Feasibility Study:
NC 12 Ocracoke Island Hot Spot

Ocracoke Island, Hyde County

Prepared for:
North Carolina Department
of Transportation,
Project Development and
Environmental Analysis

Prepared by:
WSP | Parsons Brinckerhoff
Raleigh, NC

December 2016

Feasibility Study

NC 12 Ocracoke Island Hot Spot
Ocracoke Island

Hyde County, North Carolina

Division 1
R-3116A
WBS No. 34525.1.3

Prepared for the
North Carolina Department of Transportation

12/21/16

Nicole H. Bennett, AICP
WSP I Parsons Brinckerhoff
Project Manager
Date

12/21/16

Nora McCann, E.I.T.
North Carolina Department of Transportation
Project Development Engineer
Date

12.21.16

Brian Yamamoto, P.E.
North Carolina Department of Transportation
Project Development Group Supervisor
Date

Table of Contents

List of Figures

List of Tables

1.0 Executive Summary

Ocracoke Island is a coastal barrier island in the southeast portion of Hyde County. The majority of the island is part of the Cape Hatteras National Seashore. Regional access is provided by three NCDOT operated ferries: Hatteras Inlet Ferry Dare County, Swan Quarter Ferry, Hyde County, and Cedar Island, Carteret County. The Hatteras Inlet Ferry is the most widely used ferry to access Ocracoke Island. NC 12 runs throughout the entire Outer Banks region of North Carolina. NC 12 and ferry operations are subject to heavy seasonal variations in traffic and use related to summer tourism. Summer weekends are the peak times for short-term population increase. In general, the summer population makeup is approximately 90 percent tourists and 10 percent permanent residents.

NC 12 is North Carolina's easternmost primary route. It is mostly a two-lane roadway that runs along the North Carolina Outer Banks from Corolla in the northeastern section of the state, Dare County, to the unincorporated community of Sea Level in southeastern Carteret County.

In 1991, NCDOT identified six "hot spots" along NC 12 in need of extensive maintenance due to continued severe storm and erosion damage.

The project's need is based on frequent overwash and flooding on NC 12; need for continual maintenance; vulnerability of the roadway in its current location due to erosion trends; and the potential for Ocracoke Village to be without reliable access to Hatteras Island and points north. NCDOT initiated the NC 12 feasibility study on Ocracoke Island because of the potential disruption of service to the island's only major arterial roadway due to storm damage and strong tidal events. The design alternatives examined in this study include beach, berm and dune nourishment, roadway relocation, bridging, and relocating the Hatteras Inlet Ferry Terminal. This feasibility study evaluates short-term (5-Year) alternatives and long-term (50-Year alternatives). Four 5-Year options and seven 50-Year options were considered.

At this time, the hot spot projects are not funded in NCDOT's State Transportation Improvement Program.

For this study, alternatives were broadly categorized as nourishment options, road and bridge options, ferry options, and combination options. Detailed descriptions and potential impacts of the options are presented in this document. A summary of key findings follows in this section. It is important to note that the applicability of Section 4(f) with regard to the Cape Hatteras National Seashore will be determined by FHWA should the project proceed to the National Environmental Policy Act (NEPA) phase using federal funds. In other projects involving NC 12, FHWA has determined that NC 12 was jointly developed with the Cape Hatteras National Seashore and, as such, Section 4(f) did not apply to the Seashore. Early coordination between the National Park Service and FHWA is recommended, should the project proceed to the NEPA phase with federal funds.

<u>Beach Nourishment Options</u>

- The availability of sand for fill, in both the short- and long-term, its transport method and permitting concerns are key constructability considerations for these options.

- The nourishment of the beach, berm, and dune alternatives will likely have minor potential impact on recreational resources.

- These options have the potential for impacts to Section 4(f) resources.

- Minor visual resource impacts may occur with these options.

- Minor temporary impacts to protected species, Submerged Aquatic Vegetation (SAV), and Essential Fish Habitat (EFH) may occur with these options. No impact is anticipated to Significant Natural Heritage Areas (SNHA) or wetlands.

- The two 5-year beach nourishment alternatives range in cost from $1,350,000 to $13,950,000. The former is primarily a dune re-nourishment and the latter dune and beach re-nourishment.

- The 50-year beach nourishment alternative has an approximate cost of $41,600,000. The cost for the long term option includes one pre-nourishment treatment and template nourishments every four years or 12.5 nourishment cycles over the course of 50 years.

<u>Road and Bridge Options</u>

- Constructability concerns include: the ability to maintain construction activities within existing easements, the manner of transporting and staging of construction materials, the ability to transport prefabricated bridge parts, and construction methodology. Limitations on construction activities during peak tourist season are also a factor. There are campgrounds near the study area. Construction activities could be limited to minimize impacts to such areas during peak tourist season.

- These options are expected to have moderate impacts to recreation access points.

- These options are likely to enhance bicycle and pedestrian travel throughout the island.

- These options may constitute a use under Section 4(f). There are three conditions that constitute a use by using road and bridge options. First, it may be determined that Seashore land is permanently incorporated into a transportation facility. Second, there may be a temporary occupancy of the Seashore land. Finally, there may be a constructive use of the Seashore land.

- Permanent use and potential for constructive and temporary use under Section 4(f).
- Visual impacts range from minor, with roadway relocation options, to substantial, for new bridge options.
- These options are likely to affect sea turtles, piping plover, and red knot. Only the Pamlico Sound Bridge (50-Year Option 1) is expected to impact SAV and EFH. There are also expected to be impacts to SNHAs.
- Costs for these five options are as follows:
    - 5-Year Option 4: approximately $76,700,000
    - 50-Year Option 1: approximately $194,750,000
    - 50-Year Option 2: approximately $188,800,000
    - 50-Year Option 3: approximately $234,950,000
    - 50-Year Option 4: approximately $248,450,000

Ferry Options

- Constructability concerns include: land and harbor acquisition, channel development, terminal facility development during concomitant operations, and permitting.
- Travel time to and from the island will be increased with implementation of a ferry option. This could affect visitors to the island and delivery of goods and services.
- These options have the potential to reduce access to some recreational opportunities, including bicycle and pedestrian access, if NC 12 is not maintained north of the ferry terminal. The ferry terminal associated with the proposed alternatives would either be an additional dock at the current Ocracoke Island Ferry Terminal at Silver Lake in Ocracoke Village, or at a proposed new site just south of the Ocracoke Pony Pens.
- There are potential Section 4(f) impacts with the conversion of NPS land to develop new ferry facilities. In addition, the Ocracoke Historic District could be affected, depending on the design of Option 6.
- There could be moderate visual impacts from additional ferry infrastructure and new ferry terminal.

- There is limited potential for impact to protected species, SNHA, or wetlands. Dredging for a new ferry route could disrupt SAV and EFH habitats.
- The total estimated cost for installing, operating, and maintaining a ferry system that would service the current traffic demand over the course of the next 50 years was determined to be approximately $2,030,350,000 billion for Option 6 and $2,148,600,000 for Option 7. These costs also include crew, supporting facilities (including a new shipyard), maintenance, and vessel replacement at 30 years.
- NCDOT is required by law to provide at least one free route to all locations in the state. Currently, the ferry between Hatteras Island and Ocracoke Island serves as the free route to Ocracoke Island, while the ferries from Swan Quarter and Cedar Island are tolled. If the ferry from Hatteras Island were to become tolled, one of the other routes would need to be fare-free.

A summary of costs for all alternatives is presented in Table 1.

Table 1 Cost Summary Table

5 –Year Alternatives			
Option 1 Large Scale Beach Nourishment	**Option 2** Dune Nourishment	**Option 3** Relocate Roadway & Dune Nourishment	**Option 4** Bridge over Hot Spot
$13,950,000	**$1,350,000**	**$19,700,000**	**$76,700,000**
50 –Year Alternatives			
Option 1 Pamlico Sound Bridge	**Option 2** Bridge throughout Hot Spot	**Option 3** Roadway Relocation & Bridging	**Option 4** Bridging in Existing Easement
$194,750,000	**$188,800,000**	**$234,950,000**	**$248,450,000**
50 –Year Alternatives - continued			
Option 5 Large Scale Beach Nourishment	**Option 6** Ferry Service to Ocracoke Village Ferry Terminal	**Option 7**[1] Service to New Ferry Terminal North of Ocracoke Village	**-----**
$41,600,000	**$2,030,350,000**	**$2,148,600,000**	**N/A**

[1] Does not include cost of new ferry terminal

Next Steps
Factors to consider as the project advances to study under the NEPA include the following:

Short-Term Alternatives

- Natural Environment
  - Beach/dune nourishment sources
  - Protected species impacts
  - Habitat modification
- Constructability
  - Easement requirements
  - Beach/dune nourishment volumes
  - Construction material transport to site, staging (especially for in-easement alternatives)
  - Durability through short-term timeframe
- Recreation
  - Section 4(f) impacts
  - Access maintenance during construction

Long-Term Alternatives

- Costs
  - Ferry acquisition and maintenance
  - New harbor facility development & maintenance
  - Channel development and maintenance
  - Long term nourishment costs

- Constructability
  - Construction methodology
  - Material transport requirements, construction staging within Seashore
  - Permit/ new easement requirements

- Nourishment
  - Costs of template nourishment maintenance
  - Continued availability of suitable sand sources

- Natural Environment
    - Submerged Aquatic Vegetation (SAV)
    - Essential Fish Habitat (EFH)

- Recreation & Access
    - Section 4(f) - access to NPS recreation facilities
    - Bike and pedestrian access
    - Off road vehicles (ORV)
    - Economic impact
        - Travel convenience

Investigations and studies that may be conducted include:

- Natural environment studies
- Economic impact studies
- Section 4(f) Evaluation
- Detailed sand sediment analysis
- Storm surge analysis to determine bridge height, design
- Offshore surveys to determine sand source availability
- Studies to determine extent of dredging and potential for shoaling if ferry terminal is moved
- Shoreline studies to determine likelihood of a breach in the study area

To help prepare for an emergency situation, potential options may-include:

- Stockpiling temporary bridges that can accommodate an appropriate set of spans. This would allow NCDOT to react swiftly in an emergency storm situation. Also, depending on the specific span length ranges of temporary bridges that may be required to respond to post-storm conditions, cored slab units could also be stockpiled for the purposes of constructing emergency temporary bridges.

- Stockpiling precast prestressed concrete piles for the purposes of building the foundations for temporary bridges. This would also allow NCDOT to be prepared in the event that a temporary bridge is needed to respond to post-storm conditions.

2.0 Introduction

2.1 Project History

In August 1991, NCDOT sponsored a research project conducted by North Carolina State University (NCSU) to identify vulnerable sections of North Carolina's coastal highways and options available for maintaining them. The study concluded that NC 12 has six critical sections, or "hot spots," between Oregon Inlet and the southwestern tip of Ocracoke Island. One of the hot spots is located at the north end of Ocracoke Island and extends from the Hatteras Inlet Ferry Terminal south for approximately five (5) miles. This is the project area described herein. NCDOT initiated planning studies for the project in 2001, but funding to complete construction was never allocated. Currently, the State Transportation Improvement Program (STIP) (FY 2016 – 2025) does not include funding to improve this section of NC 12; however, this feasibility study will aid decision-makers as they consider funding for future projects in this area.

Established in 2002, the project's Purpose and Need was to "*implement interim measures to maintain the integrity and viability of the transportation system (movement of people, goods, and services) with minimal interruption of traffic service due to a moderate storm event at the Ocracoke Island Hot Spot for a period of 10-15 years until a long-term solution is in place.*"

This statement will need to be revised during the project's NEPA phase since the timeframes for this report have changed. However, the primary objectives of the project remain the same. The project's need is based on frequent overwash and flooding on NC 12; need for continual maintenance; vulnerability of the roadway in its current location due to erosion trends; and the potential for Ocracoke Island to be without reliable access to Hatteras Island and points north. This includes tourists who access the island via the Hatteras Inlet Ferry.

2.2 Funding

As part of implementing the new Strategic Transportation Investments (STI) Law, NCDOT released its draft 10-year STIP on December 4, 2014 which scheduled the statewide projects proposed for full or partial funding between 2016 and 2025. The purpose of the STI Law is to allow NCDOT to maximize North Carolina's existing transportation funding to enhance the state's infrastructure and support economic growth, job creation, and high quality of life.

STI established the Strategic Mobility Formula, a new way of allocating available revenues based on data-driven scoring and local input. Proposed transportation projects go through a prioritization process during which they are evaluated through an analysis of the existing and future conditions, the benefits the project is expected to provide, the project's multi-modal characteristics, and how the project fits in with local priorities. Generally, the projects that increase capacity, safety, connectivity, and economic development score higher under the prioritization formula. The NC 12 R-3116A Hot Spot project was not included in the latest Prioritization 4.0 (P4.0) process, which is currently underway. The project is anticipated to be included for evaluation and prioritization in the Prioritization 5.0 process which is anticipated to begin sometime in 2017.

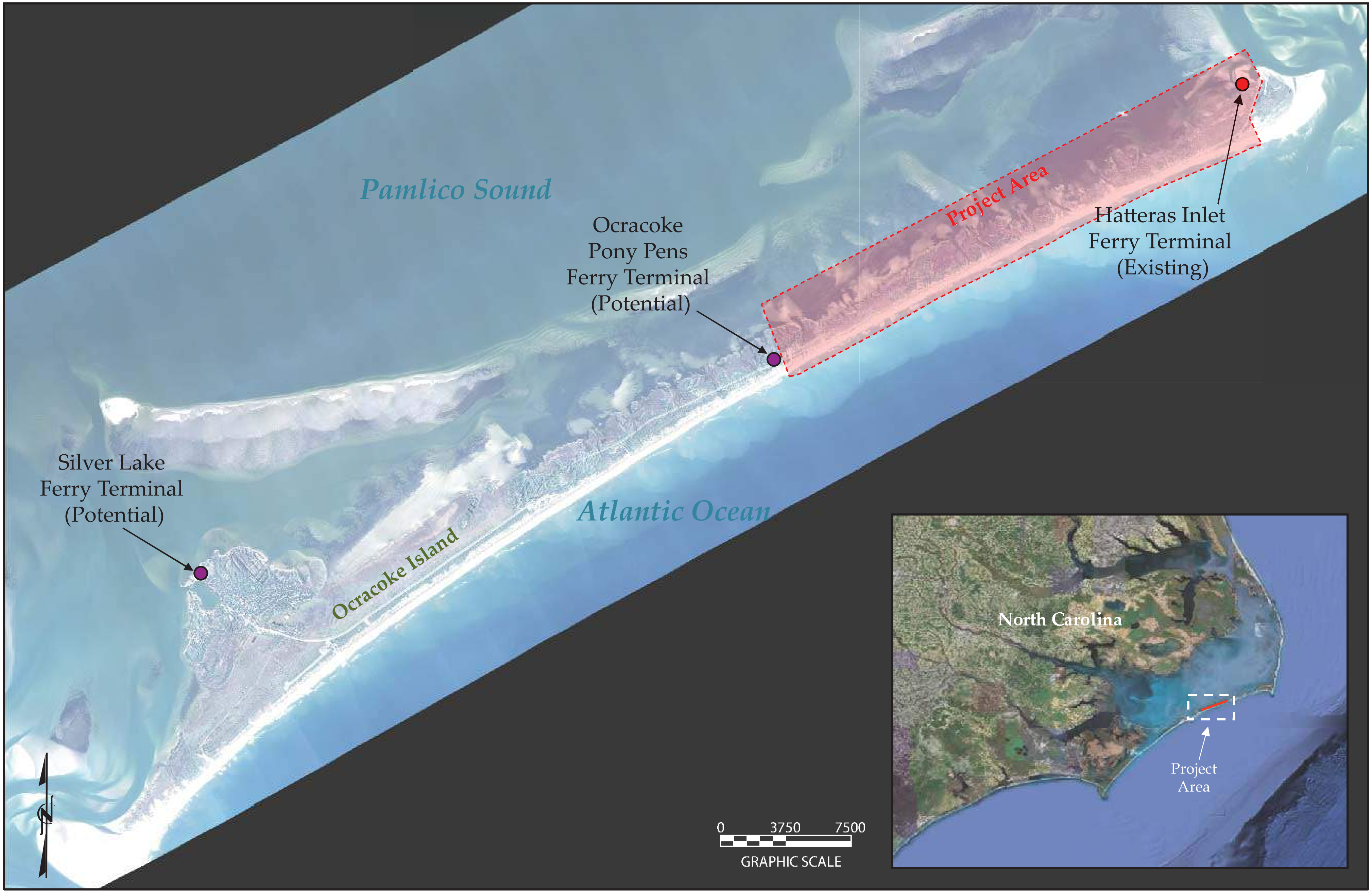
2.3 Problem Statement and Purpose of Study

Figure 1. Storm Damaged Section of NC 12

NC 12 is the lifeline to Ocracoke Village. The approximate 5.25 mile project section of NC 12 on Ocracoke Island is vulnerable to loss of pavement, breach and overwash due to its low elevation, flat topography and the short distance between the ocean beach and Pamlico Sound. When the project section, or "hot spot," is damaged during storms and strong tidal events, travel is cut off and repairs are needed (see Figure 1). Because of this potential to cut off service on the island's only major arterial roadway, NCDOT initiated this feasibility study. This study will consider the feasibility of implementing five-year and 50-year design options to maintain the operation of NC 12 on Ocracoke Island.

