DRAFT

ENVIRONMENTAL ASSESSMENT FOR

DUNE WORK

AT PRIME HOOK NATIONAL WILDLIFE REFUGE

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I. SUMMARY OF PROPOSED ACTION

The U.S. Fish and Wildlife Service (Service) proposes short-term interim measures to scrape sand from washover areas in Unit II on Prime Hook National Wildlife Refuge (Refuge) to build up approximately 700 feet of duneline south of Fowler Beach, and fill recently-created inlets, which are partly on refuge lands and partly on private property (Alternative II or the Preferred Alternative). The proposed action will also permit the utilization of sediment scraped from refuge lands to repair approximately 3,200 feet of duneline on private lands connected to the refuge's dune. Overwash sand from refuge land will also be used to fill in other mini-inlet(s) on private property south of Fowler Beach Road. Staging of equipment, sand, and personnel may take place on refuge land during project construction.

The Service also evaluated the following alternatives:

- Alternative 1 (No Action)
- Alternative 3: Duneline reconstruction using material from off-site sources

In addition to these three alternatives, we have also considered several other alternatives, which are not being pursued given the short term nature of the current action, but are appropriate for subsequent consideration by the Service or the State of Delaware on a longer term basis.

II. INTRODUCTION

A. Document Purpose and Structure

The Service has prepared this Environmental Assessment (EA) in compliance with the National Environmental Policy Act (NEPA) to ensure that we are acting in accordance to the letter and spirit of NEPA to foster excellent action, make decisions based on the environmental consequences, and take actions to protect, restore, and enhance the environment (40 CFR 1500-1508).

The purpose of this EA is to determine if the Proposed Action will have significant impacts to the environment, to address unresolved environmental issues, to discuss legal and policy concerns raised by this proposal, to document the basis for a decision on the proposal, and to facilitate interagency coordination between the Service and the Shoreline and Waterway Management Section (SWMS) of the Delaware Department of Natural Resources and Environmental Control (DNREC) concerning our joint missions to manage and protect natural and cultural resources. This EA discloses the direct, indirect, and cumulative environmental impacts that would result from the Proposed Action and alternatives.

B. Background and History

Shoreline management was a minor consideration during the refuge's early history (established in 1963) until the Service and the State of Delaware created two freshwater impoundments totaling approximately 4,000 acres in 1988 (now referred to as Units II and III). Prior to 1988, a barrier dune system separated an inland salt marsh from the waters of Delaware Bay. Development existed in the Slaughter Beach area to the north and the Primehook Beach community to the south.

The purpose of the impoundment project was to convert existing, degraded salt marsh wetlands to a freshwater system with water level management capability to improve habitat conditions for wintering waterfowl. The natural, undeveloped duneline/overwash system from the last house on Slaughter Beach at Unit I south to the first house at Primehook Beach community in Unit II covered approximately three miles of shoreline. The natural dune system was a discontinuous, low mound and/or ridge system interspersed with overwash areas that regularly moved from place to place. Some areas were covered with vegetation while others were bare.

Unit II (south of Fowler Beach Road) was largely created directly behind a natural dune system, while the more southern Unit III is currently not directly impacted by Delaware Bay due to its location behind the developed Primehook and Broadkill Beach communities. Due to the obstruction of tidal flows, both of these units gradually converted from salt marsh-dominated habitats to fresh/slightly brackish water pond habitats. Units I and IV have remained tidally influenced salt marsh habitats (Fig. 1) and are not proposed to be altered pursuant to this EA.

The Service's application for a State permit to impound the salt marsh included the construction of a large concrete water control structure with nine bays to hold stop logs, but did not include work to mechanically change the dune system. Establishment of the impoundments utilized existing State roads as dike infrastructure (Fowler Beach, Prime Hook and Broadkill Roads), without involving any changes to those existing roads (such as increasing road elevation). The Delaware Bay shoreline parallel to Unit II at that time was located about 150 feet eastward of its current position.

The Service produced an EA in 1988 covering the actions of converting the salt marsh areas to fresh water impoundments. This EA did not explicitly discuss how the bayside dune or berms would be maintained if storm action or erosion lowered them.

The final State permit included a condition for the Service to construct a higher and contiguous duneline across the three-mile-long stretch of shoreline described above (along units I and II). The Service did not plan nor budget any shoreline work. Instead, the Delaware Department of Natural Resources and Environmental Control conducted all duneline manipulation prior to project completion by pushing sand east from the overwash area to create a low dune form. At that time, most of the barrier island was in private ownership. In 1999, DNREC, under cooperative agreement, again moved sand east from the overwash fans towards Delaware Bay to recreate the dune for Units I and II.

This duneline was overwashed and breached in small segments along Unit I (north of Fowler Beach Road) beginning in 1991. Continual breaching of Unit I dunelines created expansive overwash areas, and a new mini-inlet was formed by Hurricane Ernesto storm surge and wave fetch in 2006. Because this Unit had always been managed as a salt marsh, even after impoundment construction, the Service decided in 2008 to no longer repair the Unit I duneline and the system is allowed to function naturally today.

The duneline in Unit II (south of Fowler Beach Road) remained unbreached until two strong, back-to-back Nor'easters demolished dunes in 1998, creating wide overwash bands into the impoundment. The Lewes tide gauge, which is located about 9 miles southeast of the refuge, generally records a mean sea level range of 4.08 feet and a diurnal range of 4.65 feet. Water levels attributed to the storm surges included 11.40 feet on January 28, 1998, and 11.27 feet on February 25, 1998 (http://tidesandcurrents.noaa.gov). No inlets were formed as a result of the storm, and in 1999, duneline repair work, again conducted by the State, was considered minor. It again involved pushing the sand from the overwash fan back eastward to heighten the dunes.

Repairs to the Unit II duneline damaged by Hurricane Ernesto in 2006 were also minor and the State pushed sand from the overwash fan eastward to reform a dune (under contract from the Service). In 2008, sand was again scraped and bulldozed to replace the stationary duneline that was lost due to storm activity. The Service paid for that work and Service personnel performed the work on privately owned portions of the duneline, which was considered routine and reasonable maintenance. More recently, however, the increasing frequency of dune overwash events and the significant damage they cause has elevated such dune modification activities beyond the level of infrequent and minor repairs.

Repeated Nor'easter storm events in fall/winter 2009 created storm surge conditions that overwashed the duneline along Unit II, and breached underlying remnant marshes along an area immediately south of Fowler Beach Road. Water-level data were recorded on October 17-18, 2009 (10.12 and 10.01 feet, respectively), and again on November 12-13, 2009 (10.53 and 10.37 feet, respectively). Higher than normal water levels were also recorded on December 19, 2009 (9.91 feet) and on March 13, 2010 (9.67 feet). All of these storm events created extreme coastal flooding of refuge lands, public roads, and adjacent private beach properties, as well as erosion and repositioning of refuge shoreline and sandy beach habitats. Additionally, a mini-inlet formed, which severely eroded the duneline. It is currently accommodating a substantial overwash, which is facilitating the flow of tidal waters from Delaware Bay into Unit II (Fig. 2).

C. Current Conditions

Although the exact acreage of the overwash has not been measured, it appears that approximately 20 acres of former marsh/open water on the eastern edge of the Unit II impoundment are now covered with sand. The tide flows in and out every day, twice daily. None of the overwashed area has re-vegetated as yet. Prior to inlet formation, Unit II only received saltwater from the bay during the most extreme high tide events. The water flowed from Unit I through the culverts under Fowler Beach Road. Approximately

80 percent of Unit II can be classified as brackish marsh today, while only about 20 percent is still fresh (located mostly on the southern side of the impoundment).

The continued influx of saltwater has killed approximately 80 percent of the freshwater vegetation. However, salt-tolerant vegetation is becoming established along the northern end of Unit II. In addition, some areas that are typically vegetated with freshwater species appear to have converted to open water. Due to the increased flow of water into Unit II through the inlets, more saline water than has been previously recorded is flowing into Unit III through the culvert under Prime Hook Road. This freshwater marsh is now vulnerable to conversion to salt marsh.

It is expected that even if the duneline is reconstructed and the inlets are filled, some portions of Unit II will continue to be highly saline and will not become fresher due to the presence of highly saline water already in the Unit and the occasional inundation of the area from Unit I during high tides.

III. PURPOSE AND NEED FOR THE PREFERRED ALTERNATIVE

A. Purpose

The purpose of scraping overwash sediment to rebuild the duneline along Unit II (the Proposed Action) is to minimize impacts of coastal flooding and reduce erosion for the short term while a long-term restoration and management plan, based upon increased availability of scientific information, is developed. The Service announced in 2005 that it was initiating its Comprehensive Conservation Plan (CCP) process. It is our intention to continue to develop the refuge's CCP, which will outline the multiple, large-scale and long-term factors that contribute to habitat management decisions over the next 15 years. The CCP will address impoundment and shoreline management in further detail, and will contain long-term strategies to manage habitat for wildlife consistently with national management policies while considering the impacts of that management to the surrounding community. This will provide some time to analyze new information and to re-assess refuge management options through the CCP and post-CCP planning process.

Previous maintenance actions that moved sand bayward counteracted the natural processes that sustain dune systems in the face of storm events, sea level rise, and shoreline subsidence. The continuation of these practices is likely to further weaken the integrity of the dune and marsh system over time. However, given the degree of degradation of the current system, we are concerned that inaction in the short term may inadvertently increase the amount of open water in the impoundments and increase the challenges inherent in restoring the system's integrity.

Most barrier dune systems respond to storms and sea level rise through a process known as 'barrier island roll-over.' Without human manipulation, a barrier beach does not remain in the same alignment when there is an insufficient supply of sand; instead, it sustains itself by moving landward, thereby still buffering salt marshes on the interior. In places where barrier islands are artificially maintained in fixed alignments, barrier islands tend to narrow, providing less width for upland vegetation, which can anchor the sand. Salt marshes are very sensitive to water levels and if they cannot maintain their elevation, marsh vegetation dies, the peat layer beneath crumbles and breaks apart, and the amount of open water increases. To maintain the health of the interior system, a steady supply of sediment is needed, which is carried into the interior system through inlets and across barriers by high water events. Even if the barrier is not interrupted by an inlet, cross-island overwash events move sediments into the interior, which are then reworked by the tides to increase salt marsh elevation. If a barrier island is subject to erosion along its outer face, and marshes along its interior shore disintegrate, the barrier system then is subject to increased lowering and disintegration. This is already occurring in barrier systems along the southeast Atlantic and Gulf Coasts (Climate Change Science Program 2009).

Given our increased state of knowledge concerning marsh and barrier systems, and the increased challenges to sustain these systems in light of sea level rise and surface subsidence, we now understand that converting salt marsh to freshwater impoundments in 1988, and the subsequent duneline maintenance, however well-intended, probably exacerbated the problems we confront today. However, at present, the optimal restoration plan for the entire system is not immediately clear.

