPJ SCHNABEL.GDT 4/6/05

Schnabel
Schnabel Engineering South, LLC

TEST BORING LOG

Project: New Point Comfort Lighthouse
Matthews County
Virginia

Boring Number: WB-2
Contract Number: 04131286

Boring Contractor: Fishburne Drilling, Inc.
Chesapeake, Virginia
Boring Foreman: M. Young
Drilling Method: 3-1/4" Mud Rotary
Drilling Equipment: CME-45C (Automatic Hammer)
SEA Representative: S. Price
Dates Started: 3/22/05 **Finished:** 3/22/05
Location: See Location Plan, Figure A1

Mudline Elevation: -2.1± (feet)

Water Depth Observations

	Date	Time	Depth	Casing	Caved
Completion	3/22	8:45	4.0'	---	---

DEPTH (ft)	STRATA DESCRIPTION	CLASS.	ELEV. (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	Fine to coarse poorly graded sand, trace silt, contains organic matter, wet - dark tan and dark gray	SP		B1		2+10+7+5 SPT		TABB FORMATION
4.0	Fine to medium poorly graded sand with silt, contains mica, wet - dark brown	SP-SM	-6.1		5	3+3+4+4 SPT	W=30.5%	
9.0	Fine clayey sand, contains shell fragments and organic matter, wet - dark gray	SC	-11.1		10	WOH/24" SPT		
14.0	Lean clay, trace sand, contains shell fragments, wet - gray	CL	-16.1	B2	15	1/12"+1/12" SPT	PP<0.25tsf W=70.0%	
19.0	Fine to medium clayey sand, contains shell fragments, wet - dark gray	SC	-21.1	B1	20	WOH/24" SPT		
	do, fine to coarse, contains organic matter, black				25	1+2+2+1 SPT		
29.0	Fine to coarse silty sand, contains shell fragments, wet - brown	SM	-31.1	C1	30	8+10+8+8 SPT		YORKTOWN FORMATION
34.0		SC	-36.1		35			

continued on next page

Comments:
1. Elevations referenced to estimated mean sea level.
2. Depths referenced to mudine.

Schnabel Engineering South, LLC

TEST BORING LOG

Project: New Point Comfort Lighthouse
Matthews County
Virginia

Boring Number: WB-2
Contract Number: 04131286
Sheet: 2 of 2

DEPTH (ft)	STRATA DESCRIPTION	CLASS.	ELEV. (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	Fine to medium clayey sand, contains shell fragments, wet - brown *(continued)*	SC		C1		14+10+10+17 SPT		YORKTOWN FORMATION
37.0	Boring Terminated at 37.0 ft		-39.1					

Comments:
1. Elevations referenced to estimated mean sea level.
2. Depths referenced to mudine.

TEST BORING LOG 04131286 (RICHMOND).GPJ SCHNABEL.GDT 4/6/05

Schnabel Schnabel Engineering South, LLC

TEST BORING LOG

Project: New Point Comfort Lighthouse
Matthews County
Virginia

Boring Number: WB-3
Contract Number: 04131286
Sheet: 1 of 1

Boring Contractor: Fishburne Drilling, Inc.
Chesapeake, Virginia

Boring Foreman: M. Young

Drilling Method: 3-1/4" Mud Rotary

Drilling Equipment: CME-45C (Automatic Hammer)

SEA Representative: S. Price

Dates Started: 3/22/05 **Finished:** 3/22/05

Location: See Location Plan, Figure A1

Mudline Elevation: -3.9± (feet)

Water Depth Observations

	Date	Time	Depth	Casing	Caved
Completion	3/22	12:30	3.0'	---	---

DEPTH (ft)	STRATA DESCRIPTION	CLASS.	ELEV. (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	Fine to coarse poorly graded sand, trace silt, wet - gray	SP		B1		7+17+8+8 SPT		TABB FORMATION
4.0	Fine to coarse silty sand, wet - dark brown	SM	-7.9		5	WOH/6"+1+1+1 SPT		
9.0	Fine to medium silty sand, contains shell fragments, wet - brown	SM	-12.9	C1	10	6+10+10+12 SPT	W=28.7%	YORKTOWN FORMATION
					15	10+17+23+26 SPT		
17.0	Boring Terminated at 17.0 ft		-20.9					

Comments:
1. Elevations referenced to estimated mean sea level.
2. Depths referenced to mudine.