2.4 Project Limits

The project area (see Figure 2) is located in southeastern Hyde County, North Carolina, on the northern extent of Ocracoke Island. The project area starts on NC 12 approximately 0.25 mile south of the Hatteras Inlet Ferry Terminal on Ocracoke Island and extends to a point approximately 5.5 miles south along NC 12 to the entrance of the National Park Service's (NPS) Ocracoke Pony Pens. While NCDOT has a 100 foot wide easement for NC 12, the project area is otherwise within NPS-owned lands in the Cape Hatteras National Seashore (Seashore). The project corridor's width is bounded on the east by the mean high water line on the beach and to the west in Pamlico Sound, approximately 2,800 feet west of the existing NC 12 centerline. Two new ferry terminal locations are also being considered for this study: one is located south of the Pony Pens, and the other would be adjacent to the existing ferry terminal on Silver Lake.



NC 12 IMPROVEMENTS PROJECT FEASIBILITY STUDY NORTH CAROLINA DEPARTMENT OF TRANSPORTATION DIVISION OF HIGHWAYS PROJECT DEVELOPMENT AND ENVIRONMENTAL ANALYSIS BRANCH	Hyde County NCDOT Div. 1	Project Study Area	Figure 2

3.0 Coastal Conditions

3.1 Shoreline and Erosion Studies

A *Vulnerability Analysis and Coastal Engineering Evaluation for NC 12 at Ocracoke Island* was prepared in 2010 (Moffatt and Nichol). The purpose of the study was to assess the vulnerability of NC 12 along Ocracoke Island. The work built on prior investigations conducted by Moffatt and Nichol in 2003, 2004, and 2005. For the 2010 study, the area evaluated included approximately 4.8 miles of NC 12 between stations 430 and 685 (see Figure 3.) The study was updated in 2014.

Coastal studies have revealed that a critical area of erosion was identified along 2.6 miles of shoreline (Station 530 to 665, See Figure 3A). This portion of NC 12 is particularly vulnerable to damage from the because of its exposure to high frequency (2-year) storm events. This section summarizes key findings of the 2010 study and 2014 update.

3.1.1 Definition of Vulnerability and Methods for Evaluation

Vulnerability of NC 12 is defined with respect to maintenance requirements and storm damage.

- Maintenance Requirements: Maintenance requirements are considered to be excessive when NC 12 becomes vulnerable to repetitive overwash and sand deposits. Potential for increased maintenance is evaluated based on a single parameter – the setback distance of the roadway from the Mean High Water Level (MHWL). Consistent with previous studies done for NCDOT, when the setback is less than 230 feet, the roadway is considered to be vulnerable to damage from storm events and overwash and thus is likely to require increased maintenance. The projected shoreline position was evaluated based on the assumption that the average historical shoreline recession rate is representative of the erosion that will occur over the planning horizon.

- Storm Damage: Vulnerability with respect to storm damage (damage to or undermining of the road) was evaluated following general methods outlined in prior studies. Storm damage was assessed based on the area of erosion above the 4-foot contour (between the edge of the roadway and the beach) for a series of storm events. Volumes are computed before and after a storm in order to determine material loss due to the wave climate generated by the storm. If the dune area loss above the 4-foot contour is more than 50 percent of the total material, then the area of roadway is considered vulnerable to that storm. For this study, it is assumed that an acceptable level of risk of storm damage is a 50-year return period storm event (i.e. a storm event with a 1/50 or 0.02% chance of occurring in any given year). A detailed methodology and model results are included in the 2010 report.

3.1.2 Setback

The setback is defined as the distance from where Mean High Water (MHW) intersects the shoreline to the center of the roadway. Setback information for the project area was updated in 2014. Table 2 shows the setback distance measured at each of the stations (as shown in Figures 3A – 3D) based on 2013 aerial photography and compares this data to the setback distance established in the 2010 report. The 2010 numbers indicated that the shoreline is closest to the highway between stations 605 and 620, where the existing setback was less than 150 feet. The 2014 update shows notable changes in the estimated setback at stations 585 and 605, where there has been 118 feet and 55 feet of shoreline recession in four years. This finding is consistent with the 2010 vulnerability analysis report, which determined that this section of roadway (specifically at station 605) is most vulnerable to damage and requires regular maintenance to rebuild a protective dune. This is discussed further in the next section.

Table 2. Setback Distance from Roadway Centerline

Station	Setback Distance (ft.) (2010 Report)	Setback Distance (ft.) (2014 Update)
430	420	397
475	384	357
505	295	266
540	287	271
565	226*	197*
585	216*	98*
605	124*	69*
620	145*	132*
650	251	163*
685	421	331

* These locations have a setback distance less than NCODT's optimal distance of 230 feet.

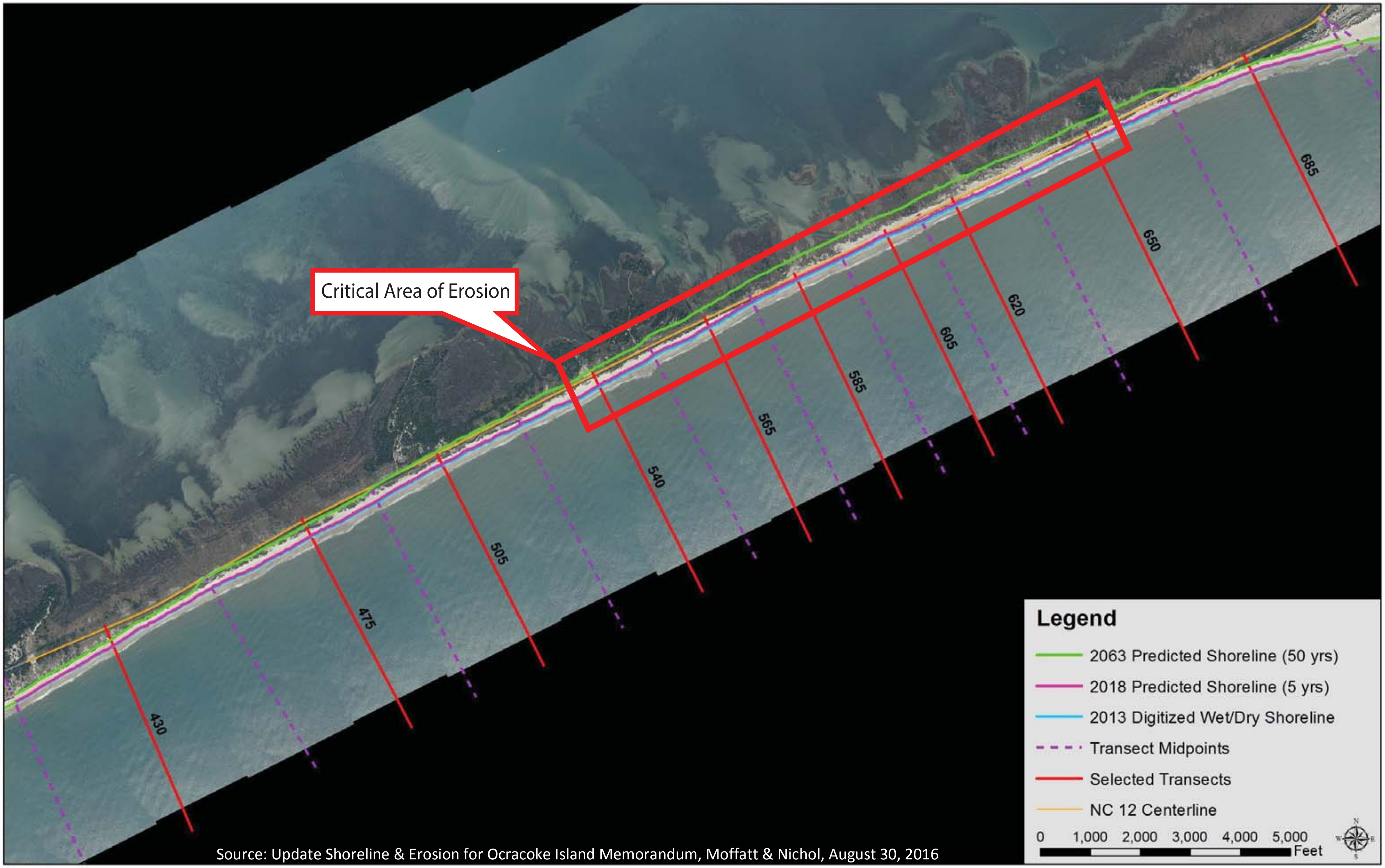
3.1.3 Background Erosion Rates

For the 2010 study, historical shoreline erosion rates were evaluated for the project area. Prior estimates of the long-term shoreline erosion rates along Ocracoke Island were updated by including the most recent shoreline delineation (2008) in the shoreline database (see Table 3). The highest erosion rates (8.6 and 9.4 feet/year) correspond to the area with the least setback distance, between stations 585 and 620.

Table 3. Estimated Average Annual Erosion Rates (from 2010 Study)

Station	Annual Erosion Rate (ft./yr.)
430	2.9
475	5.2
505	6.0
540	7.5
565	8.2
585	8.6
605	8.6
620	9.4
650	8.3
685	3.1

The 2014 update used a digitized shoreline from 2013 aerial photography. The setback distance was measured based on the aerials and compared to the shoreline established in the 2010 report. The background erosion rates shown in Table 3 were used to approximate the amount of erosion that would occur in 5 years and 50 years. The results are presented in Table 4 and illustrated in Figure 3A – 3D.



Source: Update Shoreline & Erosion for Ocracoke Island Memorandum, Moffatt & Nichol, August 30, 2016

NC 12 IMPROVEMENTS
PROJECT FEASIBILITY STUDY

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
PROJECT DEVELOPMENT AND ENVIRONMENTAL ANALYSIS BRANCH

Hyde County
NCDOT Div. 1

Project Area with Projected Shorelines

Figure 3A

NC 12 IMPROVEMENTS PROJECT FEASIBILITY STUDY NORTH CAROLINA DEPARTMENT OF TRANSPORTATION DIVISION OF HIGHWAYS PROJECT DEVELOPMENT AND ENVIRONMENTAL ANALYSIS BRANCH	Hyde County NCDOT Div. 1	**Shorelines – Southwest Reach**	Figure 3B

NC 12 IMPROVEMENTS PROJECT FEASIBILITY STUDY NORTH CAROLINA DEPARTMENT OF TRANSPORTATION DIVISION OF HIGHWAYS PROJECT DEVELOPMENT AND ENVIRONMENTAL ANALYSIS BRANCH	Hyde County NCDOT Div. 1	**Shorelines – Central Reach**	Figure 3C

NC 12 IMPROVEMENTS PROJECT FEASIBILITY STUDY NORTH CAROLINA DEPARTMENT OF TRANSPORTATION DIVISION OF HIGHWAYS PROJECT DEVELOPMENT AND ENVIRONMENTAL ANALYSIS BRANCH	Hyde County NCDOT Div. 1	**Shorelines – Northeast Reach**	Figure 3D

Table 4. 5-Year and 50-Year Erosion Rate Analysis (2014 Update)

Station	Annual Erosion Rate (ft./yr.)	5-Year Erosion (ft.)	50-Year Erosion (ft.)
430	2.9	14.5	145.0
475	5.2	26.0	260.0
505	6.0	30.0	300.0
540	7.5	37.5	375.0
565	8.2	41.0	410.0
585	8.6	43.0	430.0
605	8.6	43.0	430.0
620	9.4	47.0	470.0
650	8.3	41.5	415.0
685	3.1	15.5	155.0

3.1.4 Baseline Conditions

The vulnerability of NC 12 to storm damage and maintenance was evaluated at each of the ten stations shown in Figures 3A-3D. This evaluation uses the shoreline shown on December 2013 aerial photography as the starting point for predicting 5-year and 50-year shorelines based on background erosion rates. This work builds on prior investigations, most recently documented in the 2010 Vulnerability Analysis & Coastal Engineering Evaluations (VA&CEE).

3.1.4.1 Maintenance Requirements

Table 5 identifies the existing setback of the mean high water line (MHWL) and the projected setback based on continued shoreline recession (assuming historical erosion rate) for 5-year and 50-year planning horizons in decennial time blocks. The grey cells indicate that the roadway is vulnerable to shoreline erosion and will likely require frequent maintenance (Setback <230 ft.). Currently, the roadway is vulnerable between stations 565 and 620. If recession continues at the historical rate, by 2020, NC 12 between stations 505 and 650 will require frequent maintenance.

Table 5. NC 12 – Vulnerability to Maintenance

Station	Erosion Annual Rate (ft./yr.)	Setback Distance from Road to Mean High Water Line (MWHL) (ft.)					
		2010	2020	2030	2040	2050	2063
430	2.9	417	388	359	330	301	263
475	5.2	379	327	275	223	171	103
505	6.0	289	229	169	109	49	-29
540	7.5	280	205	130	55	-20	-118
565	8.2	218	136	54	28	-110	-217
585	8.6	208	122	36	-50	-136	-248
605	8.6	116	30	-56	-142	-228	-340
620	9.4	135	41	-53	-147	-241	-363
650	8.3	243	160	77	-6	-89	-197
685	3.1	418	387	356	325	294	254

Notes:

1. Straightline erosion rates used to 2063 horizon.
2. Negative figures indicate road inundated by MHWL

3.1.4.2 *Storm Damage*

Table 6 presents the vulnerability of the roadway to storm damage. Vulnerability with respect to storm damage was assessed based on the area of erosion above the 4-foot contour (between the edge of the roadway and the beach) for a series of storm events. Volumes are computed before and after a storm in order to determine the material loss due to the wave climate generated by the storm. If the dune area loss above the 4-foot contour is more than 50 percent of the total material, then the profile is considered vulnerable to that storm. For this study it is assumed that an acceptable level of risk of storm damage is a 50-year return period storm event.