National wildlife refuge management policies emphasize the need to examine the historic functioning of natural ecosystems prior to substantial human-related changes to the landscape. These policies also direct us to restore the biological integrity, diversity, and environmental health of the natural systems we manage (see 601 FW 3). The evaluation of Units II and III in the CCP will include an examination of maintenance costs in relation to habitat management benefits. An understanding of local subsidence will be developed from current road, water control structure, and dike elevations relative to mean sea level (msl), and associated elevational changes since 1987. Estimated marsh accretion rates from radiometric data (^{210}Pb and ^{137}Cs substrate core samples) collected by the Delaware Department of Natural Resource and Environmental Control's Coastal Program in 2009 and 2010 will be incorporated. Costs associated with managing the impoundments, which will likely include raising State roads that are used as dikes, annual soft armoring of the duneline, and repairing and raising water control structures will also be presented. This analysis will be used to propose and support future decisions regarding impoundment and shoreline management objectives. Approaches in light of sea level rise and other climate change factors will be addressed as well. Alternative approaches for freshwater wetland habitats will also be evaluated, especially as some of the lower-lying adjacent areas now managed as upland were former wetlands and may be appropriate to evaluate for adaptation to freshwater impoundments.

Public concerns have been raised about access to the Primehook Beach community via Prime Hook Road (State-owned), which has recently been impassible more frequently under high water conditions. This problem might be improved by constructing a causeway or elevating the road, but that option requires significantly more planning between the Service and the Delaware Department of Transportation. Additionally, funding for a project of that nature would need to be secured.

Much of the sand that would be used to reconstruct the artificial dunes as proposed now rests on federal lands. While federal resources can generally not be utilized to enhance private lands, and while the State will be financing all work on the private lands, this action would be taken as a short-term effort to maintain the status quo and to allow time to determine the optimal restoration approach to sustain long-term habitat integrity on refuge lands.

The Service is disinclined to choose the No Action Alternative because we have not yet developed a final management approach, which will be accomplished in the on-going CCP process (a draft is expected for public review and comment later in 2010). The short-term need for repairs to the Unit II duneline, especially in light of safety, habitat changes and other concerns of the neighboring community, is evident. Therefore, we believe it is prudent to consider the proposed duneline work through this EA, as needed, in the short term until final determinations are made regarding long-term management, either in the CCP or in subsequent step-down plans.

B. Project Location

Prime Hook National Wildlife Refuge is located in Sussex County, Delaware (Fig. 1). Refuge lands involved in this project are located along the Delaware Bay between the end of Fowler Beach Road and the Primehook Beach community to the south. Approximately 700 feet of the project area is located on the refuge immediately south of Fowler Beach Road, and the remainder is on private lands. The project location involves a complex patchwork of refuge and private ownership (Fig. 2).

C. Decision Framework

Given the purpose and need of the project, the Coastal Delaware National Wildlife Refuge Complex refuge manager may recommend selection of the Proposed Action or either of two other analyzed alternatives. The refuge manager may also approve appropriate mitigation measures to implement any action alternative used that would minimize negative environmental effects on soils and coastal sediment resources, vegetation, migratory birds and other wildlife, invertebrates, and cultural and historical resources.

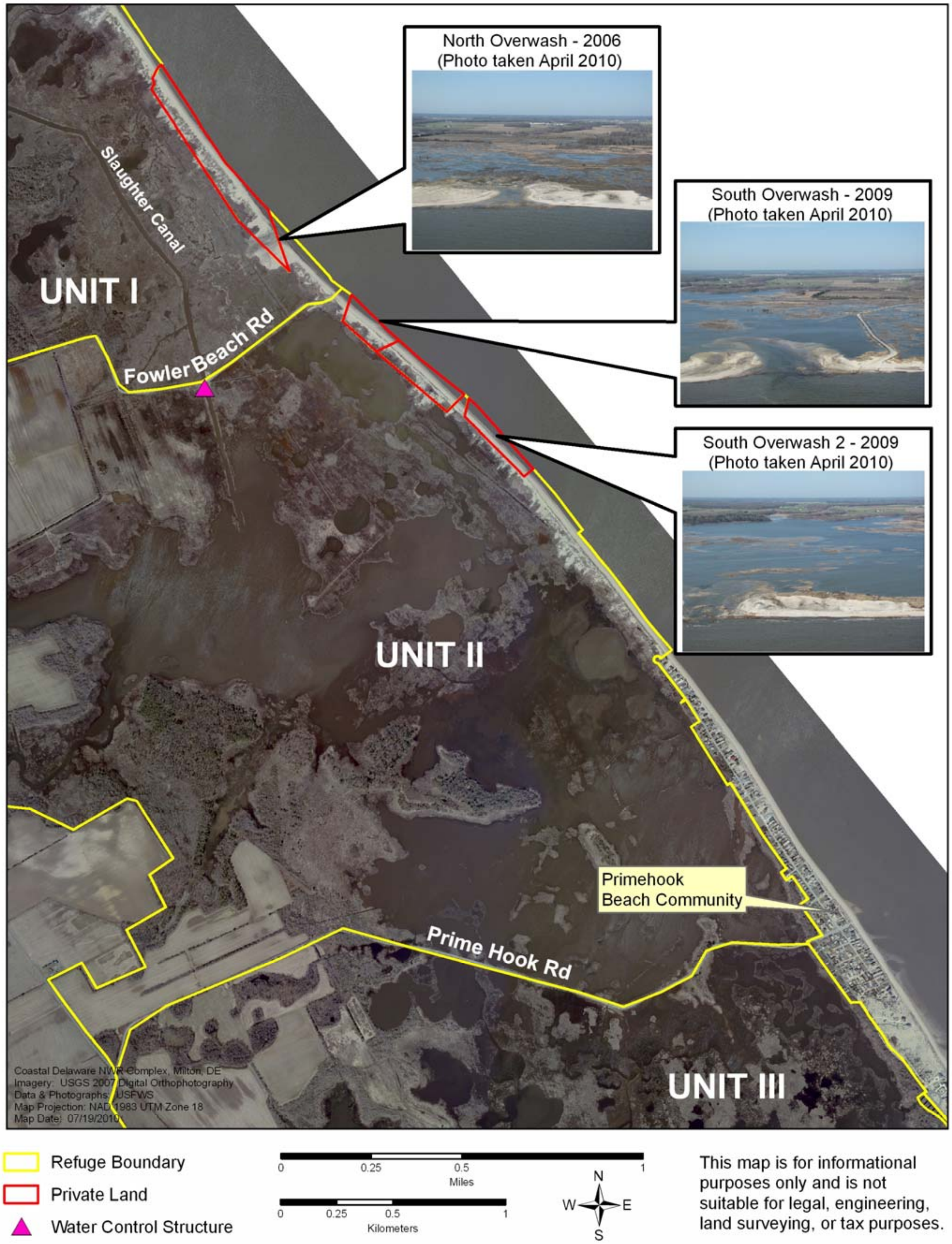
D. Public Involvement

The refuge manager and State officials have attended several public meetings and responded to many written inquiries regarding public concerns related to refuge shoreline management issues. The Proposed Action has been developed in consultation with our State partners and in consideration of requests for action by the public. This EA will be available for public review and comment for 30 days.

Figure 1 - Prime Hook NWR Vicinity Map

PRIME HOOK NATIONAL WILDLIFE REFUGE

Figure 2. 2010 Dune Work Project Area



Coastal Delaware NWR Complex, Milton, DE
Imagery: USGS 2007 Digital Orthophotography
Data & Photographs: USFWS
Map Projection: NAD 1983 UTM Zone 18
Map Date: 07/19/2010

This map is for informational purposes only and is not suitable for legal, engineering, land surveying, or tax purposes.

E. Coastal Beach and Shoreline Management Issues

Coastal beach and shoreline management issues are influenced by important factors, including:

- Local geologic framework of the refuge
- Physical processes (sea level rise, storms, subsidence, extreme wind and waves)
- Sediment processes and supply
- Human activity
- Climate change and sea level rise impacts

Human activities that attempt to slow beach erosion with the construction of groins, jetties, and repetitive sand replacement (beach nourishment) projects overwhelm and mask natural responses and physical processes that shape and sustain barrier island shorelines and associated marshes (Riggs et al. 2009). When barrier beach island shorelines are armored against erosion, they cannot evolve as they would naturally, and erosion and breaching of natural areas adjacent to developed shorelines is accelerated. Coastal habitats are part of a complex system consisting of more than just beach, and while shoreline erosion threatens property near or on the coast, it can also profoundly influence marshes behind the beach (Northeast Climate Impacts Assessment [NECIA] 2007). For example, overwash development from storm activity is an important mechanism for moving sediment into the back-barrier and associated wetlands, maintaining the ecological integrity of barrier island and sandy beach habitats. This process is prevented when shorelines are armored, regardless of the use of hard or soft techniques (Defeo et al. 2009; NECIA 2007).

Current rates of sea level rise and climate change are already having profound effects on coastal ecosystems. However, as a direct effect of either destroying and/or armoring shoreline habitats by human activity throughout the United States, coastal beach habitats are being degraded by human-caused alterations to the coastal environment to an even greater extent than negative impacts from sea level rise and climate change (Coch 2009; Neal et al. 2009; Riggs et al. 2009; Titus et al. 2009).

Barrier beach inlet formation can be inappropriately labeled as the only cause of flooding of private property during storm events. Yet there are many other extenuating causes and effects involved. Physical forces that affect coastal beach flooding include increased storms and storm intensities, heavier precipitation patterns, extreme wind and wave conditions, extensive run-off from uplands, low elevation of roads and private properties with respect to local mean sea level, local geologic features, sediment supply, and human activities. These factors increase the level of complexity of coastal flooding seen at the refuge and adjacent private lands.

For example, a summary of the data collected at the Lewes tide gauge illustrates that the number of times water levels exceed “mean higher high water” (MHHW) and, more importantly, instances of consecutive tides above MHHW, have been increasing in frequency and duration over recent decades (http://www.tidesandcurrents.noaa.gov; Fig. 3). When refuge impoundments were established in the late-1980s, there were typically

10 to 20 instances per year of consecutive tides above MHHW. By the 2000s, there were typically 15 to 25 such events per year. In 2009, there were over 30 events. This pattern is likely exacerbating any coastal flooding that the area around the refuge has experienced historically. As another example, instances of coastal flood warnings issued by the National Weather Service for the area have increased and coincide with events of consecutive tidal events above MHHW (Fig. 4).

The Climate Change Science Program (CCSP) report (2009) states that increased sea level rise rates will raise groundwater tables and increase surface water levels. This will significantly slow the rate at which coastal areas can drain, with drainage being further exacerbated by increased flooding effects from rainstorms and prolonged flooding duration of coastal environments long after a storm passes through. As a result, roads below one meter elevation can expect to remain submerged for longer periods of time in these coastal zones.

Current dominant public perceptions are that the only solution to storm flooding is a static engineered response of holding the shoreline in a permanent position. This may be one solution to protect private beach property; however, it may not be a viable solution for managing beach habitats and back-barrier wetlands for coastal wildlife, nor are climate scientists projecting that this approach will be sustainable given even modest projections for sea level rise (CCSP 2009). Refuge shorelines will continue to be impacted by climate change, mostly through increased rates of local sea level rise and changes to storm tracks, frequency, and intensity.