TEST BORING LOG 04131286 (RICHMOND).GPJ SCHNABEL.GDT 4/6/05

Schnabel Engineering South, LLC — TEST BORING LOG	Project: New Point Comfort Lighthouse Matthews County Virginia	Boring Number: WB-4 Contract Number: 04131286 Sheet: 1 of 1

Boring Contractor: Fishburne Drilling, Inc.
Chesapeake, Virginia

Boring Foreman: M. Young

Drilling Method: 3-1/4" Mud Rotary

Drilling Equipment: CME-45C (Automatic Hammer)

SEA Representative: S. Price

Dates Started: 3/22/05 **Finished:** 3/22/05

Location: See Location Plan, Figure A1

Mudline Elevation: -4.3± (feet)

Water Depth Observations

	Date	Time	Depth	Casing	Caved
Completion	3/22	9:40	3.0'	---	---

DEPTH (ft)	STRATA DESCRIPTION	CLASS.	ELEV. (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	Fine to medium poorly graded sand, trace silt, wet - dark tan	SP		B1		18+30+15+10 SPT	W=22.6%	
4.0	Fine to medium sandy lean clay, contains shell fragments, wet - green gray	CL	-8.3	B2	5	WOH/12"+5 +2 SPT	PP<0.5tsf W=29.4%	TABB FORMATION
9.0	Fine to coarse poorly graded sand with silt, contains shell fragments, moist - brown	SP-SM	-13.3	C1	10	8+6+5+4 SPT		YORKTOWN FORMATION
					15	4+4+6+8 SPT		
17.0	Boring Terminated at 17.0 ft		-21.3					

Comments:
1. Elevations referenced to estimated mean sea level.
2. Depths referenced to mudine.

Schnabel Schnabel Engineering South, LLC

TEST BORING LOG

Project:	New Point Comfort Lighthouse Matthews County Virginia
Boring Number:	WB-5
Contract Number:	04131286
Sheet:	1 of 1

Boring Contractor: Fishburne Drilling, Inc. Chesapeake, Virginia

Boring Foreman: M. Young

Drilling Method: 3-1/4" Mud Rotary

Drilling Equipment: CME-45C (Automatic Hammer)

SEA Representative: S. Price

Dates Started: 3/22/05 **Finished:** 3/22/05

Location: See Location Plan, Figure A1

Mudline Elevation: -3.6± (feet)