The grey cells indicate locations where the road is vulnerable to less than a 50-year storm event.[1] Under 2014 projected conditions, at stations 505, 585, 605, and 620, the road is vulnerable to storm damage (<50 year return period storm event). The portion of NC 12 along stations 605 and 620 is vulnerable to damage in a 2-year or 3-year storm event. With continued shoreline recession, in four years, damage to this section of roadway is imminent. After four years, NC 12 will be vulnerable to storm damage at stations 564 and 650.

Engineering and planning mitigation strategies to reduce the vulnerability of NC 12 including nourishment, roadway relocation, bridge construction, and ferry terminals will be guided by the locations where NC 12 was shown to be less than 230 feet from the 50-year shoreline. Decisions on alternative development will also be guided by the NPS guidelines, potential impacts to natural resources, the availability of sand resources and anticipated costs for implementation.

[1]The term "50-year storm" is used to define a storm that statistically has a 2-percent chance of occurring in any given year. The storm's intensity refers to the frequency at which a particular amount of rainfall in a given duration (from 30 minutes to 24 hours) is expected to "return," on average. Storms may be classified by any time period from one year to 100 year storms." A 100-year storm refers to storm rainfall totals that have a one percent probability of occurring at that location in that year. A "100-year storm" on one day does not decrease the chance of a second 100-year storm occurring in that same year or any year to follow.

Table 6. NC 12 – Vulnerability to Storm Damage (Recurrence Interval)

Station	Beginning of Cycle (Years)	After 4 Years (Years)
430	150	150
475	85	75
505	38	18
540	150	120
565	78	44
585	18	13
605	3	<1
620	2	<1
650	55	37
685	150	150

Grey cells indicate where the road is going to be vulnerable to less than a 50-year storm event.

3.2 Dredging Operations – Potential Sand Resources

The dredging of the existing channel within Hatteras Inlet results in a potential source of sediment that is close to the study area. The US Army Corps of Engineers (USACE) is responsible for dredging operations between the Hatteras Island ferry terminal and the Hatteras Inlet channel. Based on communications with USACE staff, dredging operations by the USACE yield on average approximately 80,000 cubic yards (cy) of beach compatible material every four years.

The remainder of the Hatteras Inlet/Ocracoke ferry terminal channel is maintained by the NCDOT Ferry Division. Typically, the ferry channel from Hatteras Inlet to the Ocracoke terminal is dredged annually; however, dredging quantities and frequencies have varied historically with the occurrence of storm events. Following major storm events resulting in significant overwash and loss of dunes, this upland material has typically been used to rebuild the small frontal dune system along the Ocracoke Island hot spot. The average annual dredging quantity from 1975-2004 was approximately 55,000 cubic yards. Data from 2005 to 2010 were not available.

3.3 Nearshore/Offshore Sediment Sources

A sand resource study developed by the North Carolina Geological Survey (NCGS) provides nearshore/offshore sediment availability information in the vicinity of the study area. Twelve potential sand resource areas were identified. South of Diamond Shoals, five target areas were identified for the fine-grained beaches of Ocracoke, one potential area for the medium-grained scenario applicable to Hatteras, and one compatible for both. The closest potential target area is Ocracoke 3, sited within 1 to 3 miles of the hot spot. Based on NCGS analysis, approximately 45.8 million cubic yards of potentially-compatible beach material would be available from the Ocracoke 3 area. The material is characterized as fine grand sands, which is generally compatible with the sediments on Ocracoke Island beaches.

3.4 Consideration of Geotextiles

In similar projects dealing with stabilizing and protecting NC 12 against shoreline erosion, the use of geotextile containers has been suggested to slow or stop beach erosion. Geotextile containers consist of an engineering textile filled with sand. Applications include installations in the core of a sand dune re-construction project, as breakwaters (parallel to the shoreline), and as groins (perpendicular to the shoreline). Geotextile containers are not a reasonable alternative for long-term reliability of NC 12 for two reasons.

First, their installation would likely face serious permitting obstacles under North Carolina state law. The potential use of geotextile containers for shoreline protection would be regulated by the North Carolina Administrative Code on Ocean Hazards. North Carolina Administrative Code outlines specific use standards for the ocean hazard areas. According to the use standard for all activities:

> "Permanent erosion control structures may cause significant adverse impacts on the value and enjoyment of adjacent properties or public access to and use of the ocean beach, and, therefore, are prohibited. Such structures include bulkheads, seawalls, revetments, jetties, groins and breakwaters."

NCDOT is not aware of any changes or pending changes in state law or regulations that would lessen the regulatory constraints on the use of geotextile containers.

Second, the stability of geotextile container installations during storm events, such as hurricanes, that occur along the North Carolina coast is a concern. Failure modes for geotextile containers during storm events could include failure because of scour (undermining at the base), rotation, and lateral displacement. One NCDOT goal is to minimize the necessity of major repairs to NC 12 following storm events, and NCDOT is concerned that geotextile containers would not adequately support that goal.

4.0 Design Considerations and Criteria

4.1 Design Criteria

Design criteria were developed for the road relocation, bridge, and beach nourishment alternatives. Additional criteria were developed for the ferry alternatives. Table 7 through Table 10 present these criteria.

Table 7. Design Criteria for Beach Nourishment

Element	Dune and Berm Nourishment	Dune Nourishment	Roadway Relocation and Dune Nourishment
NC 12 Setback from Mean High Water	230 feet	110 feet*	230 feet
Dune Crest Elevation above Grade (NAVD 88)	15 ft.**		
Maximum Crest Width	25 ft.		
Landward / Seaward Slope	5:1 / 3:1		
Berm Elevation above Grade (NAVD 88)	4 ft.	0 ft.	4 ft.

* Dune nourishment developed with consideration given to the NPS guidelines.

** Dune crest heights may vary depending on the surrounding dune system.

Table 8. Design Criteria for Roadway Relocation

Element	Roadway Relocation Values (for All Options with Roadways)
Functional Classification	*Major Collector*
Design Speed	*60 mph*
Posted Speed	*55 mph*
Access Control	*None*
Lane Widths	*12 ft.*
Number of Lanes	*Two*
Terrain	*Level*
Right-of-way width	100
Shoulder Width	8 ft. (5 ft. paved)

Note: Italicized values are those that are <u>not</u> changed from the existing NC 12 design.

Table 9. Design Criteria for Bridges

Element	Bridge Values	
	5-Year Options Bridging	50-Year Options Bridging
Bridge Type	24" cored slab bridge with concrete overlay	Pre-stressed concrete 72" bulb-tee girder
Lane Widths	*12 ft.*	
Number of Lanes	*Two*	
Shoulder Width	6 ft. – 5 in.	8 ft.
Bridge Deck Width	36 ft. – 10 in.	40 ft.
Center Barrier	None	

Note: Italicized values are those that are not changed from the existing NC 12 design.

Table 10. Design Criteria for Ferry Terminals

Element	New Ferry Terminal Values
Access Channel Width	*At least 200 ft. in width*
Turning Basin	*No less than 400 ft. x 400 ft.*
Docks	*At least 3*
Ramps	*At least 3*
Stacking Lanes	*At least 3*

Note: Italicized values are those that are not changed from the existing NC 12 design.

Note: Formal design of a new ferry terminal was not scoped for this project. The design criteria presented above are based on discussions on the general feasibility of relocating the Hatteras Inlet Ferry Terminal farther south on Ocracoke Island between the project area and Ocracoke Village and the NCDOT Ferry Division.

4.2 Traffic Estimate

A 2040 traffic estimate was prepared using data and methodology shown in Appendix A. The 2040 AADT and annual growth rates were compared to historical forecasts for the R-3116A project (Ocracoke Island Hotspot) as well as the R-3116B project (Hatteras Village Hotspot) to the immediate north of the project on Hatteras Island. This comparison is shown in Table 11. Based on the R-4070B (Buxton Hot Spot) draft forecast, it is apparent that while volumes are forecast to be higher on Hatteras Island, overall future growth will be slower than anticipated on Ocracoke Island.

Table 11. Comparison of Forecasts/ Estimates

Time Period	NC 12 Hatteras Village Hot Spot Improvements (R-3116B) Forecast (June 2014)			Ocracoke Island (R-3116A) Forecast (2002)			Ocracoke Island (R-3116A) Forecast (2014)		
	2013	**2040**	**Growth Rate**	**2002**	**2025**	**Growth Rate**	**2013**	**2040**	**Growth Rate**
Average Annual Daily Traffic (AADT)	NA	NA	NA	3,000	6,600	3.5%	2,200	4,200	2.4%
Summer Weekday	5,800	7,900	1.1%	NA	NA	NA	3,500	6,700	2.4%
Summer Weekend	8,400	11,400	1.1%	NA	NA	NA	5,100	9,800	2.4%

As indicated in Table 11, the estimated AADT for the R-3116A forecast is 4,200 vpd in 2040. Based on this finding, the NCDOT Roadway Design Manual recommends the provision of a two-lane roadway with 8 foot shoulders (2 foot paved) for this type of facility. The paved shoulder policy also indicates that a 5- foot paved shoulder may be considered along bike routes.

5.0 Environmental Setting

5.1 Human Environment

5.1.1 Socio-economics

Ocracoke Island is home to 948 permanent residents (2010 US Census). The island's economy is based almost entirely on tourism, which peaks during the summer months and declines during the winter off-season. The summer population is approximately 90 percent tourists and 10 percent permanent residents. Of the tourist population, 70 percent are day trippers who make their arrival to and departure from the island within one day.

Ocracoke Island is not connected to the mainland or other barrier islands via bridges; residents and visitors alike are dependent on using the ferry system to travel to and from the island. Three ferry lines serve Ocracoke: the Hatteras Inlet Ferry, the Cedar Island Ferry, and the Swan Quarter Ferry. While some amenities are present on the island, especially during peak tourist season, permanent residents depend on the ferry system for routine trips such as daily commutes, school-related travel, trips to medical care facilities, and shopping, either on the mainland or other islands.

On the island, residents and visitors primarily make use of recreational opportunities provided by the Cape Hatteras National Seashore.

5.1.2 Land Use

Existing land use within the project area on Ocracoke Island is Ocracoke Village, approximately seven miles south of the project area, and NPS park land (Cape Hatteras National Seashore). Ocracoke Village contains residential and commercial properties that serve both permanent residents and tourists. Commercial and private docks are located along the perimeter of Silver Lake in Ocracoke Village. The Cape Hatteras National Seashore is a federally designated National Seashore (1937) preserving portions of the Outer Banks of North Carolina from Bodie Island through Hatteras Island to Ocracoke Island, stretching over 70 miles. Its primary intended purpose was that of a public recreational area. It is managed by the National Park Service. Cape Hatteras is a combination of natural and cultural resources, and provides a wide variety of recreational opportunities.

There are five main types of recreational opportunities found along the Seashore including on Ocracoke Island; water and sand-based activities, camping, fishing, hiking and hunting. The water-based activities include swimming and surfing (which may be enjoyed on the high-energy Atlantic Ocean or the calmer Pamlico Sound side). Sand-based activities include sunbathing and shell-hunting on the ocean side. Approximately three miles south of the project area, one of four National Seashore campgrounds can be found on Ocracoke Island with tent, trailer, and motor home sites. Camping is allowed between April and October. The Seashore offers a variety of fishing opportunities. Several kinds of fish can be caught from the surf, piers, and freshwater ponds or from boats in the inlets, the sound, and offshore in the Gulf Stream. Hiking designated trails can be used to explore other aspects of a barrier island beyond the beach. The islands also provide a variety of habitats and are a valuable wintering area for migrating waterfowl. Waterfowl hunting is permitted during designated seasons and with strict guidelines.

5.1.3 Cultural Resources

Three resources in Ocracoke Village are either listed on or eligible for the National Register of Historic Places (NRHP). These include:

- Ocracoke Historic District (Status: Listed on the NRHP since 1990). This historic district is a maritime community with homes built between 1823 and 1959. It encompasses the areas of Ocracoke Village immediately adjacent to Silver Lake and extending two to three blocks outward. This district does not include, but is immediately adjacent to, the Silver Lake ferry terminal on three sides.

- Ocracoke Light Station (Status: Listed on the NRHP since 1977). The Ocracoke Light Station, located southeast of Silver Lake, is the conical brick lighthouse built in 1823. It is the oldest functioning lighthouse on the North Carolina coast.

- Ocracoke Lighthouse Keeper's Quarters (Status: Study List/Eligible for NRHP since 1977). This dwelling, adjacent to the lighthouse, was built in 1823 with improvements made in 1868 and 1897.

A detailed cultural resources survey will need to be completed as part of the NEPA process for this project.

5.1.4 Bicycle and Pedestrian Facilities

5.1.4.1 Bicycle Facilities and Use

North Carolina offers a designated cross-state system of Bicycling Highways. These routes generally parallel major highways. There are nine different routes covering 3,000 miles of North Carolina. Bicycle Route 7, the Ocracoke Option, connects Bike Route 2 (near Wilson) and extends 170 miles to the southeast to Ocracoke Island. The route passes through New Bern and Beaufort and utilizes the Cedar Island Ferry to Ocracoke Island.

The regional bicycle route is part of the Outer Banks Scenic Byway. From Whalebone Junction in Dare County to Beaufort in Carteret County, this Scenic Byway traces the easternmost parts of North Carolina along the state's barrier islands. The unique maritime culture shared by the 21 coastal villages along this route led to its designation as a national scenic byway.

Locally, Ocracoke Island offers several levels of bicycling facilities for residents and tourists. There is one trail that allows off road cycling. Currently 0.25 miles of NC 12 immediately north of Ocracoke village has striped lanes. There are 3.25 miles of paved shoulder south of the project area. The remaining portions of NC 12 on the island have varying degrees of shoulder width that are used to access activities. This is particularly true within Ocracoke Village, home to several bicycle rental facilities and narrow streets best navigated by this form of transport.

5.1.4.2 Pedestrian Facilities and Use

There are no sidewalks in the project area. Visitors to the Seashore frequently stop on the side of NC 12 to walk over the sand dunes east of NC 12 to reach the Atlantic Ocean.

Wildlife trails used by visitors to the sound side are west of NC 12. These trails do not cross NC 12.

Pedestrians cross NC 12 in Ocracoke Village to get from vacation homes to the beach, and to commercial recreation facilities and other commercial uses.

5.1.5 Section 4(f) Resources

Section 4(f) of the Department of Transportation Act of 1966, as amended (49 USC 303), states that the US Department of Transportation (USDOT) may not approve the use of land from a significant publicly owned park, recreation area, or wildlife and waterfowl refuge, or any significant historic site, unless a determination is made that the project will have a *de minimis* impact or unless a determination is made that:

- There is no feasible and prudent avoidance alternative, as defined in 23 CFR 774.17, to the use of land from the property; and
- The action includes all possible planning, as defined in 23 CFR 774.17, to minimize harm to the property resulting from such use.

There are four properties that could require Section 4(f) evaluation; the Cape Hatteras National Seashore, Ocracoke Historic District, Ocracoke Light Station, and the Ocracoke Lighthouse Keeper’s Quarters.

The Cape Hatteras National Seashore (Seashore) is a publicly-owned resource that serves as a park and recreation area. The project area is located entirely within the Seashore within an easement granted by the NPS. Facilities belonging to NPS within the project area include part of the Pony Pens, two beach user parking lots, two dirt sound access roads, and an off-road vehicle ramp. One of four National Seashore campgrounds can be found on Ocracoke Island with tent, trailer, and motor home sites. Camping is allowed between April and October.