In the past, shoreline management was not an issue for the refuge and passive management of shorelines, that is, nature taking its course, was the general philosophy from 1963 to 1987. However, present climatic conditions, coupled with relative sea level rise rates, force us to review this management approach. Environmental conditions of the refuge’s coastal habitats have rapidly been changing over recent years, believed to be due at least in part to increased sea level rise effects, subsidence of local and regional landforms, subsidence of local roads, more severe and frequent storm effects, and prolonged frequency and duration of flooding.

These changes have moved shoreline management to the forefront of refuge management concerns. This has necessitated the short-term remedy recommended by the Proposed Action, which will provide some time to analyze new information and to re-assess refuge management options through the CCP and post-CCP planning process. The Service must now assess beach and wetland sustainability within a very different climatic and physical environment than was experienced when current management regimes were established.

Figure 3. Number of Events of Consecutive (2 or more) High Tides above MHHW per Year Recorded at the Lewes, DE, Tide Gauge.

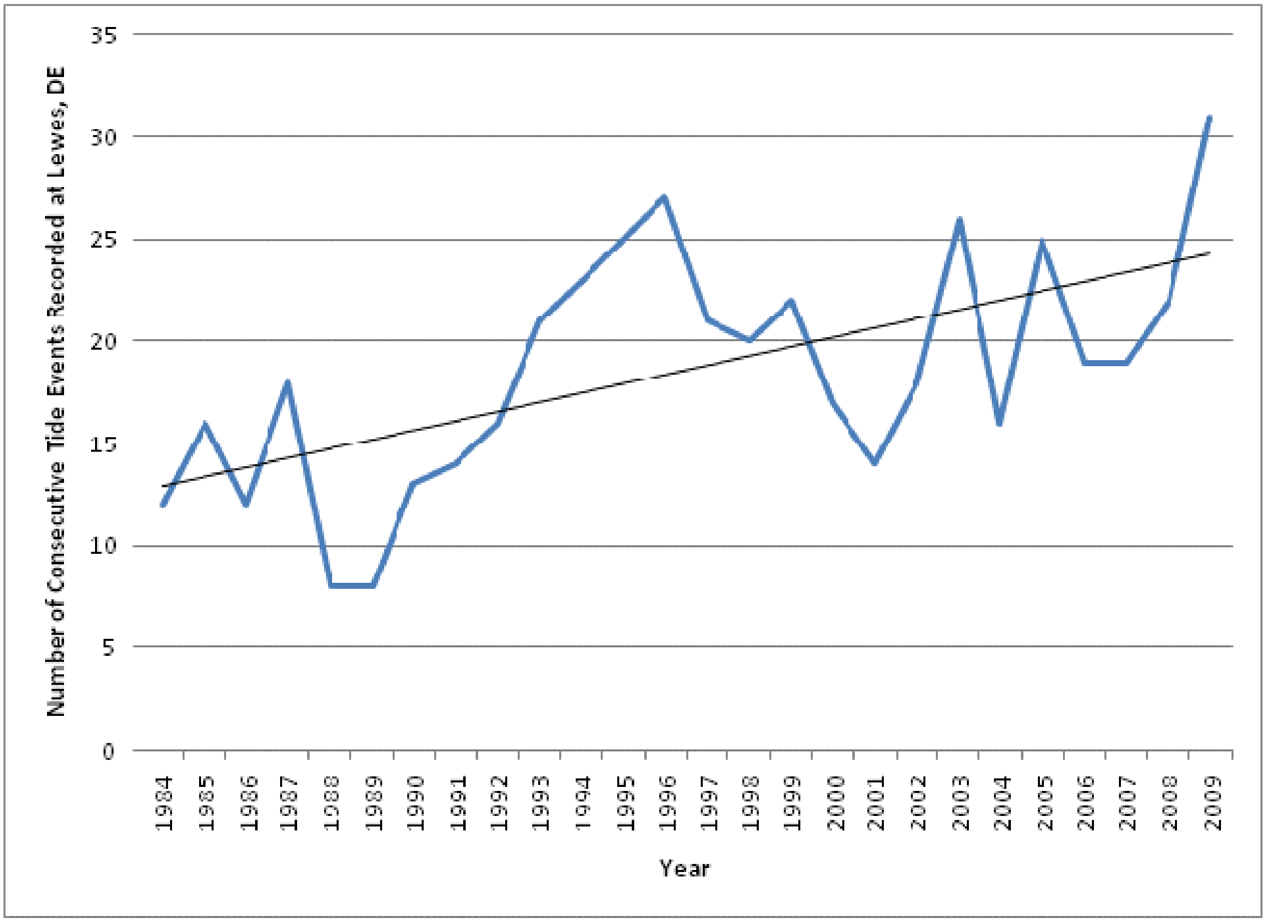
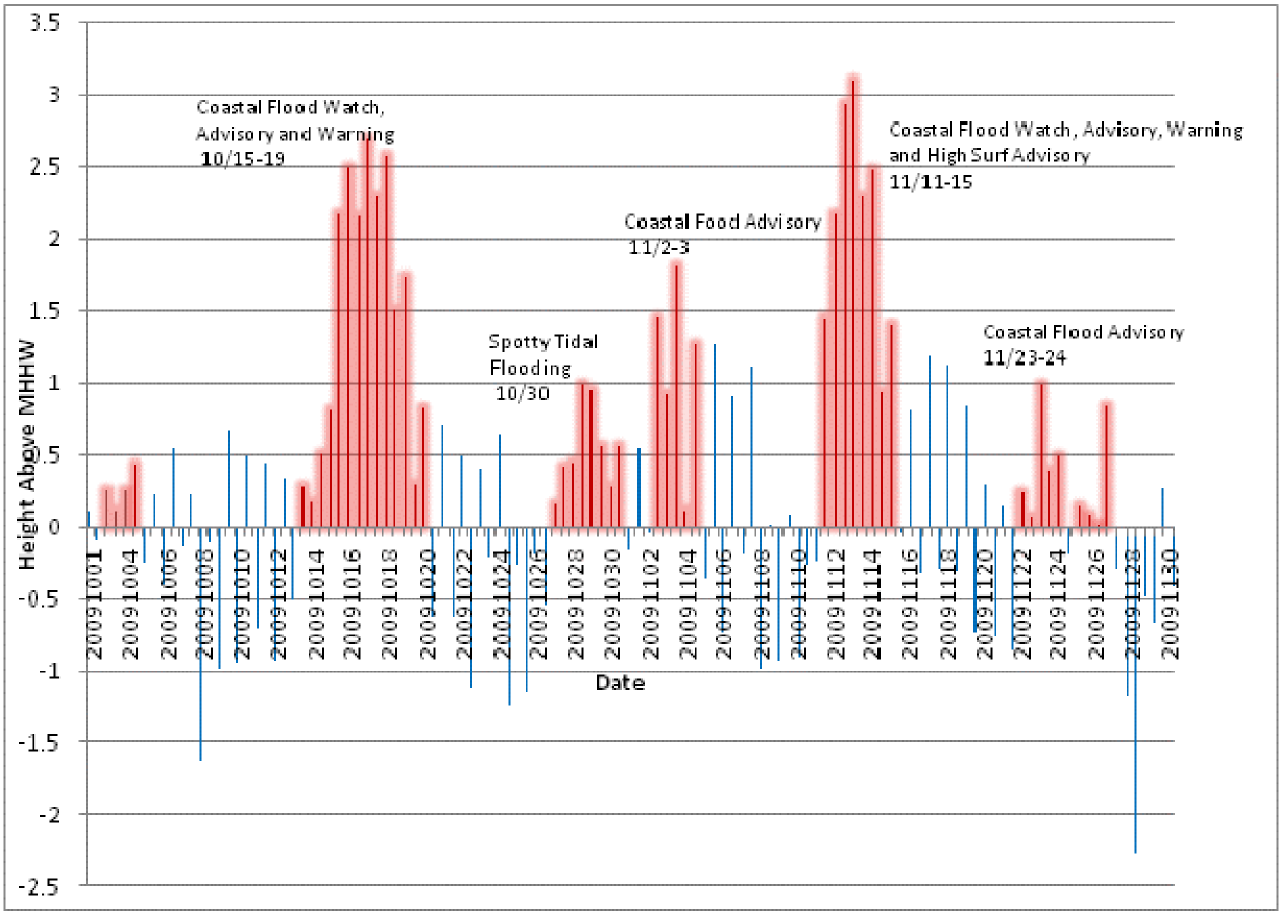


Figure 4. Consecutive High Tide Events Above MHHW During October – November 2009.



IV. ALTERNATIVES

A. Summary of the Alternatives

The Proposed Action Alternative is presented with two other reasonable alternatives in comparative form, defining the differences between each alternative, and providing a basis for choice among options by the decision maker. Each alternative considered will be further evaluated by comparing environmental consequences.

- <u>Alternative 1 (No Action)</u>
- <u>Alternative 2 (Preferred Alternative):</u> Short-term soft duneline reconstruction using sand scraped on-site
- <u>Alternative 3:</u> Duneline reconstruction using material from off-site sources

B. Description of Alternatives

1. Alternative 1 (No Action). This alternative would allow the existing overwashes to continue to build, and would allow regular tidal flow into Unit II. No dunelines would be repaired.

This alternative would:

- Allow overwash and inlet formations to remain intact with the natural dunelines transgressing and forming on their own and re-establishing tidal flow into back-barrier marshes.
- Expect that the inlets will form and reseal themselves and that washover areas will fluctuate in size and location as the ecosystem self-adjusts in response to various factors and physical processes (e.g., relative sea level rise, recurrent storm history, wave dynamics, local and regional subsidence rates, sediment supply, and legacy effects from human activities).
- Permit natural conversion of a manmade freshwater system back to a brackish or salt marsh system or open water.

2. Alternative 2 (Proposed Action). The Proposed Alternative would involve reconstruction of approximately 700 feet of duneline on refuge land using on-site sediments on an interim basis until the CCP is finalized. Those sediments would be used to repair dune both on and off the refuge (off-refuge lands involved in the project include 3,200 feet of duneline on private lands held by three individual landowners). In addition, newly created inlets south of Fowler Beach Road will also be filled. Due to the dynamics of the system, it is likely that a portion of the sediments used for this project originated on both refuge and private lands before being relocated by the overwash process.

The Proposed Action would:

- Reestablish dunelines on refuge lands utilizing existing sand on the landward side, with the purpose of joining dunes on private lands.

  - The resulting dune would be approximately 700-feet-long, 50-feet-wide at the base, and 4-feet-high, with a 5:1 slope.
  - The size of the dune will be limited by available sand (an 18 to 24-inch-deep base must remain in place to support the weight of the equipment).
  - The estimated volume of sand needed for the project ranges between 84,000 and 140,000 cubic feet.
- Close recently formed inlets south of Fowler Beach Road.
- Allow sand that has likely washed onto the refuge to be moved back onto private land.
- Only be conducted if the entire duneline along Unit II, including portions on private land, are slated for reconstruction.
- Include pre- and post-work shoreline profiles to document the conditions and quantities of material to be reconfigured.
- Take approximately two to three weeks to complete, weather permitting
- Not involve the use of federal funds to perform work on private lands. The estimated project cost for the entire project is $11,000 to $13,000.
  - Construction costs are $125-$150 per hour, depending on equipment involved.
  - Mobilization and de-mobilization will cost approximately $1,000.