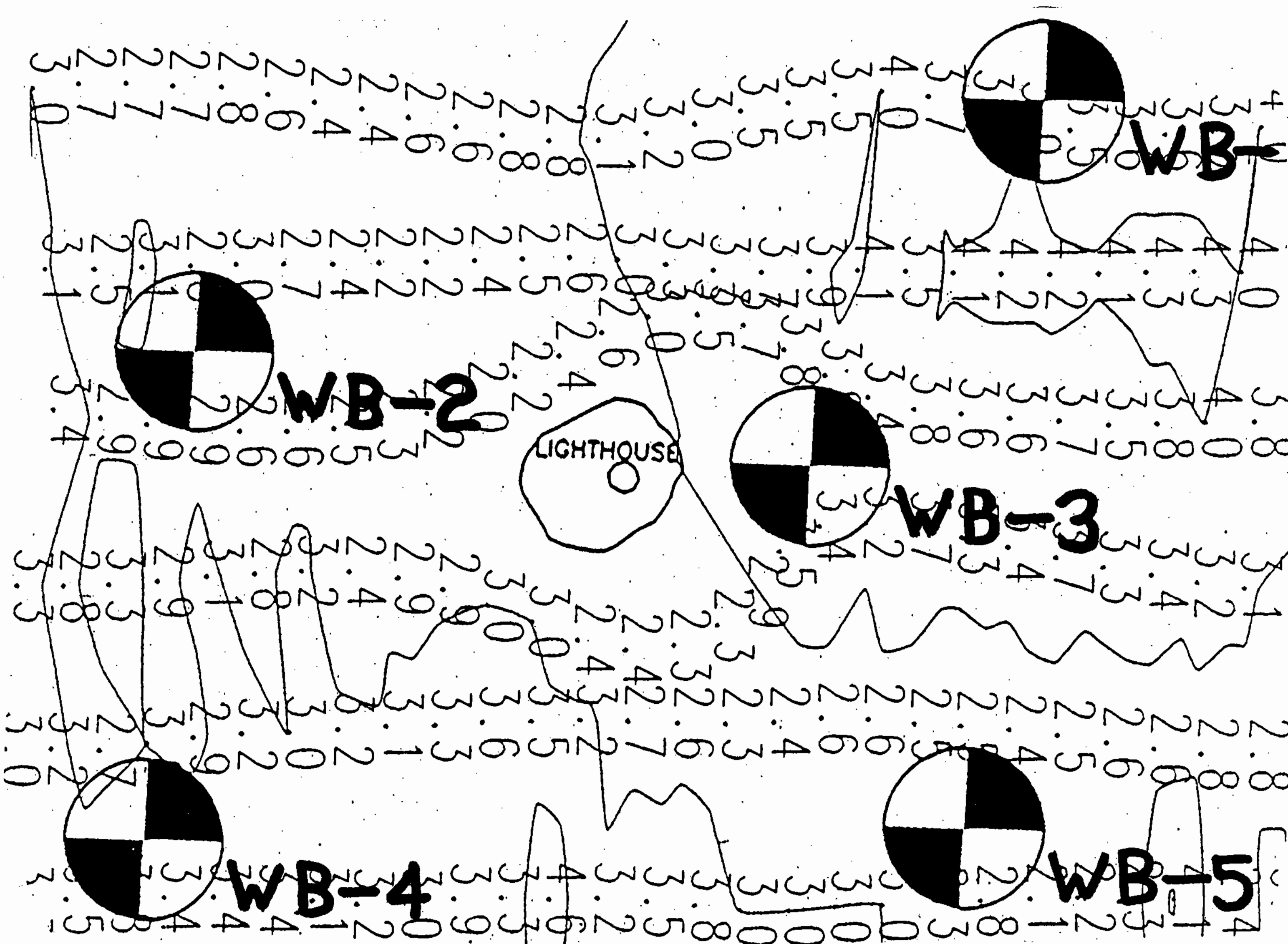
Water Depth Observations

	Date	Time	Depth	Casing	Caved
Completion	3/22	10:45	3.0'	---	---

DEPTH (ft)	STRATA DESCRIPTION	CLASS.	ELEV. (ft)	STRATUM	SAMPLING DEPTH	SAMPLING DATA	TESTS	REMARKS
	Fine to medium poorly graded sand, trace silt, contains organic matter, wet - gray	SP		B1		15+15+7+8 SPT		TABB FORMATION
4.0	Fine to coarse clayey sand, contains shell fragments, wet - green gray	SC	-7.6		5	1+1+2+2 SPT	W=20.8%	
9.0	Fine to medium silty sand, contains shell fragments, wet - brown	SM	-12.6	C1	10	4+7+9+9 SPT		YORKTOWN FORMATION
					15	9+15+19+21 SPT	W=28.4%	
17.0	Boring Terminated at 17.0 ft		-20.6					

Comments:
1. Elevations referenced to estimated mean sea level.
2. Depths referenced to mudine.

TEST BORING LOG 04131286 (RICHMOND).GPJ SCHNABEL.GDT 4/6/05



Planned boring locations are shown.
See Table of Boring Coordinates in Appendix A for actual offset locations.

Schnabel

Schnabel Engineering South, LLC

New Point Comfort Lighthouse

Matthews County, Virginia

BORING LOCATION PLAN	SCALE: 1"=100'	DATE: 03/05	CONTRACT NO.: 04131286
	DRAWN BY: S.P.	CHECKED BY: F.M.	ATTACHMENT: 1