Three resources in Ocracoke Village are either listed on or eligible for the National Register of Historic Places (NRHP). These resources were described in Section 5.1.3, Cultural Resources.

A determination regarding the applicability of Section 4(f) for the Seashore will be made by the Federal Highway Administration (FHWA) during the NEPA process if the project proceeds using federal funds. For other projects involving NC 12, FHWA determined that the Seashore was ‘jointly developed’ with NC 12 and as such the Seashore was determined to be exempt from Section 4(f). An important next step in this project's development to have early coordination between the NPS and FHWA to determine the applicability of Section 4(f) with regard to the Seashore.

5.1.6 Visual Character

The Outer Banks of North Carolina are known for the rare and striking beauty of the natural setting of the barrier islands. NC 12 is designated as a Scenic Byway by the NCDOT between the community of Ocracoke on Ocracoke Island and Whalebone Junction on Bodie Island. Views on Ocracoke Island are characterized by a low vertical profile with a slightly rolling terrain and scattered vegetation. Sandy beaches are along the oceanfront and inlet side of the island, while the salt marsh and mudflats can be viewed on the sound side of the island. From NC 12, users generally see vegetated dunes on the ocean side, and lower-lying vegetated terrain on the sound side. From the beach, views of NC 12 are generally obscured by the vegetated dunes that border the roadway.

5.2 Natural Environment

5.2.1 Significant Natural Heritage Area

The majority of the project area, generally on the sound side of NC 12, is designated as a Significant Natural Heritage Area, classified as Ocracoke Island Eastern End.

5.2.2 Terrestrial Communities

The Natural Resources Technical Report (NRTR) prepared in 2010 by PBS&J (now Atkins) identified seven terrestrial communities in the study area, including: dune grass, maritime dry grassland, maritime shrub, salt shrub, brackish marsh, and salt marsh. These communities are described below:

5.2.2.1 Maintained/Disturbed

Maintained/disturbed areas are scattered throughout the study area in places where the vegetation is periodically mowed, such as roadside shoulders. Maintained/disturbed areas also include NC 12 as well as gravel or paved parking areas along NC 12. The plant species are similar to those of Dune Grass and Maritime Dry Grassland communities.

5.2.2.2 Dune Grass

The Dune Grass community occurs within the study corridor adjacent to and seaward of NC 12. This community is characterized by a dynamic environment of shifting sands driven by wind accretion and erosion as well as erosion from lunar and storm tides. The constant stress of sea salt spray prevents many natural competitors from successful vegetative colonization within this community. The specialized, salt tolerant sea oat is the dominant plant species within this community. Other, less salt tolerant species survive with lower abundance such as beach grass, seaside blue stem, trailing wild bean, silverleaf croton, dune pennywort, and panic grass.

5.2.2.3 Maritime Dry Grassland

The Maritime Dry Grassland community occurs throughout the study corridor adjacent to NC 12 on the beach and sound sides. The community is characterized by low dunes and overwash terraces from previous stochastic events. This community is dominated by saltmeadow cordgrass, with lower abundances of firewheel and trailing wild bean. These plant species are tolerant of overwash and exposure to salt spray and quickly recover after burial. In localized areas with more protection from stressors, isolated shrubs characteristic of the Maritime Shrub community occur with some regularity. Typically, if the protection by dune areas persists for years, the isolated shrub patches will become more common, and the grassland will succeed into the less salt tolerant Maritime Shrub community.

5.2.2.4 Maritime Shrub

The Maritime Shrub community occurs in areas more protected from salt and overwash stressors than Maritime Dry Grassland. Located closer to the Sound than Maritime Dry Grassland, Maritime Shrub is dominated by short shrubs that are stunted by sea salt spray carried above the tops of low dunes. Dominant species include southern bayberry, yaupon holly, and live oak. If dune accretion continues to offer protection from salt stress, this community will succeed to Maritime Evergreen Forest. If overwash occurs or dunes are damaged or removed, this community will grade into Maritime Dry Grassland. Maritime Shrub communities occasionally have high water tables, and may contain isolated wet depressions. This community can be relatively stable and persist for many years, but is highly dependent upon dune stability.

5.2.2.5 Salt Shrub

The Salt Shrub community is very similar to Maritime Shrub, but is recognized separately by Schafale and Weakley (1990) because it occurs as raised areas within Salt or Brackish Marshes rather than a continuous vegetation zone that runs parallel to the ocean/sound waterlines. Salt Shrub is periodically flooded by salt or brackish water. Dominant vegetation is similar to Maritime Shrub, but also supports inclusions of marsh species.

5.2.2.6 Brackish Marsh

The Brackish Marsh community is found along the study corridor’s northwestern boundary. Brackish Marsh is distinguished from Salt Marsh by dominance of black needlerush, with saltmeadow cordgrass and sawgrass present in lower abundance. The boundary of this extensive community undulates in and out of the study corridor, dependent upon drainage networks and local topography. The presence of this community is reflective of the width of the littoral (intertidal) zone. In areas where the littoral zone is narrow, the ecosystem grades directly from the lower elevation Salt Marsh into higher elevation Salt Shrub and Maritime Shrub communities. If the littoral zone is extensive, then minor changes in elevation occur over long distances inland, and the normal tidal flooding regime will give rise to a distinct zonation in vegetative communities. The Brackish Marsh community is acclimated to irregular flooding resulting from extreme lunar (spring) tides, the cumulative influence of lunar high tide and a long fetch of wind driven tide, and storm events.

5.2.2.7 Salt Marsh

The Salt Marsh community is found at the lowest elevations along the study corridor's northwestern boundary. Salt Marsh is distinguished from Brackish Marsh by homogenous dominance of smooth cordgrass. The boundary of this extensive community undulates in and out of the study corridor, primarily associated with the two named tidal creeks near the study corridor's southwestern terminus. The Salt Marsh community is acclimated to tidal flooding associated with semidiurnal, lunar tides.

5.2.3 Terrestrial Wildlife

Terrestrial communities in the study area are comprised of both natural and disturbed habitats that may support a diversity of wildlife species (those species actually observed are indicated with *). The grassland and shrub communities within the study area favor small mammal species like the cotton mouse, marsh rabbit*, and raccoon*. Reptiles and amphibian species that may use grassland and shrub habitats within the study area include Carolina anole*, rough green snake*, eastern coachwhip, and yellow rat snake. Birds utilizing grassland and shrub communities include palm warbler, common yellowthroat, and common grackle. Mammal species that commonly exploit marsh communities within the study area include river otter*, nutria*, mink* and muskrat. Birds that commonly use marsh habitats include saltmarsh sparrow*, Nelson's sparrow, great egret*, tricolored heron*, red-winged blackbird*, and northern harrier*. Reptiles and amphibians may include eastern mud turtle, Carolina diamondback terrapin, common snapping turtle*, and banded water snake.

5.2.4 Aquatic Communities

While terrestrial habitats are more common within the study area, the salt creeks and ponds provide adequate habitat for a variety of aquatic wildlife. Salt creeks could support blue crab, fiddler crab, bluefish, and flounder. Pond habitats could provide adequate habitat for banded water snake, eastern mud turtle, green treefrog and Fowler's toad.

5.2.5 Protected Species

Table 12 shows the Hyde County species currently listed as protected by USFWS as of March 25, 2015.

Table 12. Protected Species Listed for Hyde County

Scientific Name	Common Name	Federal Status	Habitat Present
Alligator mississippiensis	American alligator	T(S/A)	No
Chlonia mydas	Green sea turtle	T	Yes
Eretmochelys imbricate	Hawksbill sea turtle	E	Yes
Lepidochelys kempii	Kemp's ridley sea turtle	E	Yes
Dermochelys coriacea	Leatherback sea turtle	E	Yes
Caretta	Loggerhead sea turtle	T	Yes
Canis rufus	Red wolf	E	No
Calidris canutus rufa	Rufa red knot	T	Yes
Charadrius melodus	Piping plover	T	Yes
Picoides borealis	Red-cockaded woodpecker	E	No
Trichechus manatus	West Indian manatee	E	No
Amaranthus pumilus	Seabeach amaranth	T	Yes
Aeschynomene virginica	Sensitive joint-vetch	T	No

The following species listed by USFWS as endangered have habitat present within the study area:

Sea Turtles. Five species of endangered sea turtle have habitat within the study area, including the green sea turtle, the hawksbill sea turtle, Kemp's ridley sea turtle, leatherback sea turtle, and loggerhead sea turtle. Sea turtle nests have been documented within 50 feet of the study corridor in 2008 and 2009. The eastern fringe (upper ocean beach) of the study corridor contains suitable habitat for turtle nesting.

Piping Plover. North Carolina is an important breeding and wintering habitat for this bird species. They nest most commonly where there is little or no vegetation, but some may nest in stands of beachgrass. The study corridor provides poor nesting and roosting habitat but moderate feeding habitat. Coordination with the National Park Service has confirmed that no nests have been documented within the study corridor.

Seabeach Amaranth. This vegetation occurs on barrier island beaches where its primary habitat consists of overwash flats at accreting ends of islands, lower foredunes, and upper strands of noneroding beaches (landward of the wrack line). The study area includes dune and grassland habitats suitable for seabeach amaranth. National Park Service biologists indicated that while there are historical records of seabeach amaranth within the study area, no recent occurrences have been identified. NCNHP records, updated May 2009 indicate no known seabeach amaranth occurrences within 1.0 mile of the study area.

Rufa red knot. The rufa red knot has been listed as threatened by the USFWS as of January 2015. The rufa red knot is a migratory bird species that uses the Outer Banks of North Carolina as a stopover point along its long migration pattern.

The American oystercatcher while not listed as endangered by USFWS, is a species found in the project area that has special conservation status:

American oystercatcher. The American oystercatcher is classified as a Species of High Concern in shorebird conservation plans for the Eastern and Gulf coasts of the United States because of its small overall population (11,000 individuals), widespread habitat loss, and the threats it faces both during the breeding and non-breeding seasons. The species occurs only in the coastal zone in areas that support intertidal shellfish beds. All thirteen states along the Atlantic Coast of the United States list American oystercatcher as either officially threatened or endangered, or as a Species of Greatest Conservation Need in their state wildlife action plans. In North Carolina the official state designation is significantly rare. Northward migration begins in late winter. On the Outer Banks of North Carolina, oystercatchers begin to arrive on breeding territories in late February.

Biological determinations will be made for each species during the NEPA process.

5.2.6 Wetlands

Within the project study area, wetlands are likely to be found on the sound side of NC 12, in mostly non-contiguous patches, with a higher concentration located at the north end of the island. Wetland types present in the project area are anticipated to be variations of the Cowardin classification E2EM (estuarine, intertidal, and emergent).

5.2.7 Essential Fish Habitat

Pamlico Sound and the marine water column in the Atlantic Ocean are considered Essential Fish Habitat (EFH), as well as the estuarine emergent wetlands and several salt creeks on Ocracoke Island.

5.2.7.1 Submerged Aquatic Vegetation (SAV)

Submerged Aquatic Vegetation (SAV) is found throughout the Pamlico Sound. As it was mapped in 2008 by the USFWS and its partners, there are approximately 17 square miles of SAVs immediately west of the island. At its widest area of growth, SAVs can be found up to two miles from the island. Its growth is most dense along the west central coastline of the island and is less so southwesterly along the shoreline towards Ocracoke Village.

6.0 Description of Alternatives

Engineering and planning project alternatives to reduce the vulnerability of NC 12 were reviewed, including: beach nourishment, dune nourishment, roadway relocation, bridges, and ferries. Key considerations for developing alternatives included: guidelines by the National Park Service (NPS), the potential impact to human and natural environmental resources, constructability, travel convenience, the availability of sand resources, damage potential with shoreline erosion and/or storm overwash, dredging requirements, effects on National Park Service uses, and anticipated costs for implementation.

Using the above guidelines and considerations, short-term (5-Year) and long-term (50-Year) alternatives were developed. Several options were developed for each alternative. These include:

- 5-Year Alternatives:
  - Option 1 – Large Scale Beach Nourishment. This option includes nourishment along 4.65 miles of the beach to a predetermined project baseline. The nourishment seeks to ensure a suitable distance between the roadway and the shoreline is maintained.
  - Option 2 – Dune Nourishment. Sand would be used to nourish 3.63 miles of dune. This option would comply with current NPS requirements that generally preclude nourishment of the ocean beach.
  - Option 3 – Roadway Relocation and Dune Nourishment. NC 12 would be relocated relative to the forecast 2018 (5-Year) shoreline and sand would be used to nourish a protective dune along the east side of the roadway.
  - Option 4 – Bridge over Hot Spot. NC 12 would be bridged within the existing easement throughout most of the hot spot. Bridging the hot spot removes the need for major dune construction and berm nourishment.
- 50-Year Alternatives:
  - Option 1 – Pamlico Sound Bridge. A bridge would be constructed from the project's northern terminus on existing NC 12, through the Pamlico Sound along the west side of Ocracoke Island, terminating along existing NC 12 approximately four miles south of the starting point.
  - Option 2 – Bridge Alternative throughout Hot Spot. A bridge would be constructed starting at the project's northern terminus on existing NC 12, through NPS land and west of the forecast 50-Year shoreline, terminating approximately two and a half miles south on existing NC 12.

- Option 3 – Relocate Roadway and Bridging. NC 12 would be relocated to the west of the 2063 (50-Year) projected shoreline, and bridges would be constructed over streams and small coves.

- Option 4 – Bridge in Existing Easement. NC 12 would be bridged within the existing roadway easement throughout nearly all of the project area.

- Option 5 – Large Scale Beach Nourishment. The dune and beach nourishment cycles would occur once every 4 years for up to 50 years. Under this option, sand would be used to nourish 4.82 miles of the beach and existing dune system.

- Option 6 – Ferry Service to Ferry Terminal in Ocracoke Village. Ferry service would be extended from the Hatteras Inlet Ferry Terminal on Hatteras Island to the Ocracoke Island Ferry Terminal at Silver Lake in Ocracoke Village.

- Option 7 – Ferry Service to New Ferry Terminal North of Ocracoke Village. Ferry service would be extended from the Hatteras Inlet Ferry Terminal on Hatteras Island to a new ferry terminal located between the project area and Ocracoke Village.

6.1 Short-Term (5-Year) Alternatives

6.1.1 5-Year Option 1 – Large Scale Beach Nourishment

5-Year Option 1- Large Scale Beach Nourishment (see Figure 4) includes nourishment of a dune and berm, and is intended to maintain a setback of 230 feet and withstand up to a 50-year return period storm. This option includes a “pre-nourishment” cycle, which is a one-time placement of sand along 25,076 feet (4.75 miles) of the beach to a predetermined project baseline. Another nourishment, called a “template nourishment” will occur four years later and will nourish 15,654 feet (2.96 miles) of the dune and berm.[2] The template nourishment is designed to maintain the beach profile set during the pre-nourishment cycle. The template nourishment will assure a suitable distance from the shoreline is maintained.

No road realignment or bridging is proposed under this option. The sand volume anticipated to complete this option is approximately 1,208,700 cubic yards (cy) for the pre-nourishment, and 224,900 cy for the template nourishment, for a total of 1,433,600 cy

---

[2] Pre-nourishment requirements are estimated as a function of historical erosion rates. Pre-nourishment is defined as the quantity of material required to be placed on the beach such that the design template is maintained for the entire time until the next re-nourishment cycle; thereby providing the protection afforded by the design template throughout the life of the project. This approach to maintaining a minimum design profile is typical of USACE designed beach nourishment / storm risk reduction projects.

of sand resources. For this option, sand resources are anticipated to come from offshore sites, described in Section 3.3.