The Delaware Department of Natural Resources and Environmental Control (DNREC) will serve as the cooperating agency and partner of the Service to complete the proposed action on both private and Service lands. The Service has been working closely with DNREC throughout the planning process. The Shoreline and Waterways Management Section (SWMS) of DNREC has jurisdiction for implementing the State's Beach Preservation Act by issuing coastal construction permits for beach scraping on public and private lands. It also has the specialized expertise to conduct refuge dune work. SWMS will also facilitate and coordinate the linkage between refuge land and private land dune reconstruction, and coordinate with private landowners involved in the project. The refuge will re-vegetate the dunes with American beach grass as part of the restoration prior to the growing season following the work.

Concurrently, the Service will develop protocols and contract specifications/proposals for scientific investigations that will be initiated or continued to improve our understanding of the local system. These ongoing and proposed studies, which will occur over at least a five-year period, will be conducted in conjunction with State and federal partners, and will characterize and monitor a number of variables critical to the understanding of this complex system.

To date, the refuge has acquired data regarding elevations of the marsh surface along repeatable transects, at the water control structures, and along the State-owned roads that form impoundment dikes. These measured elevations will be compared to the constructed elevation (in the case of the water control structures and roads), and with tidal data such as mean higher high water.

Surface elevation tables (SET) will be used to monitor current and future marsh accretion within refuge wetlands. Sediment cores will be analyzed to further quantify historic accretion rates. Marsh accretion rates will be examined in relationship to current and projected sea level rise rates, as well as in response to management actions. Utilizing National Park Service protocols, the refuge proposes to characterize the changing coastline position and topography twice annually.

A network of real-time monitoring stations will be established throughout the wetland complex, measuring variables such as water level, salinity, pH, temperature, and dissolved oxygen. Transect sampling will be used to characterize the reach of the saltwater prism into adjacent freshwater supplies. Sampling protocols will be developed to quantify suspended sediment concentration and selected nutrients (ammonium, nitrate and nitrite, ortho-phosphorus, dissolved nitrogen and phosphorous, and chlorophyll A) from key locations throughout the wetland units. Sampling will be conducted following storm events, as well as under normal conditions.

It may take several years to collect and analyze enough data to develop sufficient understanding of the system to fully refine future management plans. This comprehensive monitoring program will enable the refuge to further define management needs in response to the changing environment, to evaluate management approaches, and revise or adapt restoration actions in light of the system response.

3. Alternative 3. The same duneline repairs and filling of existing inlets would occur; however, no sand would be scraped from refuge lands to complete the work. All materials needed to complete work on refuge lands would be hauled from off-site sources. Additionally, no materials existing on refuge lands would be scraped to reconstruct dunes and fill inlets on private lands.

This alternative would:

- Reestablish dunelines on refuge lands utilizing sand hauled from off-site sources. The estimated cost of material is $47,000 to $78,000 (based on $15 per cubic yard).
- Fill inlets south of Fowler Beach Road with sand from an off-site source.
- Not utilize existing on-site sediment from refuge washover areas.
- Not permit the use of refuge sediments for repairs on private property. Construction partners would be permitted to access refuge property to complete work on private property.
- Only be conducted if the entire duneline along Unit II, including portions on private land, are slated for reconstruction.
- Take approximately two to three weeks to complete, depending on weather and material availability.

As in the Proposed Alternative, the Service would work closely with our partners at DNREC, along with neighboring private landowners.

C. Alternatives Considered But Not Studied in Detail

1. Elevate Prime Hook Road. Community concerns regarding interrupted access and impaired emergency evacuation and response could be permanently alleviated if the State elevated Prime Hook Road. That route is the only road leading in and out of the Primehook Beach community, a private community of about 206 homes or landowners (as of 2004). One alternative would be to elevate the road on a causeway, which would not impair tidal flushing. If an elevated dike is utilized, it must be designed with sufficiently large conduits and/bridges to prevent obstruction of sediments and nutrients. Any road work planning and construction would be coordinated with Service personnel.

2. Avoid use of overwash sediments to reconstruct the dunes. In some communities, beachfront sediments or sand from the intertidal zone are used as a source for dune enhancement. The State of Delaware has determined that there is insufficient sediment to remove sand from the beachfront; therefore, this option will not be permitted by the State.

3. Only use 'federal sand' to restore overwash areas on federal lands. Insufficient quantities of sand remain on private lands adjacent to the project site to restrict the use of 'federal sand' just to federal property. The only practical option is to follow Alternative 3, which is substantially more costly. Given the patterns of ownership, refuge lands are immediately behind private lands. This sand has previously rested on private land, although given the history of dune manipulation, it may have moved back and forth several times. The justification here, as explained above, is that this short-term action will help preserve the federal lands and waters of the interior system until a long-term restoration program is implemented through the CCP process.

V. AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

This section describes the affected environment and environmental consequences that considered alternatives would have within the project area, if implemented. It summarizes the physical, biological, historic and cultural environments of the affected project area and the potential changes to those environments due to implementation of each alternative action. This section also examines the environmental effects from past and present actions, and reasonably foreseeable future actions in the face of the changing environment and accelerated sea level rise.

A. Impacts on Soils and Coastal Sediment Budgets

1. Affected Environment

Project site soils are mostly sand, marsh mud, and marine sediments. Regional sediment plans developed by the U.S. Army Corps of Engineers (2004) in the Northeast recognize sand as a vital natural resource and that sand and marine sediment processes are critical components of coastal barrier islands, sandy beach, and associated salt marsh ecosystems. To understand the environmental consequences of the alternatives in this EA, the geologic framework of the refuge and the surrounding area that influences the physical functioning of the affected environment merits further examination.

Delaware is located on the flank of the Baltimore Trough Geosyncline, a massive downfold of the Earth's crust, filled with sediments. The relative instability of this crust is the cause of local subsidence of the area. Delaware's coastal zone is a low-lying coastal plain and part of a larger geological structure known as the Atlantic coastal plain-continental shelf. Its shorelines are migrating rapidly in geologic time, in a landward direction. This is caused by several geological and physical processes (Kraft et al. 1976):

- Subsidence or sinking of the continental shelf and Atlantic coastal plain.
- Sea level rise relative to the land.
- Erosion and redistribution of sand and marine sediments in the coastal zone, known as littoral drift, or the transport and redistribution of sand in the littoral zone under the influence of waves, tides, and currents.
- Dynamic position shifting of shorelines as they migrate landward and upward, known as marine transgression or barrier island roll-over, in response to sea level rise, storm activity and changing weather patterns as the main driving forces.

Scientists have subdivided the immediate coastal zone of Delaware into six zones based on local geomorphic features and lithology (Kraft et al. 1976). It has been estimated that approximately 450,000 cubic yards of sand move by any one point on the coast during an average year (Turner 1968). For this massive flow of sand to occur, coastal erosion must take place in some areas while sand accretes in others. In general, the net littoral drift, or flow of sand, in the surf zone is northward along the Delaware shoreline. From time to time the average littoral drift shifts southward around Bethany Beach. This shift of the point or loci of change between northerly and southerly flows is not fully understood (Kraft et al. 1976). Additional study of the off-shore dynamics is needed before the local system is well understood.

Littoral drift flows in the Delaware Bay are even more complex. Tidal flow floods seawater into the bay in high arcs, sweeping around then turning and ebbing back along the shoreline. For this reason, the dominant littoral drift from Broadkill Beach south into Lewes is southeast. However, littoral drift is not fully understood in terms of direction or magnitude on the smaller beaches or shoreline areas of the bay.

Strong littoral drift flows also have the effect of accreting or eroding back-barrier marshes. Geological evidence indicates the present area covered by the Great Marsh in Lewes and the Primehook marshes was coastal lagoon in the near past (i.e., about 500 years ago) demonstrating how open water areas with significant sediment accretion rates can evolve into marsh systems. These two areas may be well-positioned along the lower mouth of the bay to receive sediment during northeast storm events (Kraft et al. 1976; Steveson and Kearney 2009).

Refuge sandy beach and shoreline habitats are located in a geomorphic zone which starts at the upland surface at Bower's Beach southward to the area of the Great Marsh in Lewes to the Roosevelt Inlet, and is one in which the littoral drift of sand is in fairly continuous motion. This zone is characterized by areas of broad coastal marsh separated from the waters of the Delaware Bay by a continuous ribbon of a narrow band of sandy coastal barrier island beach. Most of these “ribbons of sand” are rarely higher than 8 to 10 feet and range from five to several hundred feet wide (Kraft et al. 1976).

Another characteristic of the geomorphic zone of the refuge is the rapid erosion and landward migration of these ribbons of sand at rates of up to 10 feet per year or more. Erosion rates vary throughout particular segments of barrier beach based on local geomorphological features and human activities. The entire coastal zone of the Delaware Bay is unstable and subject to sediment compaction, tectonic subsidence and relative sea level rise with average rates of erosion continuing or accelerating into the future along a very low-lying Atlantic coastal plain setting in relation to mean sea level (Kraft et al. 1976).

During spring tides and storms, sand is easily washed across barrier islands and into marsh areas. Although the sediment supply along the western shore of the bay is less than the Atlantic transport, there is a sufficient supply of sand and gravel to maintain a continuous estuarine washover barrier. Washover fans, broad marshes, inlets, tidal creeks, and diverted river channels such as the Broadkill River extend from washover barrier beaches on the upland areas with Pleistocene sediments characteristic of the Delmarva Peninsula (Kraft et al. 1976).

The shoreline segment south of Slaughter Beach to Primehook Beach is characterized by a continuous estuarine saline fringe and washover barrier with broad marshes containing Holocene muds about 10 feet thick (Kraft et al. 1976). Fowler Beach is typical of this shoreline type, with Pleistocene sands and gravels of Slaughter Neck continuing into the shallow subsurface beneath Fowler Beach. Draper Inlet and Slaughter Creek were tidal drainages flowing through Slaughter Neck into the bay during the 18th and 19th centuries, which were later sealed by sediment transport processes and are no longer directly connected to the bay (Stauss 1980).

2. Environmental Consequences

   a. Alternative 1 (No Action)

   If the No Action Alternative were implemented, regular tidal flow would continue to enter Unit II through the newly formed inlets. “Elevation capital” accrued through recent overwash events would likely move to back-barrier environments as shorelines continue to naturally transgress landward. Tidal flow would become more completely re-established, reverting impounded marshes back to a brackish and ultimately a salt marsh environment. In the long run, these conditions may enable the marsh to better keep up with sea level rise, as the effects of “storm sedimentation” could aid in the vertical accretion of these marshes.

   This alternative may improve the current low rate of sediment accretion. Analysis of sediment cores for the presence of radioisotope fallout (^{137}Cs and ^{210}Pb) deposited at a known time in the past can provide a measure of accretion over recent decades. Preliminary data from radiometric coring conducted by DNREC's Coastal Program indicates that Unit II marshes have not been keeping up with current sea level rise rates over the last 50 years (DNREC 2010, unpublished data). Marsh accretion rates were spatially and temporally variable, and dependent to a large degree on storm-dominated sediment dynamics and overwash processes to supply sediment to coastal marsh and barrier beach systems (Aubrey and Speer 1985; Leatherman and Zaremba 1986; Roman et al. 1997).

Washover and inlet formation can contribute to the sediment budget of the refuge's sandy beach and marsh environments in the long term. Washover is a major process in the retreat mechanism of coastal barrier beaches in response to sea level rise (Dillon 1970; Kraft et al. 1973; Kraft et al. 1976).

b. Alternative 2 (Proposed Action)

If the Proposed Action Alternative were implemented, marine transgression of the shoreline would be temporarily halted, as it had been between the late 1980s and through the fall of 2009. The marsh system behind the duneline would contain less sediment than is now present due to the scraping activities associated with dune reconstruction and inlet filling. If those deposits remained in their current locations, they could contribute to the long-term build-up of the back-barrier marshes, which would improve the recovery of the Unit into a functioning salt marsh (improving "elevation capital"). Artificially stabilizing the duneline may result in the temporary loss of washover sediments from nearshore sources.

In the short term it is expected that the beach system will once again re-position the duneline to a new equilibrium point in response to daily tidal action and effects of storm activities. Conducting the Proposed Action work after August 15 may allow some onshore transport to bring more sand to the beach face during calm conditions, offsetting sediment deficits from winter months when large waves move sand from the beach to the offshore zone, thereby providing more sand to rebuild dunelines. Often in coastal storms, a beach can lose several hundred feet of sand, and then in the following weeks regain some of that sand (Pratt 2009).

Dolan and Godfrey (1973) demonstrated that sandy beach and marsh ecosystems can have reduced sediment budgets due to artificial dunes. They compared the response of a stabilized duneline (dunes artificially built up to sufficient height to restrict overwash) to an unstabilized barrier beach duneline and evaluated both responses to a hurricane. Although the unstabilized dunelines were overwashed, by lowering the natural dune crest and moving it landward, this section of the shoreline maintained a broader beach. In contrast, the stabilized shoreline lost most of its beach sediments to offshore environments. Also, shifting sand from one location to another on the same beach offers little to no effective solution to coastal erosion and flooding of beach properties and at best is only a temporary fix because barrier migration or roll-over is inevitable unless dunes are continually rebuilt (Coch 2009; DNREC 2004; DNREC

Secretary's Order No. 2009-W-0048; Levine et al. 2009; Pilkey and Young 2009; Riggs et al. 2009;).

c. Alternative 3

If Alternative 3 were implemented, environmental consequences related to the flow of tidal waters and deposition of sediments would be similar to Alternative 1. However, recently deposited washover sediments would remain within Unit II and might aid the establishment of marshland behind the constructed duneline.

Sand placed on the project site must be similar in character to the sand naturally occurring on the beach. When using sand from off-site sources, it is important to consider the appropriate grain size for each specific project. Characterizations of sand from the project area can be achieved by conducting an analysis to determine the grain size of sand needed, and to avoid sand particles that are too small that tend to be transported in suspension when overwashed with water (Wanless 2009). Improper sand sources (incorrect sediment grain size) could have adverse impacts on piping plover or horseshoe crab habitats. The SWMS has successfully conducted beach nourishment projects hauling sand from off-site sources to project sites that have been found to successfully create suitable habitat for horseshoe crabs and piping plovers (DNREC 2004). Refuge staff would work with SWMS to ensure proper sand size was obtained for this project.

B. Impacts on Vegetation

1. Affected Environment

Vegetation usually colonizes newly formed overwash habitats, and new dune growth is subsequently initiated. Due to the dynamic nature of constantly shifting sands, only a limited number of plant species are suited to this environment. The current overwashes are generally not vegetated because they are in an early stage of development. However, as several growing seasons pass, sea rocket (*Cakile edentula*) would be the first plant to pioneer the site. It typically sprouts in the wrack line. Other plants that colonize bare sand include beach pea (*Lathyrus japonica*), seaside spurge (*Euphorbia polygonifolia*), glasswort (*Salicornia* sp.), beach heather (*Hudsonia tomentosa*), and American beachgrass (*Ammophila breviligulata*). Nor'easter events and storm surges can wash in giant reed (*Phragmites australis*) rhizome remnants, which if long enough (greater than 8 inches) can remain viable and colonize dune areas. American beach grass and overwash dune grassland communities of the mid-Atlantic are considered rare. Many of the highest quality occurrences are on public land (NatureServe Report 2006).

Overwash dune grassland habitat is restricted to storm-generated overwash areas of maritime dune systems. It is typically small in extent and not usually more than a few acres in size. It is best developed on barrier islands of Delaware, Maryland, Virginia, and North Carolina. As part of a very dynamic system, this community is extremely ephemeral, buried by sand deposition over time and/or appearing in newly formed overwashes in other areas subjected to storm-energy forces. Because of the dynamic forces structuring this vegetation community, it requires sufficient area to accommodate the constantly shifting mosaic. Although not extremely rare, the community is restricted to a specialized habitat and is threatened by a number of human activities, including shoreline armoring, artificial dune stabilization, and trampling by off-road vehicle use (NatureServe Report 2006).

The Unit II impoundment is located behind the project area. The impoundment has been managed as a freshwater marsh since 1988. Vegetation is composed of a mixture of moist soil plant species such as smartweed (*Polygonum spp.*), barnyard grass (*Echinochloa spp.*), and cattails (*Typha spp.*), that are not salt tolerant. Specific vegetation composition can vary annually due to flooding regimes. This manmade system is managed using one water control structure located at the junction of the Slaughter Canal and Fowler Beach Road (Fig. 2).

Salinity is one of the key ecological factors influencing the type of vegetation that will be sustained in wetlands behind barrier beach island shorelines. Salinity variation is biologically very significant. Fresh water is defined as the dissolved salt content of a water column ranging from zero to 0.5 parts per thousand (ppt). Brackish environmental conditions are defined as greater than 0.5 to 29 ppt, and saline conditions range from 30 to 50 ppt. Brackish salinities can further be reduced to three classes: oligohaline, mesohaline, and polyhaline, and saline conditions can be mixoeuhaline, metahaline or hyperhaline.

Desirable moist soil vegetation that has been targeted for management in refuge freshwater impoundments do best when growing in oligohaline environmental conditions (0.5 to 5.0 ppt) averaging from 1 to 2 ppt. Target moist-soil wetland plants can survive in mesohaline (> 5.0 to 18 ppt) conditions but yield smaller annual seed production per acre of wetland habitat compared to plants growing under oligohaline conditions.

From 1991 to 2008, salinity ranges recorded at the water control structure between Units I and II ranged from 0 to 12 ppt with seasonal averages of about 5 to 8 ppt. However, in the past two years these ranges and averages have been steadily increasing. From 2008 to 2010, the formerly freshwater Unit II system has had increasing salt water intrusion. The Mother's Day 2008 Nor'easter and overwash in Unit I, and subsequent storms, have continually added to the saltwater in Unit II. Salinity ranges in 2009 ranged from 5 to 30 ppt with averages creeping up to 15 ppt. During the first four months of 2010, average salinities are up to 20 ppt. In 2008 and 2009, moist-soil vegetation in the northern portion of Unit II was replaced by halophytic vegetation. Species such as glasswort (*Salicornia spp.*), saltmeadow cordgrass (*Spartina patens*), and smooth cordgrass (*S. alterniflora*) have recolonized about 20 percent of the area in the northern, more saline portions of the Unit II impoundment, replacing smartweed, barnyard grass, and cattails. A large portion of Unit II is currently either mudflat or open water, and the remainder of the unit is in a state of fluctuation in response to changing salinity levels. Only a small portion of the unit, primarily in the southern half, could still be considered freshwater marsh. Over the last few months an outbreak of an algal species (Genus *Cladophora*) has occurred in the unit. The refuge staff is working with our partners to determine the source of this issue.

2. Environmental Consequences

a. Alternative 1 (No Action)

If Alternative 1 were implemented, tidal flows established from inlets formed in fall 2009 would continue to introduce new sediments to Unit II that could aid in the restoration of the unit to salt marsh. The higher saline conditions would result in greater halophytic vegetation re-colonizing back-barrier wetlands and washover habitats. Freshwater plant species would continue to decline and be replaced by salt marsh vegetation species. Without a concerted effort to raise marsh levels, some additional portions of the unit may convert to open water due to subsidence and low accretion rates.

b. Alternative 2 (Proposed Action)

If Alternative 2 were implemented, daily tidal flow would be terminated, trapping higher saline waters behind the stabilized dunes. During growing seasons, these saline waters would increase in salinity due to evaporation and also increase soil salinities. Overwash salinity data taken in 2008, 2009, and 2010 from Units I and II show that this phenomenon occurs even when inlets are open, especially during the summer months. These environmental conditions eliminate the growth of annual freshwater moist-soil vegetation behind stabilized dunes. The area will most likely be colonized by halophytes or salt marsh vegetation if growing conditions allow. Scraping during construction may disturb any newly established American beach grass or overwash dune grassland herbaceous communities; however, to date little vegetation has colonized the site. Planting dune grass after reconstruction may also help reduce impacts because grass roots hold bulldozed sand in place, and may allow ghost crabs (*Ocypode quadrata*) to burrow more effectively (Peterson et al. 2000).

c. Alternative 3

Consequences of Alternative 3 are very similar to those for the Proposed Alternative, except that more sediment and substrates would be available for salt-tolerant vegetation to colonize Unit II, as washover habitats would not be scraped to stabilize the dune.

C. Impacts on Migratory Birds and Other Wildlife

1. Affected Environment

The refuge project area contains horseshoe crab (*Limulus polyphemus*) spawning habitats, beach nesting habitats for shorebirds, an osprey nesting platform, spring and fall migration habitats for shorebirds and other migratory birds, intertidal and beach habitats that provide microhabitats for a diversity of infauna (organisms that burrow and reside in marine and sandy sediments) and small fishes.

Barrier island sandy beach and associated coastal habitats are priority conservation habitat types within the Delaware Bay and Mid-Atlantic Region. The undeveloped shorelines and associated salt marsh habitats support the greatest diversity of species of conservation concern. Beach overwashes provide habitats that can sustain many State and federally listed bird species such as piping plover (*Charadrius melodus*), American oystercatcher (*Haematopus palliatus*), least tern (*Sternula antillarum*), common tern (*Sterna hirundo*), and black skimmer (*Rynchops niger*).

Delaware Bay sandy beach and coastal wetland communities also support a noteworthy shorebird migration that has worldwide ecological significance. Despite the heavy loss of these habitats to development, Delaware Bay coastal habitats remain one of the region's and Western Hemisphere's most important migratory stopovers for hundreds of bird species, especially shorebirds. Undeveloped beach and overwash patches are considered important habitats for these birds, regardless of patch size (USFWS 2003).

Shoreline and sandy beach habitats are shaped by storm surges and other physical driving forces like tides. Storm events and daily high tides deposit wrack composed of algae, vascular plant fragments, assorted mollusks, whelk casings, remnants of clams, crabs, other macroinvertebrates, and small fish. Coupled with spawning sites for horseshoe crabs that supply clusters of highly nutritious eggs in the sand, wrack lines provide rich and plentiful natural food resources for migrating and nesting shorebirds in spring and summer. Shorebird nesting seasons range from March 1 to September 1. Peak spring shorebird migrations range from April 15 to June 1, and peak fall shorebird migrations occur from July 1 to September 1. As many as 8,000 shorebirds have been documented using the overwash in Unit I during the spring migration.