6.1.2 5-Year Option 2 – Dune Nourishment

5-Year Option 2 - Dune Nourishment (see Figure 5) was developed with consideration of the NPS guideline that restricts the location of placed material to the dune and the portion of the beach profile above mean high water level. Under this option, sand resources would be used to nourish 19,200 feet (3.63 miles) of dune. This option was developed to comply with NPS nourishment requirements that currently preclude nourishment of the ocean beach.

No road realignment or bridging is proposed with this option, as the dune nourishment is intended to be suitable for protecting NC 12. The sand volume anticipated to complete this option is 139,000 cy. Under this option, sand is anticipated to come from NCDOT Ferry Division dredging or United States Army Corps of Engineers (USACE) dredging operations.

Each five year alternative will include one pre-nourishment treatment and one template nourishment after four years. The latter is to return sand to pre-erosion levels. Sand dunes would require 25 percent of pre-nourishment sand volumes between years 4 and 5 to be at design heights at the conclusion of the project.

6.1.3 5-Year Option 3 – Roadway Relocation and Dune Nourishment

5-Year Option 3 - Roadway Relocation and Dune Nourishment is shown in Figure 6. With this option, NC 12 would be relocated 140 feet inland from the existing roadway, 230 feet away from the forecast 2018 (5-Year) shoreline. Sand would be used to nourish a protective dune along the east side of the relocated NC 12.

The relocated roadway would be approximately 20,000 feet (3.78 miles) long, and sand resources would be used to nourish 12,070 feet (2.28 miles) of existing dune. The sand volume anticipated to complete this option is 256,000 cy. Sand resources for this option are anticipated to come from NCDOT Ferry Division or USACE dredging operations.

Each five year alternative will include one pre nourishment treatment and one template nourishment after four years. The latter is to return sand to pre-nourishment levels following erosion. Sand dunes would require 25 percent of pre-nourishment sand volumes between years 4 and 5 to be at design heights at the conclusion of the project.

6.1.4 5-Year Option 4 – Bridge over Hot Spot

5-Year Option 4 - Bridge over Hot Spot is shown in see Figure 7. For this alternative, NC 12 would be bridged within the existing NC 12 easement throughout most of the hot spot. Construction of this option would be accomplished by providing a detour alongside existing NC 12 as the bridge is built. Bridging the hot spot precludes the need for major dune construction and berm nourishment. The bridge would be 6,000 feet (1.15 miles) in length, with 6,500 feet (1.24 miles) of new roadway at its termini. The termini and some of existing NC 12 would be protected by 13,000 feet (2.49 miles) of dune. The sand volume anticipated to complete this option is 66,250 cy. Under this alternative, sand resources are anticipated to come from NCDOT Ferry Division or USACE dredging operations. Each five year alternative will include one pre nourishment treatment and one template nourishment after four years. The latter is to return sand to pre-nourishment levels following erosion. Sand dunes would require 25 percent of pre-nourishment sand volumes between years 4 and 5 to be at design heights at the conclusion of the project.

NC 12 IMPROVEMENTS PROJECT
FEASIBILITY STUDY

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
PROJECT DEVELOPMENT AND ENVIRONMENTAL ANALYSIS BRANCH

Hyde County
NCDOT Div. 1

5-Year Alternative:
Option 1 – Large Scale Beach Nourishment

Figure 4

NC 12 IMPROVEMENTS PROJECT FEASIBILITY STUDY NORTH CAROLINA DEPARTMENT OF TRANSPORTATION DIVISION OF HIGHWAYS PROJECT DEVELOPMENT AND ENVIRONMENTAL ANALYSIS BRANCH	Hyde County NCDOT Div. 1	**5-Year Alternative: Option 2 – Dune Nourishment**	Figure 5

NC 12 IMPROVEMENTS PROJECT FEASIBILITY STUDY

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
PROJECT DEVELOPMENT AND ENVIRONMENTAL ANALYSIS BRANCH

Hyde County
NCDOT Div. 1

5-Year Alternative: Option 3 – Roadway Relocation and Dune Nourishment

Figure 6

NC 12 IMPROVEMENTS PROJECT FEASIBILITY STUDY

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
PROJECT DEVELOPMENT AND ENVIRONMENTAL ANALYSIS BRANCH

Hyde County
NCDOT Div. 1

5-Year Alternative:
Option 4 – Bridge Over Hot Spot

Figure 7

6.2 Long-Term (50-Year) Alternatives

6.2.1 50-Year Option 1 – Pamlico Sound Bridge

50-Year Option 1 – Pamlico Sound Bridge is shown in Figure 8. For this option, a bridge would be constructed from the project's northern terminus on existing NC 12, through Pamlico Sound along the west side of Ocracoke Island, terminating at a point along existing NC 12 approximately four miles south of the origination point. Since a primary consideration in determining the location of this option is minimizing impacts to submerged aquatic vegetation (SAV), the bridge could be built using "top down" construction. This method would minimize construction impacts to Pamlico Sound and wetlands because it would eliminate the need for a temporary work bridge. However, the feasibility of top-down construction would need to be investigated in detail during subsequent phases of the project's development. If top-down construction methods are not implemented, then it is expected that a temporary work bridge(s) would be required to facilitate bridge construction.

The bridge would be approximately 17,000 feet (3.3 miles) in length, with 11,000 feet (2.2 miles) of new roadway at its termini. The termini and some of existing NC 12 would be protected by 5,950 feet (1.13 miles) of dune. The sand volume anticipated to complete this option is approximately 153,000 cy per template nourishment cycle, or 1,917,000 cy for the 50-Year timeframe. This option will include one pre-nourishment treatment and template nourishments every four years or 12.5 nourishment cycles over the course of the project.

Under this option, sand resources are anticipated to come from NCDOT Ferry Division or USACE dredging operations.

6.2.2 50-Year Option 2 – Bridge Alternative throughout Hot Spot

The 50-Year Option 2 (see Figure 9) would consist of a bridge from the project's northern terminus on existing NC 12, through NPS land at least 230 feet west of the forecast 50-Year shoreline, terminating at a point approximately two and a half miles south on existing NC 12.

The bridge could be built using "top down" construction to minimize construction phase impacts to Pamlico Sound and wetlands on the west side of Ocracoke Island because it would eliminate the need for a temporary work bridge. The feasibility of using this method will be determined in subsequent phases of the project. The bridge would be approximately 25,000 feet (4.7 miles) in length, with approximately 3,000 feet (0.5 miles) of new roadway at its termini. The termini and some of existing NC 12 would be protected by 500 feet (0.10 mile) of new dune. The sand volume anticipated to complete this option is approximately 9,000 cy per nourishment cycle, or approximately 111,000 cy for the 50-Year timeframe. This option will include one pre nourishment treatment and template nourishments every 4 years or 12.5 nourishment cycles over the course of the project.

Under this option, sand resources are anticipated to come from NCDOT Ferry Division or USACE dredging operations.

6.2.3 50-Year Option 3 – Relocate Roadway and Bridging

The 50-Year Option 3 (see Figure 10) would relocate NC 12 at least 230 feet to the west of the 2063 (50-Year) projected shoreline. Two small bridges and one larger bridge would be constructed over streams and small coves. The bridges could be built using "top down" construction to minimize construction impacts to the wetlands and terrestrial habitats because it would eliminate the need for a temporary work bridge. The feasibility of using this method will be determined during subsequent phases of the project. The relocated roadway and bridge lengths would be as follows:

- Relocated roadway - Combined, all segments would total approximately 23,000 feet (4.3 miles) in length.
- Bridge 1 (longest and northernmost) – approximately 4,000 feet (0.80 miles) in length.
- Bridge 2 (short and central) – approximately 330 feet (0.06 miles) in length.
- Bridge 3 (short and southernmost) – approximately 350 feet (0.07 mile) in length.

It is anticipated that precast pre-stressed concrete girders with composite concrete deck superstructures would be used for all three bridges. Segmental concrete superstructure may be an option for the long bridge (Bridge 1), but the optimum structure type would be determined during the final design phase of the project. All of the bridges would be supported on concrete substructure units with deep foundations. Pile bents (trestle bents) or post-and-beam bents would be the anticipated substructure types depending on the required height of the bridges above the existing ground or water.

The relocated roadway would be protected by approximately 21,000 feet (3.9 miles) of new dunes. The sand volume anticipated to complete this option is approximately 382,000 cy per template nourishment cycle, or approximately 4,776,000 cy for the 50-Year timeframe. This option will include one pre-nourishment treatment and template nourishments every four years or 12.5 nourishment cycles over the course of 50 years.

Under this option, sand resources are anticipated to come from NCDOT Ferry Dredging or USACE Operations.

6.2.4 50-Year Option 4 – Bridge in Existing Easement

For 50-Year Option 4 – Bridge in Existing Easement, NC 12 would be bridged within the existing roadway easement throughout nearly all of the project area (see Figure 11). This would be accomplished by providing a detour alongside existing NC 12 as the bridge is built. The bridge would be approximately 25,000 feet (4.7 miles) in length, with approximately 2,600 feet (0.50 miles) of new roadway at its termini. The termini would be protected by approximately 500 feet (0.10 miles) of new dune.

It is estimated that the sand volume required to complete this option is similar to 50-Year Option 2, which is approximately 9,000cy per template nourishment cycle, or 112,500cy for the 50-Year timeframe. This option will include one pre nourishment treatment and template nourishments every four years or 12.5 nourishment cycles over the course of the project.

Under this option, sand resources are anticipated to come from NCDOT Ferry Division or USACE dredging operations.

6.2.5 50-Year Option 5 – Large Scale Beach Nourishment

50-Year Option 5 - Large Scale Beach Nourishment is shown in Figure 12. It is similar to 5-Year Option 1, but includes 12 dune and berm re-nourishment cycles with the last cycle only providing half the necessary volume since it will just extend for 2 years, where the 5-Year option has only 1 cycle. The dune and berm nourishment cycles would occur once every 4 years for up to 50 Years. Under this option, sand resources would be used to pre-nourish approximately 26,900 feet (5.10 miles) of the beach and dune. The pre-nourishment would be the onetime nourishment of sand along the beach to a predetermined project baseline. The template nourishments that follow are designed to maintain the beach profile set during the pre-nourishment cycle. Each nourishment cycle will assure that a suitable distance between the roadway and the shoreline is maintained.

No road realignment or bridging is proposed under this option, as the beach and dune nourishment will be suitable for protecting NC 12 for up to a 50-Year timeframe. The sand volume anticipated to complete this option is approximately 1,454,000 cubic yards (cy) for the pre-nourishment and first year template nourishment, and approximately 226,000 cy of template nourishment every four years up to 2063, resulting in an approximate total of 4,279,000cy for the entire nourishment. This option will include one pre-nourishment treatment and template nourishments every four years or 12.5 nourishment cycles over the course of the project.

Under this option, sand resources are anticipated to come from offshore sites.

6.2.6 50-Year Option 6 – Ferry Service to Expanded Terminal in Ocracoke Village

50-Year Option 6 - Ferry Service to Ocracoke Village Ferry Terminal is shown in Figure 13. For this alternative, ferry service would be extended from the Hatteras Inlet Ferry Terminal on Hatteras Island to the Ocracoke Island Ferry Terminal at Silver Lake in Ocracoke Village. According to NCDOT Ferry Division, the property adjacent to the east of the Ocracoke Village Silver Lake Ferry Terminal may be considered for purchase to expand the terminal to accommodate the additional ferries from the Hatteras Inlet ferry route. The Hatteras Inlet South Dock at the north end of Ocracoke Island would be removed as part of this option.

6.2.7 50-Year Option 7 – Ferry Service to New Ferry Terminal North of Ocracoke Village

50-Year Option 7 - Ferry Service to New Ferry Terminal North of Ocracoke Village is shown in Figure 13. With this option, ferry service would be extended from the Hatteras Inlet Ferry Terminal on Hatteras Island to a new ferry terminal located between the project area and Ocracoke Village. For the purposes of this study, a site just south of the Ocracoke Pony Pens was assumed. This location is subject to change based on consultation with the NPS because it is within the boundary of the Cape Hatteras National Seashore. The Hatteras Inlet South Dock on the north end of Ocracoke Island would be removed as part of this option.

NC 12 IMPROVEMENTS PROJECT FEASIBILITY STUDY NORTH CAROLINA DEPARTMENT OF TRANSPORTATION DIVISION OF HIGHWAYS PROJECT DEVELOPMENT AND ENVIRONMENTAL ANALYSIS BRANCH	Hyde County NCDOT Div. 1	**50-Year Alternative: Option 1 – Pamlico Sound Bridge**	Figure 8

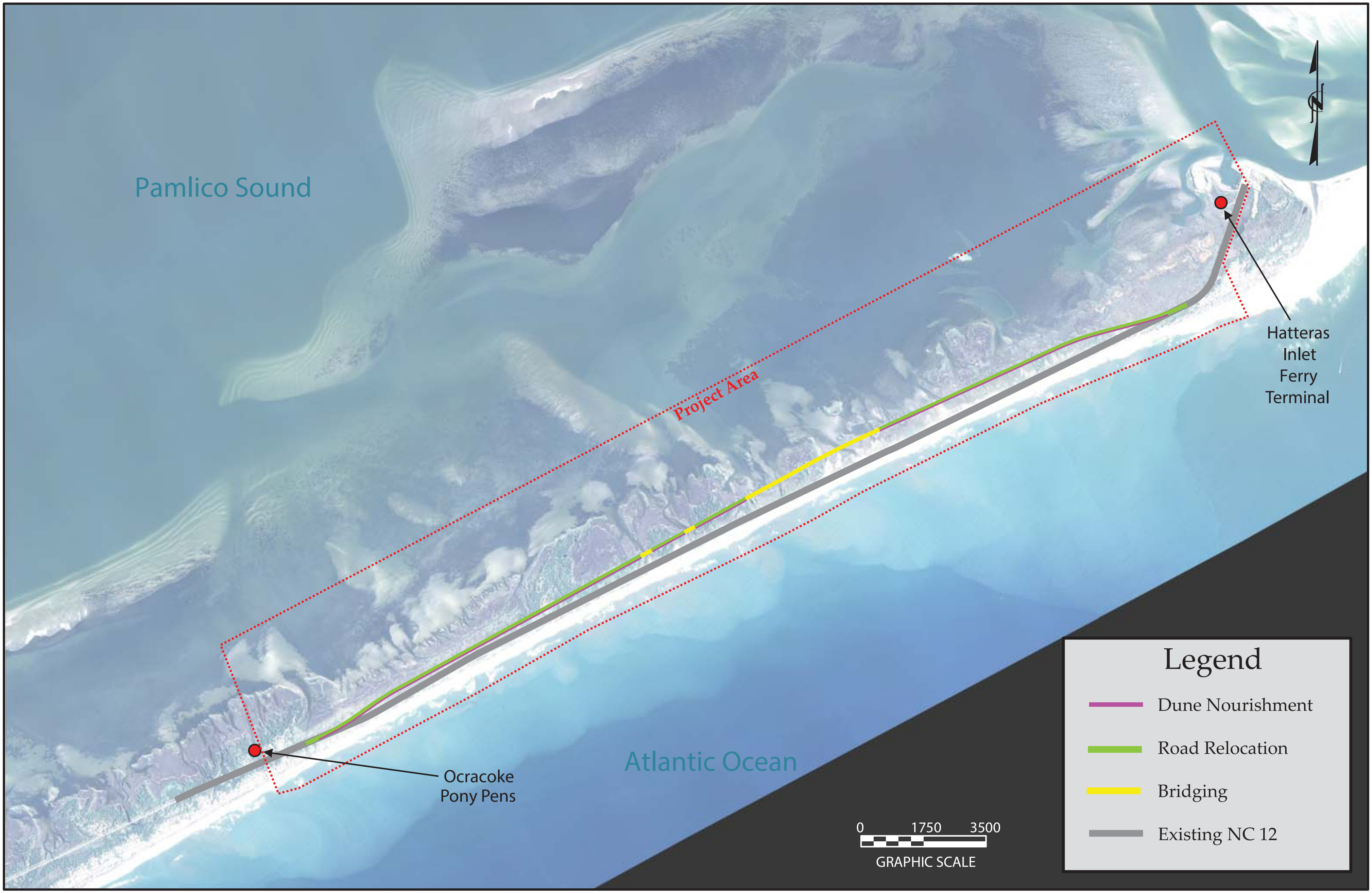
NC 12 IMPROVEMENTS PROJECT
FEASIBILITY STUDY

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
PROJECT DEVELOPMENT AND ENVIRONMENTAL ANALYSIS BRANCH

Hyde County
NCDOT Div. 1

50-Year Alternative:
Option 2 – Bridge Throughout Hot Spot

Figure 9



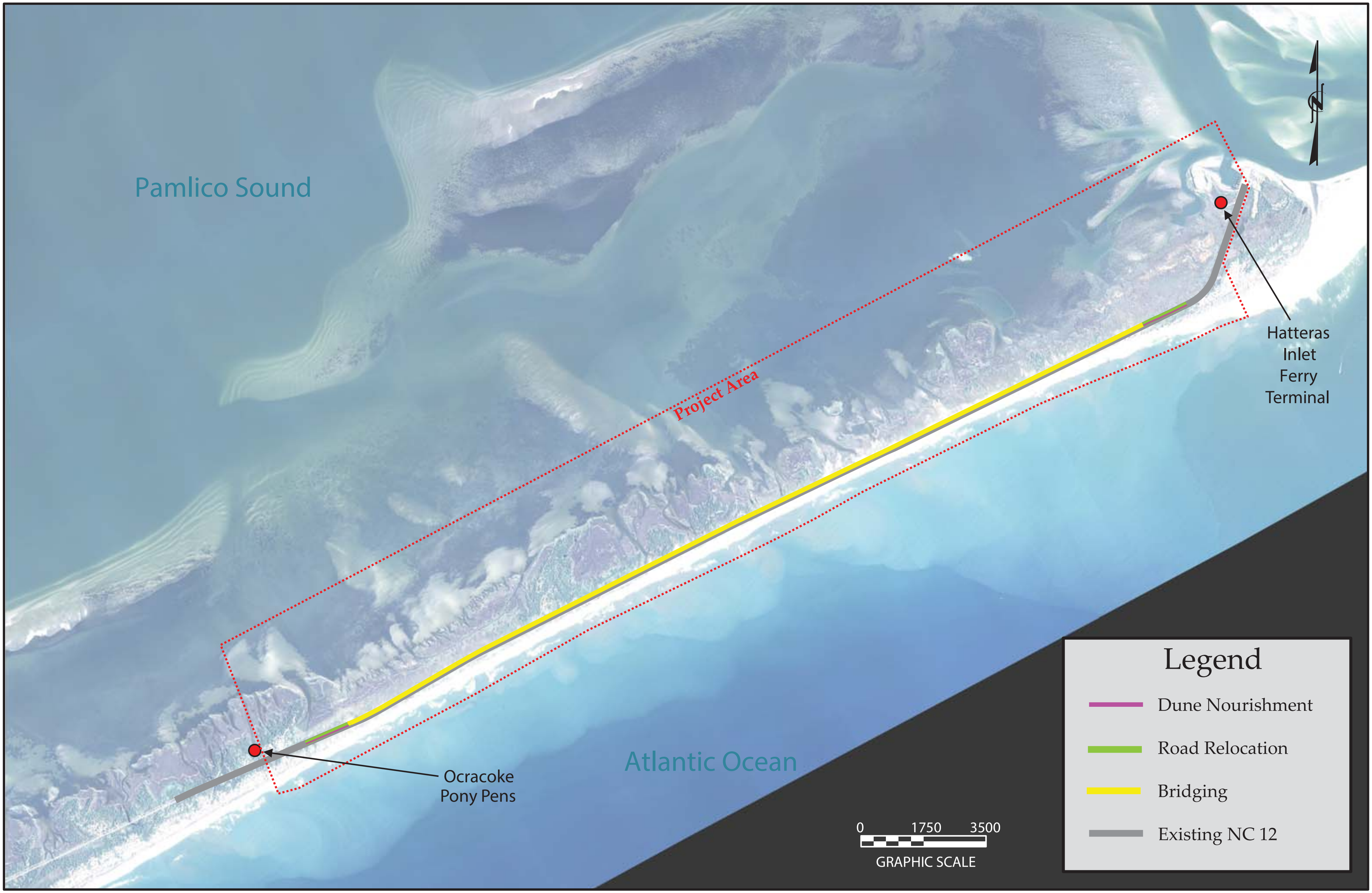
NC 12 IMPROVEMENTS PROJECT
FEASIBILITY STUDY

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
PROJECT DEVELOPMENT AND ENVIRONMENTAL ANALYSIS BRANCH

Hyde County
NCDOT Div. 1

50-Year Alternative:
Option 3 – Relocate Roadway and Bridging

Figure 10



NC 12 IMPROVEMENTS PROJECT
FEASIBILITY STUDY

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
PROJECT DEVELOPMENT AND ENVIRONMENTAL ANALYSIS BRANCH

Hyde County
NCDOT Div. 1

50-Year Alternative:
Option 4 – Bridge in Existing Easement

Figure 11

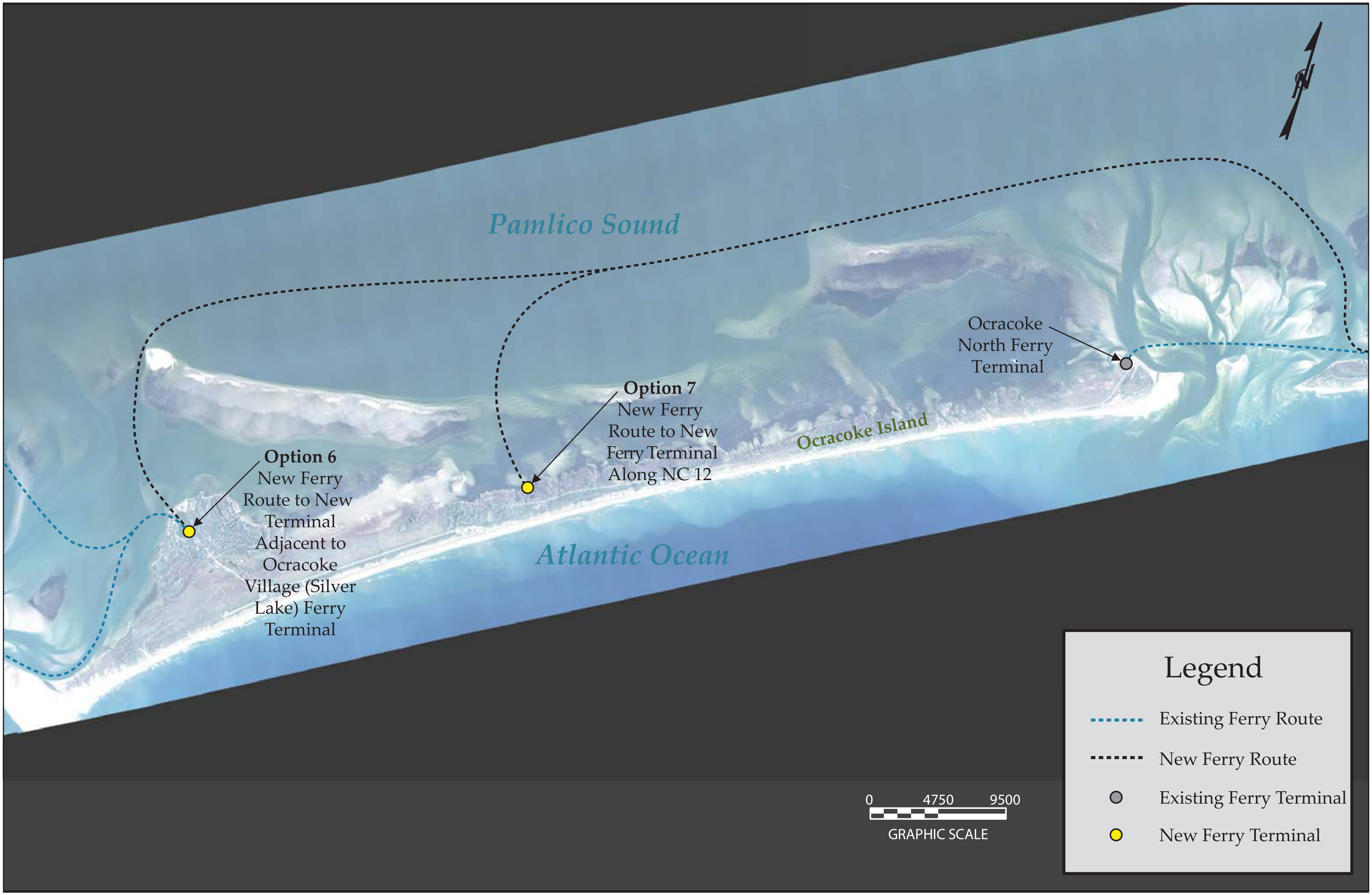
NC 12 IMPROVEMENTS PROJECT
FEASIBILITY STUDY

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
PROJECT DEVELOPMENT AND ENVIRONMENTAL ANALYSIS BRANCH

Hyde County
NCDOT Div. 1

50-Year Alternative:
Option 5 – Large Scale Beach Nourishment

Figure 12



NC 12 IMPROVEMENTS PROJECT FEASIBILITY STUDY	Hyde County NCDOT Div. 1	50-Year Alternative: Option 6– New Ferry Route to Ocracoke Village Option 7– New Ferry Route to New Ferry Terminal Along NC 12	Figure 13
NORTH CAROLINA DEPARTMENT OF TRANSPORTATION DIVISION OF HIGHWAYS PROJECT DEVELOPMENT AND ENVIRONMENTAL ANALYSIS BRANCH			

7.0 Comparison of Alternatives

A more detailed assessment of impacts for each alternative will be conducted during the National Environmental Policy Act (NEPA) documentation process but to simplify the comparison of alternatives, design options were broadly categorized as nourishment options, road and bridge options, ferry options, or a combination as shown below:

Nourishment Options

- 5-Year Option 1 – Large Scale Beach Nourishment
- 5-Year Option 2 – Dune Nourishment
- 50-Year Option 5 – Large Scale Beach Nourishment

Road and Bridge Options

- 5-Year Option 4 – Bridge Over Hot Spots
- 50-Year Option 1 – Pamlico Sound Bridge
- 50-Year Option 2 – Bridge throughout Hot Spot
- 50-Year Option 3 –Relocate Roadway and Bridge
- 50-Year Option 4 – Bridge in Existing Easement

Ferry Options

- 50-Year Option 6 – Ferry Service to New Ferry Terminal in Ocracoke Village
- 50-Year Option 7 – Ferry Service to New Ferry Terminal North of Ocracoke Village

Combination Options

- 5-Year Option 3 – Roadway Relocation and Dune Nourishment

A determination regarding the applicability of Section 4(f) for the Seashore will be made by the Federal Highway Administration (FHWA) during the NEPA process if the project proceeds using federal funds. For further details See Section 5.1.5

7.1 Nourishment Options: 5-Year Option 1, 5-Year Option 2, 50-Year Option 5

7.1.1 Human Environment Impacts

Recreation

The nourishment of the beach, berm and dune under 5-Year Options 1 and 2 and 50-Year Option 5 would likely have minor potential to affect recreational resources on the beach and in the National Seashore. While beach nourishment could occur at any time within the year, efforts could be made to minimize impacts by nourishing the beach during the off-peak tourism timeframes.

Section 4(f) Resources

5-Year Options 1 and 2 and 50-Year Option 5 have the potential for impacts under Section 4(f) because dune and berm nourishments outside of the existing easement are likely to be considered a use of the Cape Hatteras National Seashore.

Visual Character

The beach, berm, and dune nourishment design criteria shown in Table 7 indicate that dune heights could be 15 feet above grade. Currently, some dunes along NC 12 in the project area are lower than 15 feet. Because of this, minor visual resource impacts would occur with the nourishment alternatives. Views of and from the beach would have minor changes, but would still be consistent with the existing viewshed.

7.1.2 Natural Environment Impacts

Protected Species

While nourishment could temporarily impact sea turtle nesting habitat, nourishment activities could be timed to reduce impacts to sea turtles by avoiding beach nourishment between May and November (the sea turtle nesting season). There could also be temporary impacts to piping plover and red knot during construction. A detailed assessment of impacts, as well as avoidance, minimization and mitigation options will be completed during the NEPA process.

Essential Fish Habitat

With the nourishment options, marine EFH in the vicinity of the offshore sand extraction and beach replenishment operations would be affected because these activities would generate turbidity and potentially low dissolved oxygen conditions. The direct effects of beach nourishment would be temporary and localized. However, long-term indirect impacts to marine EFH and managed species could result if the post-nourishment habitat is of lesser quality compared to baseline conditions (causing changes in sediment fill characteristics, beach morphology, and hydrology, properties that largely structure beach communities).

7.1.3 Constructability

5-Year Option 1

The factors affecting the constructability of Option 1 are: availability of a sand resource for fill; manner of bringing sand onto the project area; and regulatory concerns of obtaining and using sand resources. Likely sources for the sand include the twelve potential sand resource areas identified from the North Carolina Geological Survey (NCGS) geophysical data of near shore/offshore sediment surrounding the study area. South of Diamond Shoals, five target areas were identified for the fine-grained beaches of Ocracoke. Spoils from dredging Hatteras Inlet between Hatteras Island and Ocracoke Island, including the existing spoil area on the north end of Ocracoke Island are other potential sources. However, until the sand source is identified and its location and distance are known, a transport method cannot be determined. NPS, NCDCM and USACE must agree on the permit requirements and ability to use the sand resources.

Additionally, a relatively large amount of sand is required and currently there is much competition for coastal sand resources.

<u>5-Year Option 2</u>

Constructability factors for this option are similar to those for 5-Year Option 1. A key difference is this option will require substantially less sand fill than 5-Year Option 1.

<u>50-Year Option 5</u>

The factors affecting the constructability of 50-Year Option 5 are: availability of a continued suitable sand resource for beach and dune fill over the project's design life; the transport of sand onto the project area; and NCDCM, USACE, and NPS regulatory requirements of obtaining and using sand resources.

7.1.4 Cost

The costs of the nourishment alternatives are shown below. The unit cost associated with beach nourishment is an average cost between three estimates in a May 2014 NCDOT bid abstract for obtaining sand resources for a beach nourishment project along a different section of NC 12.