Habitats created by overwash fans and spits at the edges of inlets are ideal and highly productive habitats for many species of shorebirds and other migratory birds due to the proximity to both bayside and interior feeding areas. For example, species of concern such as the piping plover and red knot (*Calidris canutus*), utilize these barrier beach and overwash habitats. Due to the amount of manipulation of barrier islands along the Atlantic Coast flyway, these habitats are rare and often degraded or compromised.

Adult horseshoe crabs gather on sandy beach environments in large numbers in spring to dig nests and lay and fertilize eggs. The start of their inshore movement from deep bay and coastal waters is triggered by lengthening daylight hours. Spawning on the Delaware Bay begins during the latter part of May and peaks with the high tide cycles during full and new moons through June. Spawning adults prefer sandy beach habitats in bays and other areas protected from wave energy. Sandy beach habitat must also include porous, well-oxygenated sediments to provide a suitable environment for egg survival and development. If optimal spawning areas become limited, spawning may occur along peat banks if sand is present or along the mouths of sandy inlets or salt marsh creeks (ERDG 2003).

Numerous waterfowl species utilize the managed freshwater impoundment behind the project area within Unit II. The moist soil vegetation provided by freshwater management provides an abundant food supply, concentrating waterfowl during migration and winter.

Peak waterfowl populations range from 21,243 in 1987 to a high of 224,693 in 1999. In 2008, the peak waterfowl population at the refuge was 90,875 birds.

2. Environmental Consequences

a. Alternative 1 (No Action)

If Alternative 1 were implemented, there would be no impact to migratory birds and other wildlife that use the project area as breeding or migration stopover habitat, such as piping plovers, American oystercatchers, black skimmers, numerous species of terns and other shorebirds, diamondback terrapins (*Malaclemys terrapin*), and horseshoe crabs. As Unit II reverts from a freshwater impoundment to a salt marsh, the abundance and/or composition of waterfowl using Unit II will likely shift. For example, American black duck (*Anas rubripes*) use may increase, while more freshwater-associated species like Northern pintail (*Anas acuta*) may decrease. Overall, the area will still provide valuable waterfowl habitat.

Remaining unmanipulated overwash fans and inlets will provide wildlife habitat, which may increase and contribute to increased breeding, feeding, and resting habitats for those species of migratory shorebirds which cluster there.

b. Alternative 2 (Proposed Action)

If the Proposed Action were implemented, construction activities would not interfere with peak spring and fall shorebird migrations or peak horseshoe crab spawning activities. The refuge manager will coordinate with State and federal biologists who monitor beach nesting birds to guide the work schedule of the project. Weekly beach bird nesting surveys conducted by the State will serve to inform all parties so that Proposed Action activities will not be initiated if there are active nesting attempts by either federally or State listed bird species. Once the project is complete, no negative impacts are anticipated for shorebirds.

Heavy equipment use, sand pushing, and dune rebuilding activities would occur primarily after August 15, once established beach bird nests have fledged, to minimize negative impacts to spawning horseshoe crabs and beach nesting birds. During construction, portions of the shoreline frequently traveled by heavy equipment will likely not be appealing to birds. They will likely find suitable undisturbed portions of the beach to forage and rest. No significant differences are anticipated in use of Unit II by waterfowl once the project is complete.

Relocation of the sediments from overwash fans will reduce the quality of these areas as wildlife habitat for the migratory bird species that tend to concentrate on these habitats.

c. Alternative 3

The same environmental consequences and mitigation measures would be generally applicable for Alternative 3 as are described for Alternative 2 above.

D. Impacts on Invertebrates

1. Affected Environment

The intertidal areas of beaches and inlets provide habitats for a great diversity and abundance of invertebrates. The environment between the grains of sand harbor interstitial organisms (e.g., bacteria, protozoans, microalgae, and meiofauna [small benthic invertebrates]) that form a distinct food web that supports zooplankton and macroinvertebrates (invertebrates which are retained on a 0.5 mm sieve).

Benthic macroinvertebrates in these habitats can reach high abundance (ca. 100,000 individuals per square meter). Surf zones and tidal inlets are important nursery and foraging areas for fishes and waterbirds because of high densities of invertebrates (Defeo et al. 2009; McLachlan and Brown 2006). The porous sandy substrate of beach ecosystems also filters water, houses and feeds invertebrates that mineralize organic matter, and recycles marine nutrients, making sandy beach habitats a crucial element in the nearshore processing of organic matter and nutrients that help to maintain high densities of invertebrates (Defeo et al. 2009).

2. Environmental Consequences

a. Alternative 1 (No Action)

If the No Action Alternative were implemented, no physical damage to invertebrate populations would occur during construction. Overwash fans and tidal inlets are formed when water flows across barrier-beaches during storm surges or spring high tide cycles, which provides rich influxes of invertebrates to the system. Storm-surge channels that cut through foredune ridges not only serve as conduits for the transport of sediment materials, but also move invertebrates from nearshore environments to the beach face and to back-barrier environments. As the overwash fan builds, the movement of daily water flow will be reduced over time, which will reduce the influx of invertebrates to the back-barrier wetlands of Unit II. This will reduce the tidal invertebrate source available to migratory birds and other wildlife; however, invetebrate availability is not expected to be limited in the unit. Tidal invertebrate sources would recharge the area during storm events and extreme high tides that exceed daily tidal flows.

b. Alternative 2 (Proposed Action)

Construction activities associated with Alternative 2 will cause temporary damage to sandy beach and washover habitats by compacting sand and disturbing the physical environment that supports invertebrates (Peterson et al. 2000). The wrack lines in the project area would be buried by sand or trampled by heavy equipment, which would temporarily disturb invertebrate prey. During construction, shorebirds that may benefit from them will forage on undisturbed portions of the beach. Wrack lines would quickly rebuild with daily tidal cycles once construction was complete.

Scraping washover sediments and rebuilding dunelines can also kill invertebrates by deep burial. Negatively affected invertebrates include benthic macroinvertebrates, terrestrial arthropods like beach dune tiger beetles (*Cicindela dorsalis dorsalis*), and other macroinvertebrates (predominantly crustaceans, mollusks, and polychaete worms). It is expected that due to the sheer volume of invertebrates, these populations would recolonize and recover fairly quickly.

Levisen and Van Dolah (1996) studied infaunal recovery after bulldozing occurred on a beach in South Carolina. Within 60 days, species abundance and diversity of the overall faunal complex and abundance of dominant taxa recovered. This study supports earlier findings that documented quick recovery of invertebrate fauna and no long-term changes to species composition from beach scraping (Baca and Lankford 1988; CSA 1991; Lankford and Baca 1987; Lankford et al. 1988). Peterson et al. (2000) documented a 100 percent increase in abundance of coquina clams (Genus *Donax*) following bulldozing activities. Lindquist and Manning (2001) did not detect any negative impacts to the amphiopod *Amphiporeia virginiana* or the polychatete *Scolelepis squanata*. The Lindquist and Manning (2001) study documented negative impacts to some species, most notably mole crabs (*Emerita talpoida*) and ghost crabs. The cause could not be determined. The majority of bulldozing activity for the Proposed Action will take place on the landward side of the dunes, which should reduce impacts to crabs. Negative environmental consequences could be mitigated if heavy equipment, washover scraping activities, and duneline rebuilding occur toward the end of the summer or later.

c. Alternative 3

The same environmental consequences and mitigation measures would be applicable for Alternative 3 as are described for Alternative 2 above.

E. Impacts on Cultural and Historical Resources

1. Affected Environment

Predictive models provide means for archaeologists and land managers to identify landforms that are likely to contain undiscovered archaeological sites and/or artifacts. These models have been used in the past at the refuge with success when surface disruptive management actions have occurred (Tetra Tech 2004).

Prehistoric cultural contexts in Delaware are described in terms of five major chronological periods that correspond to broad adaptive shifts to changing natural and cultural conditions. These cultural periods are the Paleo-Indian (14,000 to 8,500 BP [Before Present]), Archaic (8,500 to 5,000 BP), Woodland I (5,000 to 1,000 BP), Woodland II (1,000 to 500 BP), and Contact Periods (500 to 300 BP) (Custer 1984). Cultural periods are usually identified from chronologically diagnostic artifacts such as projectile points, ground and chipped stone technologies, and/or pottery styles during these cultural periods (Tetra Tech 2004).

In Delaware throughout the prehistoric period, highly productive rivers, streams, wetlands, and beach habitats repeatedly attracted Native Americans. These marine environments changed over millennia. Rising sea levels have progressively inundated the coastal zone of the Delaware Bay and stream drainages in the areas of the refuge for thousands of years (Tetra Tech 2004).

These rising sea levels eroded greater numbers of early Holocene Paleo-Indian and Archaic period sites than later Woodland II and Contact period sites. Recognizing the prehistoric settlement patterns on uplands adjacent to marine habitats (Custer and Galasso 1983) and the effects of sea level rise in former landforms, the likelihood of paleogeography and prehistoric sites on the refuge could be predicted (Tetra Tech 2004). This model was instrumental in structuring archaeological monitoring during open marsh water management (OMWM) work conducted on the refuge for mosquito control. The validity of this model has been demonstrated through the identification of eight prehistoric and two historic sites during OMWM work with artifacts recovered and associated records documented on Delaware Cultural Resource Survey Archaeological Site Forms by the Bureau of Archaeology and Historic Preservation. All artifacts retrieved from these sites are kept at Delaware State Museums in Dover, Del.

The Proposed Action areas may be located on or near moderate-to-high probability zones of prehistoric site sensitivity according to predictive models (Tetra Tech 2004). The shoreline along the refuge has migrated about 150 to 200 feet in the last 24 years, positioning proposed work possibly on or near potential archaeological zones. However, no known sites exist in the project area and the proposed work will not extend below modern overwash sand. As a part of the regulatory process, we will seek concurrence with the State Division of Historical and Cultural Affairs that no historic properties will be negatively impacted by project work.

2. Environmental Consequences

a. Alternative 1 (No Action)

No threats to cultural and historic resources would occur under the No Action Alternative. However, eventual erosion of marshland would likely occur from natural causes, thereby threatening any archaeological resources within them.

b. Alternative 2 (Proposed Action)

The Service's Regional Historic Preservation Officer anticipates concurrence from the Delaware Division of Historical and Cultural Affairs that no historic properties will be affected under the Proposed Action because no historic structures exist within the proposed work area or its viewshed and all work will be entirely within the horizontal and vertical limits of modern overwashed sands.

While it is possible that archaeological resources exist in marsh deposits beneath the sand, the construction project will require that a minimum of two feet of sand remain in place to provide stability for heavy equipment. That sand has been deposited since fall 2009 so work would not disturb strata deposited prior to that time.

c. Alternative 3

It is expected that no impacts to cultural or historical artifacts would occur if Alternative 3 was implemented.