- 5-Year Option 1: $13,950,000 (Dune and Beach Nourishment)
- 5-Year Option 2: $1,350,000 (Dune Nourishment Only)
- 50-Year Option 5: $41,600,000

7.2 Road and Bridge Options: 5-Year Option 4, 50-Year Options 1-4

7.2.1 Human Environment Impacts

7.2.1.1 Recreation

- 5-Year Option 4, Bridging Over Hot Spot. The proposed option removes the current access from NC 12 to an ORV access ramp to the ocean beach and a parking area, thereby limiting recreation access in these areas.
- 50-Year Options 1, 2, 3, and 4 (Pamlico Sound Bridge, Bridge Alternative throughout Hot Spot, Roadway Relocation and Bridging, Bridging in Existing Easement respectively). These remove the existing direct access to recreation areas. Alternative access points would be needed for continued access.

7.2.1.2 Land Use

- 5-Year Option 4 could involve the use of NPS lands for a temporary construction easement.
- Some land use conversion would occur with 50-Year Options 1, 2, and 3. 50-Year Option 1 would convert approximately 22.4 acres for roadway right-of-way and

39.8 acres for bridge right-of-way (total of 62.2 acres). 50-Year Option 2 would convert approximately 2.2 acres for roadway right-of-way and 57.4 acres for bridge right-of-way (total of 59.6 acres). 50-Year Option 3 would convert approximately 48.3 acres for roadway right-of-way and 11.3 acres for bridge right-of-way (total of 59.6 acres). 5-Year Option 4 and 50-Year Option 4 would require no land use conversion. Following construction the existing easement that is no longer needed for NC 12 would be returned to the Cape Hatteras National Seashore.

7.2.1.3 Bicycle & Pedestrian Facilities and Use

The proposed roadway and bridge alternatives will include shoulders that would be safer for bicycle and pedestrian traffic. This is the recommended minimum width for accommodating cyclists. Bridge options are proposed to have 6.5-foot paved shoulders for short-term options and 8-foot paved for long-term options. The roadway is proposed to have 5-foot paved shoulders. These shoulder widths would be an improvement to the existing paved shoulder widths in the study area, which vary in the width of usable pavement outside the roadway.

7.2.1.4 Section 4(f)

As discussed in Section 5.1.5, Section 4(f) will be applicable only if federal funds are used for the project. If federal funds are used, FHWA will make a determination as to the applicability of Section 4(f) regarding the Seashore.

- 5-Year Option 4 could have constructive use impacts to the Seashore, depending upon the visual impact of the bridge. There is also potential for temporary use if a temporary construction easement is required.

- 50-Year Option 1 has the potential for Section 4(f) impacts to the Seashore under the permanent use category because approximately 62 acres of Section 4(f) resources would be converted to a new transportation facility.

- Both 50-Year Option 2 and 50-Year Option 3 have the potential for Section 4(f) impacts to the Seashore under the permanent use category because of conversion of potential 4(f) land to a new transportation facility.

- 50-Year Option 4 has no permanent use impacts because no additional right-of-way is proposed. The construction of a phased detour likely would be within the existing easement but temporary easements could be required and those could result in a temporary use of the Seashore under Section 4(f). Also, the introduction of a bridge in the existing right-of-way could be determined to be a constructive use of the Seashore.

No impacts are anticipated to any of the three historic resources at this time. Detailed analysis and coordination with the State Historic Preservation Office (HPO) would be done should the project proceed to the NEPA phase.

7.2.1.5 Visual Impacts

5-Year Option 3 and 50-Year Option 3 are road-based options that will be constructed on new alignment through NPS land. Minor visual impacts would be associated with their development because of the removal of some established vegetation to the west of existing NC 12. Although bridges would be part of 50-Year Option 3, they would be lower lying bridges that are roughly the same grade as the roadway. Because of this, only minor visual impacts would occur.

5-Year Option 4 and 50-Year Options 1, 2, and 4 are likely to represent the greatest visual impacts because they would be prominent within the viewshed, not only because of their height and length, but also because of their presence in a high quality viewshed where no prior structures have existed. Each bridge would represent a different type of impact and are discussed separately below:

- 5-Year Option 4. This option would consist of a bridge in the existing alignment over the hot spot. As such, the structure would be prominent within the views of beachgoers in the hot spot area, thereby detracting from the coastal view experience.
- 50-Year Option 1. This option would consist of a long bridge over an expanse of Pamlico Sound west of Ocracoke Island. The structure would be highly visible to persons viewing the Sound from the estuarine shoreline. Visual impacts to beachgoers would be far less because of the distance between the bridge and the beach. With this option, construction phase visual impacts would be experienced by both sound side and beach side viewers based on the proposed construction technique.
- 50-Year Option 2. This option would consist of an elevated bridge through NPS lands west of the existing NC 12 easement. It would be equally visible to beachgoers and persons viewing from the Sound. Construction phase visual impacts would be experienced by viewers from both perspectives.
- 50-Year Option 4. This option would consist of a bridge in the existing NC 12 easement throughout the entire project area. The structure would be prominent within the views of beachgoers in the entire project area, thereby detracting from the coastal view experience.

7.2.2 Natural Environment Impacts

7.2.2.1 Significant Natural Heritage Areas (SNHA)

The following road and bridge options would affect SNHA: (this represents the acreage of the new easement within the SNHA)

- 50-Year Option 1: 32.53 acres
- 50-Year Option 2: 12.70 acres
- 50-Year Option 3: 68.31 acres
- 50-Year Option 4: 12.06 acres

7.2.2.2 Protected Species

While none of the road and bridge alternatives would be constructed on the existing beach, sea turtle species could be impacted by the proximity of construction activities. Bridge alternatives within the existing NC 12 easement would likely have to be modified to minimize harm to sea turtles from both construction lighting and vehicle headlights during operation. In addition, with 50-Year Option 4, there is potential for impacts to piping plover and red knot during construction because of the proximity to the beach.

7.2.2.3 Wetlands

All road and bridge options have the potential to affect wetlands. The options involving roadway relocation, 5-Year Option 3 and 50-Year Option 3, would likely only affect wetlands west of NC 12.

7.2.2.4 EFH

The only road and bridge based option with the potential to impact the Sound is 50-Year Option 1. Based on the aerial photo review, it is estimated that this option has the potential to impact approximately 4,600 square feet of SAV habitat. The shading created by the bridge could have minor impacts on EFH. Construction of the bridge could impact some SAV.

7.2.3 Constructability

7.2.3.1 5-Year Option 4

Primary constructability issues with this option are the ability to detour traffic during construction and completing all construction activities, including staging, within the existing easement. A temporary construction easement outside of the existing easement would require a permit from NPS.

7.2.3.2 50-Year Option 1

The factors affecting the constructability of this option include ability to transport prefabricated bridge parts and materials through the sound and ability to build the bridge using a top down approach. Currently, the Hatteras Inlet Ferry has rerouted its course due to significant shoaling immediately northwest and west of Ocracoke Island. The condition is worse south of the existing Hatteras Inlet Ferry Terminal. If Hatteras Inlet is not accessible to barges because of shoaling, an alternate means of transporting materials must be used, such as work bridges to access barges in the sound. Temporary construction easements would need to be permitted by the NPS, and any temporary impacts due to construction activities in waters or wetlands would need to be permitted by the appropriate agencies (including the USACE, NCDCM, and NCDWR).

7.2.3.3 50-Year Option 2

The factors affecting the constructability of this option include ability to transport prefabricated bridge parts (if required) and materials through the sound and ability to build the bridge using a top down approach. While work barges could use the existing Hatteras Inlet Ferry route, the depth of the route would have to accommodate the draft of the work barges and tow vessels. Any dredging within the inlet to accommodate barge traffic would require additional permitting. Barge traffic will need to be coordinated with the Hatteras Inlet ferry. In addition, construction of a bridge in the Sound would likely require an Advanced Approval from the US Coast Guard (USCG), and USCG would need to be notified of barge traffic in navigable waters so that public notices could be issued as needed. Temporary construction easements outside of the existing easement would need to be permitted by the NPS, and any temporary impacts due to construction activities in waters or wetlands would need to be permitted by the appropriate agencies (including the USACE, NCDCM, and NCDWR).

Another factor affecting constructability is the timing of construction activities during peak tourist season. Similar projects have required limiting or completely avoiding certain activities like jetting piles during peak season. This study notes the presence of campgrounds in the study area. More detailed studies during the NEPA process will determine the potential effect of construction activities on these resources and recommend the appropriate action by NCDOT.

7.2.3.4 50-Year Option 3

The factors affecting the constructability of 50-Year Option 3 are similar to those for 5-Year Option 3, with the exception of the bridges. The bridges for this option would be lower lying and, given the distance of the northernmost bridge, will likely utilize top down construction to avoid additional wetland impacts.

7.2.3.5 50-Year Option 4

Constructability concerns are similar to 5-Year Option 4. In addition to concerns about a detour and maintaining construction and staging activities within the existing easement, there is the additional consideration of potential limits to construction activities during peak tourist season.

7.2.4 Cost

Costs for the road and bridge options are shown below. In addition to the construction costs associated with new bridge construction or roadway relocation, these estimates include costs associated with the beach or dune nourishment associated with the alternatives. The unit cost associated with beach nourishment is based on an average cost between three estimates in a May 2014 NCDOT bid abstract for obtaining sand resources for a nourishment project along a different section of NC 12.

- 5-Year Option 4: $76,700,000
- 50-Year Option 1: $194,750,000
- 50-Year Option 2: $188,900,000
- 50-Year Option 3: $234,950,000
- 50-Year Option 4: $248,450,000

7.3 Ferry Options: 50-Year Options 6 and 7

7.3.1 Human Environment Impacts

7.3.1.1 Travel Time and Recreation

With both of the ferry options, the Hatteras Inlet Ferry trip time would be longer than the current ferry route between Ocracoke and Hatteras Islands. The current route is either approximately 4 miles long or 8.5 miles long, depending on whether the original channel is passable because of shoaling. It takes approximately 40 minutes to complete the 4 mile route and approximately 1 hour to complete the 8.5 mile alternate route that is currently being used by the NCDOT ferry. 50-Year Option 6 would be an approximately 20 mile route from the Hatteras Ferry terminal to the (expanded) Silver Lake Ferry Terminal on the south end of Ocracoke. 50-Year Option 7 would be an approximately 15 mile route from the Hatteras Ferry terminal to a new ferry terminal north of Ocracoke Village. These longer routes would translate to longer ferry rides. Depending upon the vessel used and the channel condition, Option 6 would take between 1.5 and 2 hours, and Option 7 would take between 1.25 and 1.75 hours. These times represent increases of approximately 1 hour 5 minutes and 45 minutes (Options 6 and 7, respectively) from the shorter current route, however it should be noted that in both cases, the drive to Ocracoke Village will be cut shorter than with the current ferry terminal at the north end of Ocracoke Island. These changes in travel times could affect visitors, commercial vehicles and delivery of goods and services, and residents.

The ferry based alternatives have the potential to reduce access to recreational opportunities with the possible closure of segments of NC 12 north of the proposed facilities. Without access provided by the NPS there could be a reduction in the number of people visiting the island.

7.3.1.2 Land Use

<u>Conversion of Private Docks and Commercial Land in Ocracoke Village.</u> The construction of 50-Year Option 6 would likely require the acquisition of private docks and commercial land space to the east of the existing Silver Lake Ferry Terminal. In so doing, these uses would be converted to state transportation facilities.

<u>Conversion of NPS Land.</u> The construction of 50-Year Option 7 would require the acquisition of NPS land to the west of existing NC 12. In so doing, the NPS land would be converted to state transportation facilities.

7.3.1.3 Cultural Resources

The 50-Year Option 6 proposes to expand ferry service to the Silver Lake ferry terminal, which is located immediately outside the Ocracoke Historic District boundary. If, as proposed, the ferry terminal were expanded, the approximately 4.5 acres of land needed for the proposed expansion might encroach upon the historic district. The other 5- and 50-Year alternatives are not expected to have any impact on cultural resources.

7.3.1.4 Section 4(f)

As discussed in Section 5.1.5, Section 4(f) will be applicable only if federal funds are used for the project. If federal funds are used, FHWA will make a determination as to the applicability of Section 4(f) regarding the Seashore.

50-Year Option 6 would alter access to a potential Section 4(f) site, as NC 12 would no longer pass through the Seashore and could impact Ocracoke Village Historic District.

50-Year Option 7 could have Section 4(f) impacts under the permanent use category because approximately 4.5 acres of potential Section 4(f) resources would be converted to new transportation facility.

7.3.1.5 Visual Impacts

50-Year Option 6 could cause moderate visual impacts through the creation of additional ferry terminal space at the Silver Lake Ferry Terminal. This additional ferry infrastructure will be seen during both construction and operation.

50-Year Option 7 also could cause moderate visual impacts through the construction of a new ferry terminal along the west side of NC 12. Although typical terminal buildings and structures are one story it is likely that this could be viewed from NC 12 and would be a visual disruption in the views of the sound.

7.3.2 Natural Environment Impacts

50-Year Option 6 would be constructed within an urbanized area in Ocracoke Village and would not have impacts on NCNHP areas, sea turtles or NPS species. 50-Year Option 7 impacts to NCNHP areas are unknown because the location is not established. It would likely not affect sea turtles that use the ocean beach, as all work would take place on the sound-side of Ocracoke Island. The presence of other threatened and endangered species and associated habitats will be a factor in establishing the location of the new ferry terminal.

Although the path(s) of a new ferry route under 50-Year Options 6 or 7 is unknown, it is likely that dredging would be necessary to facilitate construction and operation. With the dredging, the potential exists to disrupt SAV and EFH.

7.3.3 Constructability

50-Year Option 6

Since this option would be adjacent to an existing ferry terminal, the factors affecting its constructability include: acquiring the land and harbor space, performing dredging (if needed); and constructing new terminal facilities while operations are ongoing at the adjacent terminal. Additional vessels may be needed for this option. In addition, a new channel would have to be dredged for use. Excessive shoaling is present in the Hatteras Inlet, and, as a result, Hatteras Inlet Ferry has had to extend its route well beyond what it has been historically. This coupled with excessive siltation in Pamlico Sound off the west side of Ocracoke Island could prove challenging for dredging and maintaining the channel. Additionally, an appropriate location for dredge spoil disposal would need to be identified.

50-Year Option 7

For this study, it is assumed that the ferry terminal for this option would be on the west side of Ocracoke Island, just south of the Ocracoke Pony Pens. However, this location is subject to change. If constructed at this location, a channel would need to be dredged for ferry clearance, and a road would need to be constructed to the terminal. Depending on the proposed path of a new ferry route, dredging could have regulatory and permitting issues related to SAV and EFH concerns. Given that the terminal would be constructed outside of the NC 12 right-of-way, complications from vehicle traffic are not a significant concern; however, all new land required for the terminal and the access roadway would have to be authorized by the NPS, likely in a new easement. Additional vessels may be required for this option. Concerns regarding dredging and maintaining a channel are the same as with 50-Year Option 6.

7.3.4 Cost

The NCDOT Ferry Division developed costs for the 50-Year Ferry Options 6 and 7. The cost assumes providing service for 2 million vehicles per year across Oregon Inlet. Option 6 would have an existing and adjacent ferry terminal. Option 7 would have a new free standing terminal.

The total estimated cost for installing, operating, and maintaining a ferry system that would service the current traffic demand over the course of the next 50 years is approximately $2.03 billion for Option 6 and $2.15 billion for Option 7. These costs also include crew, supporting facilities (including a new shipyard), maintenance, and vessel replacement at 30 years.

The NCDOT is legally required to provide at least one free route to all locations in the state. Currently, the ferry between Hatteras Island and Ocracoke Island serves as the free route to Ocracoke Island, while the ferries from Swan Quarter and Cedar Island are tolled. If the ferry from Hatteras Island were to become tolled, one of the other routes would have to be fare-free.