F. Impacts on Social and Economic Resources

1. Affected Environment

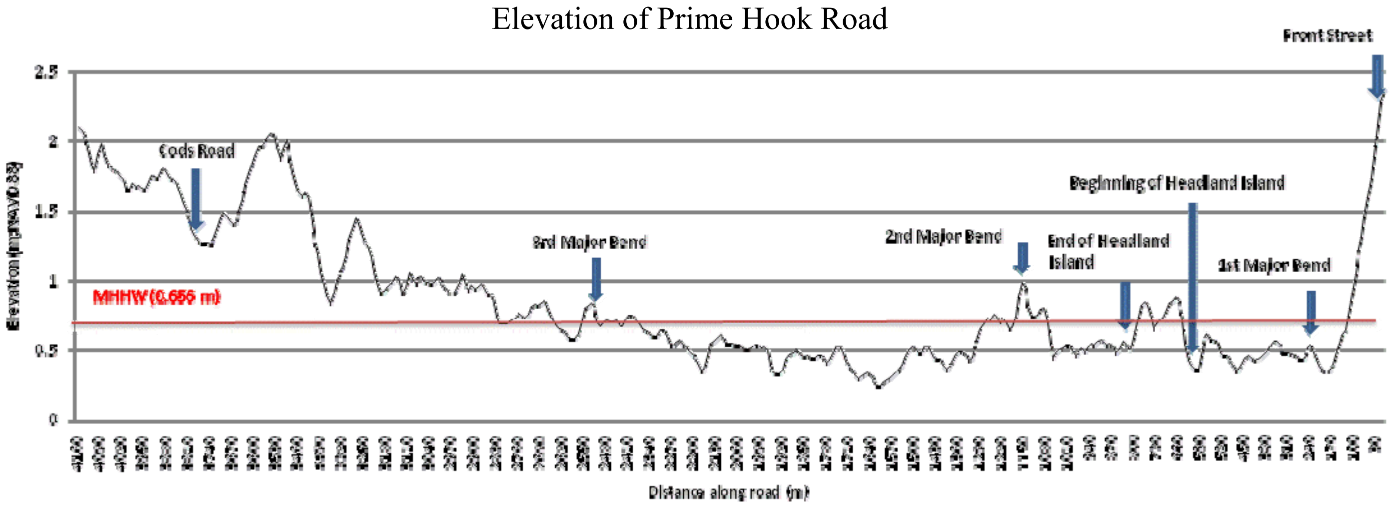
The refuge project site is intertwined with three adjacent landowners, who are all cooperators with the proposed duneline work. No structures are located on the project site. Portions of the beach in the project area are used for recreation, such as fishing, walking, and wildlife observation and photography.

The closest community to the project site is Primehook Beach, which is located approximately 1 mile south of the project area. As of 2004, there were 206 home or landowners in the community, including 43 full-time residents and 163 seasonal residents. The only road access to the community is on Prime Hook Road, which is owned by the State of Delaware. Road elevations are extremely low in several locations, below MHHW, which makes transit unsafe and/or nearly impossible during very high tides (Fig. 5).

The Prime Hook Beach Organization and several community members have contacted refuge staff repeatedly about their concerns that the inlet created in fall 2009 is negatively impacting access and egress to and from their community, and that it has exacerbated flooding in the area. However, the complexities involved in the coastal ecosystem and the trend towards more and higher intensity storms with associated extreme high tides, as discussed earlier in this document, play a significant role in the increased flooding. No single factor can be attributed to the increased flooding in the area.

The Proposed Action seeks to alleviate current concerns, while causing minimal environmental impacts, to allow the Service to proceed with the Comprehensive Conservation Plan and subsequent step-down planning process for long-term management of habitat on the refuge. The CCP will lay the groundwork and set clear strategies that will address the multitude of factors affecting the refuge and the area.

Figure 5 - Elevations of Prime Hook Road in relation to MHHW, along the segment depicted in red on the aerial photograph below.



2. Environmental Consequences

a. Alternative 1 (No Action)

If No Action were taken at this time, the local community would continue to be concerned about access and egress to and from their properties. Unfortunately, this issue has caused a significant amount of animosity between some community members and the Service. The lack of action on the part of the Service would not alleviate that situation.

b. Alternative 2 (Proposed Action)

If Alternative 2 were implemented, the local community would benefit from the temporary mitigation of concerns about flooding and shoreline erosion. In the meantime, the community members would be afforded the opportunity and the time to review future refuge management plans in more detail through the public comment period of the CCP process and subsequent step-down plans.

c. Alternative 3

If Alternative 3 were implemented, the community would benefit as in Alternative 2. This alternative, however, costs significantly more than the Proposed Action.

G. Cumulative Impacts of the Proposed Action on Sandy Beach Habitats and Reasonably Foreseeable Future Management Actions on the Refuge

The work of local and regional geologists and other scientists continues to inform our understanding of the importance of geology and site-specific geomorphological features with respect to artificially stabilized dunes and their relationship to natural shoreline erosion, accretion cycles, and sediment budgets of barrier island and back-barrier wetlands. Furthermore, by researching the geologic framework of the refuge, we understand that erosion of refuge sandy beach habitats and private beach areas has been exacerbated locally by historic and recent human activities that create “legacy effects” on sediment budgets and the saline environment of refuge coastal habitats. Most of these human effects can have long-term and cumulative sediment supply and salinity consequences. Some of these localized human activities could include:

1. Hard armoring of shorelines with cyclic beach nourishment in Slaughter Beach and Broadkill Beach communities.
2. Stabilization of Roosevelt Inlet and the construction of inner and outer breakwater seawalls in Lewes, which have changed the direction and intensity of littoral drift and sediment supply along Delaware Bay shorelines (Kraft et al. 1976).
3. Significant localized groundwater withdrawals off-refuge that increase and amplify local subsidence effects and intensify cumulative salinity intrusion effects to refuge ground and surface waters along the marsh/upland interface.

Some of the most significant impacts resulting from these activities include blocked and drawn-off littoral sand transport from refuge and Primehook Beach habitats, increased shoreline breaching potential, and expedited barrier island roll-over (Fletcher et al. 1990; Kraft et al. 1976).

Geologists, climatologists, and other scientists clarify that barrier beach island storm-driven processes are dominated by numerous and frequent inlet formations, the development of extensive overwash depositional fans, and higher rates of shoreline erosion. These are all integral processes of barrier beach island migration or roll-over that will occur more frequently in a changing climate (CCSP 2009).

Overwashes and inlets act as safety valves by adjusting and shifting in size and location in response to each and every set of unique storm conditions that generate the various wind and wave-forcing effects on shorelines. Artificial duneline stabilization disrupts the self-adjusting, safety valve function of inlet formation, the sediment by-pass system between island shorelines and the exchange of sediment from near-shore to back-barrier marshes. It negatively impacts sediment budgets of associated wetlands and suppresses natural sand movements in coastal ecosystems (S. Adamowicz, pers. comm. 2010; R. Burdick, pers. comm. 2010; Pilkey and Neal 2009; Riggs et al. 2009).

Shoreline roll-over or retreat is a cumulative effect of rising sea level and has occurred many times in history (CCSP 2009; Kraft et al. 1976; Riggs et al. 2009). Local examples where shoreline retreat is easily observed include the World War II sentinel tower and the refuge observation tower (built in 2006) at the end of Fowler Beach Road. These structures were originally built well behind the dunes and are now located in the bay or intertidal zone. The spatial and temporal effects of building groins, bulkheads, and hard armoring shorelines along Slaughter and Broadkill beaches, and establishing Lewes breakwaters, may have significantly altered the long-shore transport of sediments and reduced natural sand deposition along refuge and Primehook Beach shorelines that are today considered sediment starved. The environmental consequences of coastal erosion and flooding trigger subsequent adaptive responses by natural beach ecosystems that seek new equilibrium points to adjust to sea level rise and increased storminess. The effect of sea level rise is also compounded on gently sloping Atlantic coastal plain shorelines. A one-meter increase in sea level may not seem ominous, but trigonometry indicates that on gently sloping coasts, a one-meter rise could result in landward migration of the shoreline from 200 to 300 meters or more (Coch 2009).

Human activities that repeatedly keep shorelines in place in attempts to minimize impacts of coastal flooding and reduce erosion can and will generate long-term negative environmental consequences for sandy beach and back-barrier marshes along barrier island shorelines that are managed primarily for wildlife and conservation purposes (Defeo et al. 2009; Pilkey and Young 2009; Riggs et al. 2009). Rebuilding dunes after each storm may be desired to protect private homes and other private property; however, these repeated activities interfere with shoreline recession, barrier beach island evolution and migration, and conditions that facilitate the accretion of back-barrier salt marsh habitats.

A scenario of continual rebuilding of artificial dunes could have long-term and cumulative negative impacts and consequences. The system at Prime Hook Refuge and the adjacent community is complex, and much is still not known regarding the effects of the interaction of the multiple factors described in this document. Geologists recommend that artificial dunes not be rebuilt after storm damage to allow tidal inlet and overwash formation that reduces the vulnerability of back-barrier marshes to sea level rise by increasing vertical sediment accretion (Pilkey and Neal 2009; Riggs et al. 2009; Stevenson and Kearney 2009).

Cumulative impacts of human activities that repetitively stabilize dunelines on sandy beach habitats also have the negative consequences of significantly narrowing barrier island shoreline strands. This can ultimately lead to the collapse and disappearance of these ribbons of sand, and significantly increase the vulnerability of back-barrier marshes to sea level rise (Coch 2009; Levine et al. 2009; Pilkey and Young 2009; Reed et al. 2008; Riggs et al. 2009).

Given the information cited above, the Proposed Action is a short-term solution which allows the management action to occur as needed until decisions regarding future management of all refuge impoundments are made through the CCP and step-down planning processes. This short-term decision does not prevent the Service from implementing a different longer term solution if one emerges from the NEPA/CCP process. All plans will be available for public review and comment.

VI. CONSULTATION AND COORDINATION WITH OTHERS

This plan will go through a Section 7 review for activities associated with federally listed endangered or threatened species. Section 7 of the Endangered Species Act and intra-Service coordination and consultation with the Service's Chesapeake Bay Field Office will be conducted for Delmarva fox squirrel (*Sciurus niger cinereus*) and piping plover.

Activities associated with wetlands (e.g., dune construction) will require a Section 404 permit from the U.S. Army Corps of Engineers (Corps). In addition, the DNREC's Wetland section may require a permit for water quality certification. Permits will be obtained before initiating any project. Section 404 of the Clean Water Act regulates discharge of dredged and fill material to waters of the United States, including wetlands under federal jurisdiction. Section 10 of the Rivers and Harbors Act regulates activities along navigable rivers and waterways. Both are simultaneously administered by the Corps.

Section 401 of the Clean Water Act requires states to certify that activities authorized by the federal government pursuant to Section 404 of the Clean Water Act will not violate the State Water Quality Standards. A project specific application for Water Quality Certification is generally required for all projects requiring an Individual Permit from the Corps, as well as for certain projects that qualify for a Corps Nationwide Permit but are located in environmentally sensitive areas.

In addition, permits must be obtained from DNREC's Division of Soil and Water Conservation (Shoreline and Waterway Management Section). These permits pertain to compliance with the "Regulations Governing Beach Protection and the Use of Beaches" (effective December 27, 1983). This permit regulates construction activities within the defined beach area and landward of the DNREC building line.

Coastal Zone Management Federal Consistency is a process that requires federal agencies to follow State coastal management policies when conducting a project or issuing a permit that could affect coastal resources. It also enables increased coordination between government agencies. The program was established by Congress in 1972 by the Coastal Zone Management Act. Every coastal State implements a Federal Consistency program.

Federal Consistency requires that projects conducted directly by a federal agency, projects authorized by a federal permit and some projects implemented with federal funds be consistent with Delaware's Coastal Zone Management policies. Projects are reviewed by Delaware Coastal Management Program staff in close coordination with other agencies. If projects are consistent with the policies, Federal Consistency "concurrence" is issued.

The Service's Regional Historic Preservation Officer has reviewed this assessment. As a part of the regulatory process, we will seek concurrence with the State Division of Historical and Cultural Affairs that no cultural artifacts will be negatively impacted by project work.

This EA will be available for public review for 30 days. Comments must be submitted in writing directly to the refuge office. Comments can be sent via electronic mail (fw5rw_phnwr@fws.gov), faxed (302/684-8504), or sent to the refuge office (11978 Turkle Pond Road, Milton, DE 19968). All comments received will be reviewed and considered in the development of the final EA. A written review of all comments will be incorporated into the final EA. This draft EA will be revised once all comments have been considered and the Service has incorporated those comments into the final EA.

Once the final EA has been written, a Finding of No Significant Impact (FONSI) statement will be reviewed and signed by the Regional Director. The final EA will be released and will be available to the public upon request.

VII. LITERATURE CITED

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Glossary

Accretion: The accumulation of sediments that deposit and increase the size of a land or marsh area. This increase may be lateral or vertical.

Accretion, lateral: The extension of land by natural forces acting over a long period of time, as on a beach by the washing-up of sand from the sea or on a floodplain by the accumulation of sediment deposited by creek or stream.

Accretion, vertical: The vertical accumulation of a sedimentary deposit that increases the thickness of sediment layers.

Armored shoreline: The placement of fixed engineering structures, typically rock or concrete, on or along a shoreline to mitigate the effects of coastal erosion. Such structures include seawalls, bulkheads, and riprap.

Back-barrier: Of or pertaining to area of land between barrier island areas and the mainland.

Back-barrier flats: Low-lying sandy regions on the landward side of sand dunes often covered with salt-tolerant grasses and shrubs.

Back-barrier marshes: Marsh formed on the landward side of a barrier beach island, often containing significant coarse sediment that has washed in from the bay or seaward side.

Barrier island: A long, narrow coastal sandy strip parallel to the shore, the crest of which is above normal high water level, and that commonly has dunes, vegetated zones, and remnant marsh terraces extending landward from the beach. It is usually built up by the actions of waves and currents.

Barrier island rollover: The landward migration or landward transgression of a barrier island, accomplished primarily over decadal or longer periods of time through the process of storm overwash, periodic inlet formation, and wind-blown transport of sand.

Barrier migration: The movement of an entire barrier island in response to sea level rise, changes in sediment supply, storm surges or waves, or some combination of these factors.

Beach erosion: Carrying away of beach materials, mostly sand by wave action, tidal currents, littoral currents, wind, or storm surges.

Beach nourishment: The addition of sand, often dredged from offshore sources, to an eroding shoreline to enlarge or create a beach area, offering temporary shore protection and recreational opportunities on public beaches. It is the most popular soft engineering technique of coastal defense management schemes.

Breach: A channel through a barrier island typically formed by storm waves, tidal action, or barrier migration. Breaches commonly occur during high storm surge caused by hurricanes or Nor'easters.

Coastal Plain: Any low-lying areas bordering the bay or ocean, extending inland to the nearest elevated land, and sloping very gently towards the water.

Dike: A wall of earthen materials designed to prevent the permanent submergence of lands below sea level, tidal flooding of lands between sea level and spring high water, or storm-surge flooding of the coastal floodplain.

Downdrift: Refers to the location of one section or feature along the coast in relation to another; often used to refer to the direction of net longshore sediment transport between two or more locations (i.e., downstream).

Duneline: Any natural hill, mound, or ridge of sediment landward of a coastal berm deposited by the wind or by storm overwash, capable of movement from place to place and may be either bare of covered with vegetation. A duneline is linear in nature. An artificial dune is sediment deposited by artificial means and serving the purpose of erosion control and storm-damage prevention.

Duration: In wave forecasting, the length of time the wind blows in nearly the same direction over a body of water.

Ebb tide: The period of the tidal cycle between high water and low water; a falling tide.

Erosion: The mechanical removal of sediments by water, ice, or wind. In the context of coastal settings erosion refers to landward retreat of a shoreline indicator such as the water line, or berm crest. The loss occurs when sediments are entrained into the water column and carried landward or seaward.

Fetch: The area of open water where winds blow over with constant speed and direction, generating waves.

Flood tide: Period of time between low water and high water; a rising tide.

Forcing: To hasten the rate of a process or growth; with respect to coastal sensitivity to sea level rise, forcing generally refers to climate change factors that act to alter a particular physical, chemical, or biological system such as changes in climate like CO_2 concentration, temperatures, sea level, or storm characteristics.

Geologic framework: The underlying geological setting, structure, and lithology (rock or sediment type) of a given area. The geologic framework of Prime Hook Refuge's shoreline habitats is characterized as a saline fringe, wave-dominated barrier island setting.

Geosyncline: A very large, troughlike depression in the earth's surface containing masses of sedimentary and volcanic rocks

Geomophology (geomorphic): The external structure, form, and arrangement of rocks or sediments in relation to the development of the surface of the Earth.

Global sea level rise: The world-wide average rise in mean sea level; may be due to a number of different causes, such as the thermal expansion of sea water and the addition of water to the oceans from the melting glaciers, ice caps, and ice sheets; contrast with *relative sea level rise.*

Groin: An engineering structure oriented perpendicular to the beach, used to accumulate littoral sand by interrupting longshore transport processes; often constructed of concrete, timbers, steel, or rock.

Holocene: A geological epoch which began approximately 12,000 years ago. According to traditional geological thinking, the Holocene continues to the present. The Holocene is part of the Quarternary period. It is identified with the current warm period and is considered interglacial in the current Ice Age.

Infauna: Aquatic animals live within the bottom substratum of a body of water, such as a soft sea bottom, rather than on its surface

Littoral: Area between high and low tide in coastal waters.

Littoral transport: The movement of sediment such as sand and stones near the shore (littoral drift) in the littoral zone by waves and currents; includes movements parallel (longshore transport) and perpendicular (cross-shore transport) to the beach.

Littoral zone: In beach terminology, an indefinite zone extending seaward from the shoreline to just beyond the wave breaking zone.

Longshore transport: Movement of sediment parallel to the shoreline in the surf zone by wave suspension and the longshore current.

Mean high water (MHW): A tidal datum; average height of all of the high water marks recorded at a given place over a 19-year period (Metonic Cycle).

Mean higher high water (MHHW): The mean of the higher of the two daily high waters over a long period of time.

Mean low water (MLW): Average height of all of the low water marks recorded at a given place over a 19-year period.

Mean sea level (MSL): Average height of the surface of the sea at a given place of all stages of the tide over a 19-year period. The values of mean sea level are measured with respect to the level of marks on land (called benchmarks). Water levels measured at the Unit III water control structure is set at this datum.

Neap tide: Tide occurring near the time of quadrature of the moon with the sun (first and last quarters). The neap tide range is usually 10-30% less than the mean tidal range.

Nearshore zone: Refers to the zone extending from the shoreline seaward to a short, but indefinite distance offshore, typically confined to depths less than 5 meters (16.5 feet).

National Geodetic Vertical Datum 1929 (NGVD 29): A fixed reference adopted as a standard geodetic datum for elevations; it was determined by leveling networks across the United States and sea-level measurements at 26 coastal tide stations. Water levels measured at the Unit II water control structure is set at this datum. This reference is now superseded by the North American vertical datum of 1988 (NAVD 88).

Nor'easter: On the U.S. East Coast, a low-pressure storm system whose counterclockwise winds approach the shore from the northeast as the storm passes through. These extra-tropical coastal storms often cause significant beach erosion and property damage. Wind gusts associated with these storms can approach and often exceed hurricane force effects in intensity.

North American Vertical Datum 1988 (NAVD 88): A fixed reference for elevations determined by geodetic leveling, derived from a general adjustment of the first-order terrestrial leveling networks of the United States, Canada and Mexico. NAVD 88 supercedes NGVD 29.

Overwash: Uprush and overtopping of a coastal dune or berm. Sediment is carried with the overwashing water and transported from the beach across the barrier island and is deposited in an apron-like accumulation of sand along the backside of the barrier. Overwash usually occurs during storms when waves break through the frontal dune ridge and flow landward toward the marsh.

Pleistocene: The geological epoch from 2.588 million to 12,000 years BP covering the Earth's most recent period of repeated glaciations. The end of the Pleistocene corresponds with the retreat of the last continental glacier and also with the end of the Paleolithic age used in archaeology.

Relative sea level rise: The rise of sea level measured with respect to a specified vertical datum relative to the land, which may also be changing elevation over time; typically measured using a tide gauge, which record both the movement of the land to which they are attached and the changes in global sea level.

Sediment supply: The abundance or lack of sediment in a coastal system that is available and contributes to the maintenance and evolution of barrier island and sandy beach ecosystems, and back-barrier marshes.

Shoreline: The intersection of a specified plane of water with the beach. The line representing the shoreline approximates the mean high water line.

Spring tide: The average height of the high waters during the semimonthly times of spring tides which occur at the full and new moon cycles. Spring tides rise the highest and fall the lowest from the mean sea level.

Storm surge: An abnormal rise in sea level accompanying an intense storm, whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the storm.

Subsidence: The downward sinking or warping of the Earth's crust relative to its surroundings; downward settling of material with little horizontal movement.

Tidal inlet: An opening in the shoreline through which tidal water penetrates the land. In our geomorphic setting, a tidal inlet formed in this way provides a connection between the Delaware Bay with some Atlantic Ocean influence and back-barrier marshes.

Tide gauge: The geographic location where tidal observations are conducted. A tide gauge consists of a water level sensor, data collection and transmission equipment, and local benchmarks that are routinely surveyed into the sensors.

Transgression: The spread or extension of the sea over land areas, and the consequent evidence of such advance; any change in sea level rise that brings offshore deep-water environments to areas formerly occupied by nearshore, often resulting in barrier island rollover.

Washover: The sediment deposited landward of a beach by the process of overwash. Sediment transported by overwash can be deposited landward onto the upper beach or as far as back-barrier wetlands. Washover contributes to the sediment budget of barrier islands and is believed to be a major process in the retreat mechanism of some coastal barrier islands in response to sea level rise.

Wetland accretion: A process by which the surface of wetlands increases in elevation; see also accretion.

Wetland migration: A process by which tidal wetlands adjust to rising sea level by advancing inland into areas previously above the ebb and flow of the tides.