7.4 Combination Option: 5-Year Option 3

7.4.1 Human Environment Impacts

7.4.1.1 Recreation

5-Year Option 3 would remove the current access from NC 12 to one parking area, one ORV access ramp to the ocean beach, and two Pamlico Sound access roads, thereby limiting access to recreational opportunities in these areas.

7.4.1.2 Section 4(f)

This option has the potential for Section 4(f) impacts under the permanent incorporation use category because approximately 38 acres would be converted to a new transportation facility.

As discussed in Section 5.1.5, Section 4(f) will be applicable only if federal funds are used for the project. If federal funds are used, FHWA will make a determination as to the applicability of Section 4(f) regarding the Seashore.

7.4.2 Natural Environment Impacts

7.4.2.1 Protected Species

This option could involve lighting impacts to sea turtles.

7.4.2.2 Significant Natural Heritage Area

Approximately 45.96 acres of SNHA would be impacted by 5-Year Option 3.

7.4.2.3 Wetlands

5-Year Option 3 has the potential to impact wetlands west of NC 12.

7.4.3 Constructability

Constructability concerns for this option include the requirement for a permit from NPS and concern about construction materials transport and staging.

7.4.3.1 5-Year Option 3

The factors affecting the constructability of 5-Year Option 3 include the ability to obtain a new easement for NC 12 from NPS, the ability to offset impacts to wetland areas and NCNHP areas, availability of suitable fill for the roadbed, and manner of transporting to and staging of construction materials the project area. The ability to negotiate a new roadway easement from NPS is unknown. The ability to offset impacts to wetlands could present a challenge because NPS has stated that there are no forms of wetland mitigation on Ocracoke Island. The availability of sand fill for the roadbed would be a lesser concern because fill sand suitability criteria for roadbeds is less stringent than beach fill sand. However, the roadbed fill would still need to be transported to the project site through some means; either on trucks using the ferry or on a barge.

7.4.4 Cost

The cost of obtaining beach, berm, and dune sand resources associated with this 5-Year Option 3 is approximately $2.48 million. The associated bridge has a projected cost of approximately $17,200,000 bringing the approximate total cost to $19,700,000.

7.5 Summary

Table 13 and Table 14 summarize potential impacts for the 5-Year and 50-Year alternatives based on the considerations presented in this report. The following summarizes the table and text presented in this section for each group of options.

7.5.1 Beach Nourishment Options

- The nourishment of the beach, berm and dune under 5-Year and 50-Year alternatives will likely have minor potential impact on recreational resources.
- These options have the potential for Section 4(f) impacts. If federal funds are used, FHWA will make a determination as to the applicability of Section 4(f) regarding the Seashore.
- Minor visual resource impacts may occur with these options.
- Minor temporary impacts to protected species, SAVs and EFH. No impact anticipated to Significant Natural Heritage Areas or wetlands.
- The availability of sand for fill both in the short- and long-term, its transport method and permitting concerns are key constructability considerations for these options.
- Costs for these alternatives are expected to range from approximately $14 million to $30 million.

7.5.2 Road and Bridge Options

- Constructability concerns include: the ability to obtain permits from appropriate agencies, the manner of transporting and staging of construction materials, the ability to transport prefabricated bridge parts, and construction methodology. In addition, limitation on construction activities during peak tourist season is also a factor. There are campgrounds near the study area. Construction activities could be limited to minimize impacts to such areas during peak tourist season.
- These options are expected to have moderate impacts to recreation access points.
- These options are likely to enhance bicycle and pedestrian travel.
- Permanent use and potential for constructive and temporary use under Section 4(f).
- Visual impacts range from minor with roadway relocation option to substantial for new bridge options.
- These options are most likely to affect sea turtles, piping plover and red knot. Only the Pamlico Sound Bridge (50-Year Option 1) is expected to impact SAV

and EFH. Impacts to SNHA range from approximately 12 acres to approximately 68 acres.

- The lone 5-Year bridge option has an estimated cost of $76.7 million and the 50-Year options have a range of costs between $188.9 million and $248.5 million.

7.5.3 Ferry Options

- Constructability concerns include: land and harbor acquisition, channel development, terminal facility development during concomitant operations, and permitting.

- Travel time to and from the island will be increased with implementation of either of these options. This could affect visitors to the island and delivery of goods and services.

- These options have the potential to reduce access to some recreational opportunities, including bicycle and pedestrian access, if NC 12 is not maintained north of the ferry terminal.

- If federal funds are used and the conversion of the NPS land to develop new transportation facilities alters access there could be a Section 4(f) determination. In addition, the Ocracoke Historic District could be affected by the design of Option 6.

- There could be moderate visual impacts from additional ferry infrastructure and new ferry terminal.

- There is limited potential for impact to protected species, SNHA, or wetlands. Dredging for a new ferry route could disrupt SAV and EFH habitats.

- The total estimated cost for installing, operating, and maintaining a ferry system that would service the current traffic demand over the course of the next 50 years was determined to be approximately $2.03 billion for Option 6 and $2.15 billion for Option 7. These costs also include crew, supporting facilities (including a new shipyard), maintenance, and vessel replacement at 30 years.

Table 13. Comparison of 5 – Year Alternatives

			5-Year Alternatives			
			5 yr. Opt. 1. Large Scale Beach Nourishment	5 yr. Opt. 2. Dune Nourishment	5 yr. Opt. 3. Relocate Roadway & Dune Nourishment	5 yr. Opt. 4. Bridge Over Hot Spot
Potential Impacts		**Cost**	$13,950,000	$1,350,000	$19,700,000	$76,700,000
Potential Impacts		**Constructability**	Availability of sand resource; transport method concerns; local competition for sand resources; and required permits from NPS. Adherence to NPS Policy guidelines with regard to Beach Nourishment.	Availability of sand resource; transport method concerns; local competition for sand resources; and required permits from NPS. Less sand needed than Option 1.	New easement would require permit from NPS; concern about construction materials transport and staging.	Concern about ability to detour traffic during construction. Concerns about completing all construction activities, including staging, within the existing easement. Temporary construction easement outside existing easement would require permit from NPS
Potential Impacts		**Travel Convenience**	No change anticipated	No change anticipated	Possible delays during construction.	Possible delays during construction.
Potential Impacts		**Need for Dredging**	1,916,000 cy of sand resources needed. Sand resources expected to come from offshore sites.	139,000 cy of sand resources needed. Sand resources expected to come from existing dredging operations.	256,000 cy of sand resources needed. Sand resources expected to come from existing dredging operations.	66,000 cy of sand resources needed. Sand resources expected to come from existing dredging operations
Potential Impacts	Human Environment	**Land Use**	No change anticipated	No change anticipated	Conversion of 37.6 acres of NPS land for new NC 12 easement.	No permanent land use changes anticipated, but some NPS lands may be used for construction easement.
Potential Impacts	Human Environment	**Cultural Resources**	No change anticipated	No change anticipated	No change anticipated	No change anticipated
Potential Impacts	Human Environment	**Bike & Pedestrian**	No change anticipated	No change anticipated	Potential beneficial impact with use of proposed wider paved shoulder.	Potential beneficial impact with use of proposed wider paved shoulder
Potential Impacts	Human Environment	**Section 4(f)**	Permanent incorporation impacts are likely to occur with berm and dune nourishment outside of the existing NC 12 easement.	Permanent incorporation impacts are likely to occur with berm and dune nourishment outside of the existing NC 12 easement.	Permanent incorporation of approximately 38 acres for new NC 12 easement.	Potential constructive use possible, depending upon visual impact of bridge. Potential for temporary use associated with temporary construction easement.
Potential Impacts	Human Environment	**Visual Considerations**	Minor potential impact based on height increase of dunes over existing conditions.	Minor potential impact based on height increase of dunes over existing conditions.	Minor potential for impacts with vegetation removal.	Impact based on visual presence of new bridge.
Potential Impacts	Human Environment	**Recreation**	Minor potential to affect recreation resources. Efforts for beach fill could be performed in tourism off-season.	Minor potential to affect recreation resources. Efforts for beach fill could be performed in tourism off-season.	Loss of access to one parking area, one ORV access, and two dirt roads to the sound.	Likely loss of one ORV access and cut off of loss of access to one parking area.
Potential Impacts	Natural Environment	**Significant Natural Heritage Areas (SNHA)**	0 acres	0 acres	45.96 acres	20.83 acres
Potential Impacts	Natural Environment	**Protected Species[1]**	Minor potential temporary impact to sea turtles, but could be minimized if beach fill occurs outside of the nesting season. Minor potential temporary impact to piping plover and red knot during construction.	Minor potential temporary impact to sea turtles, but could be minimized if beach fill occurs outside of the nesting season. Minor potential temporary impact to piping plover and red knot.	Potential lighting impacts to sea turtles.	Potential lighting impacts to sea turtles.
Potential Impacts	Natural Environment	**Wetlands**	No change anticipated	No change anticipated	Potential impacts to wetlands west of NC 12.	Potential wetland impacts
Potential Impacts	Natural Environment	**SAVs & EFHs**	Potential temporary, localized impacts to EFH in offshore area associated with sand extraction from off-shore sites. Potential impacts to EFH present in the surf zone sand placement areas.	No change anticipated	No change anticipated	No change anticipated

[1]Protected species refers to species listed as threatened or endangered by the USFWS. NPS species refers to species that either are proposed for listing (Rufa red knot) or are species of high concern (American oyster catcher). Because of agency concern for these species, their impacts were considered in this evaluation.

Table 14. Comparison of 50 – Year Alternatives

			50 – Year Alternatives (Options 1-4)			
			50 yr. Opt. 1. Pamlico Sound Bridge	50 yr. Opt. 2. Bridge throughout Hot Spot	50 yr. Opt. 3. Roadway Relocation and Bridging	50 yr. Opt. 4. Bridging in Existing Easement
Potential Impacts		Cost	$194,750,000	$188,900,000	$234,950,000	$248,450,000
Potential Impacts		Constructability	Channel Dredging to deliver pre-fabricated bridge components; top down construction; Potential timing constraints for certain construction activities during peak tourist season; New permanent easement outside existing easement would require permit from NPS	Channel Dredging to deliver pre-fabricated bridge components; top down construction; NCDEQ, Potential timing constraints for certain construction activities during peak tourist season. New permanent easement outside existing easement would require permit from NPS	Channel Dredging to deliver pre-fabricated bridge components; top down construction; Potential timing constraints of certain construction activities during peak tourist season; New permanent easement outside existing easement would require permit from NPS	Concern about ability to detour traffic during construction. Concerns about completing all construction activities, including staging, within the existing easement; Potential timing constraints of certain construction activities during peak tourist season
Potential Impacts		Travel Convenience	Possible delays during construction.	Possible delays during construction.	Possible delays during construction.	Possible delays during construction.
Potential Impacts		Need for Dredging	Channel dredging for construction activity. 1,916,981 cy of sand needed (over 50 years), expected to come from existing dredging operations.	Channel dredging for construction activity. 111,187 cy of sand needed (over 50 years), expected to come from existing dredging operations.	Channel dredging for construction activity. 4,775,825 cy of sand needed (over 50 years), expected to come from existing dredging operations.	111,187 cy of sand needed (over 50 years), expected to come from existing dredging operations.
Potential Impacts	Human Environment	Land Use	62.21 acres of NPS land converted to road/bridge use.	59.66 acres of NPS land converted to road/bridge use.	59.56 acres of NPS land converted to road/bridge use.	Temporary land use changes due to new TCE needed outside the existing easement.
Potential Impacts	Human Environment	Cultural Resources	No change anticipated	No change anticipated	No change anticipated	No change anticipated
Potential Impacts	Human Environment	Bike & Pedestrian	Potential beneficial impact with use of 8-foot proposed shoulder	Potential beneficial impact with use of 8-foot proposed shoulder	Potential beneficial impact with use of 8-foot proposed shoulder	Potential beneficial impact with use of 8-foot proposed shoulder
Potential Impacts	Human Environment	Section 4(f)	Permanent incorporation of approximately 62 acres into new NC 12 easement; potential impact based on change in visual character.	Permanent incorporation of approximately 60 acres for new NC 12 easement; potential impact based on change in visual character.	Permanent use of approximately 60 acres for new NC 12 easement.	Visual intrusion could be a constructive use of the Seashore. The final determination will be made by FHWA during the NEPA phase of the project. Potential for temporary use associated with temporary construction easement
Potential Impacts	Human Environment	Visual Considerations	Impact to views from Sound and upland, less impact from beach.	Significant impact to views from beach and upland, less so for sound.	Minor impacts because of vegetation removal for new road construction.	Impact to views from beach and upland, less so for sound.
Potential Impacts	Human Environment	Recreation	Loss of access to one parking area, one ORV access, and two dirt roads to the sound.	Loss of access to one parking area, one ORV access, and two dirt roads to the sound.	Loss of access to one parking area, one ORV access, and two dirt roads to the sound.	Loss of access to one parking area, one ORV access, and two dirt roads to the sound.
Potential Impacts	Natural Environment	Significant Natural Heritage Areas (SNHA)	32.53 acres	12.7 acres	68.31 acres	12.06 acres
Potential Impacts	Natural Environment	Protected Species[2]	Potential impact to sea turtles from proximity of construction activities.	Potential impact to sea turtles from proximity of construction activities.	Potential impact to sea turtles from proximity of construction activities.	Potential impact to sea turtles from construction lighting and vehicle headlights. Due to proximity to beach, potential to impact plover and red knot during construction.
Potential Impacts	Natural Environment	Wetlands	Potential impacts to wetlands west of NC 12.	Potential wetland impacts.	Potential impacts to wetlands west of NC 12.	Potential wetland impacts.
Potential Impacts	Natural Environment	SAVs & EFHs	Potential shadow impacts to SAV habitat. Minor EFH impacts from shadowing.	No change anticipated	No change anticipated	No change anticipated

[1]Protected species refers to species listed as threatened or endangered by the USFWS. NPS species refers to species that either are proposed for listing (Rufa red knot) or are species of high concern (American oyster catcher). Because of agency concern for these species, their impacts were considered in this evaluation.

Table 14. Comparison of 50 – Year Alternatives (concluded)

50 – Year Alternatives (Options 5-7)					
			50 yr. Opt. 5. Large Scale Beach Nourishment	**50 yr. Opt. 6. Ferry Service to Ocracoke Village Ferry Terminal**	**50 yr. Opt. 7. Ferry Service to New Ferry Terminal North of Ocracoke Village**
Potential Impacts	Cost		$41,600,000	$ 2,030,350,000	$ 2,148,600,000(does not include new ferry terminal)
Potential Impacts	Constructability		Availability of continued sand resource; Easement from NPS may be needed to place sand within Seashore	Land and harbor space acquisition; dredging and related permitting; channel maintenance. Additional ferry vessels may be needed.	Land acquisition; dredging and related permitting; and channel maintenance. Additional ferry vessels may be needed.
Potential Impacts	Travel Convenience		No change anticipated	Longer ferry trip, increased travel time (1 hour 5 minutes).	Longer ferry trip, increased travel time (45 minutes).
Potential Impacts	Need for Dredging		4,279,000 cy of sand needed (over 50 years), expected to come from offshore sites.	Dredging will likely be necessary for the new ferry channel. This may disturb SAV and EFH.	Dredging will likely be necessary for the new ferry channel. This may disturb SAV and EFH.
Potential Impacts	Human Environment	Land Use	No change anticipated	4.5 acres of land converted to transportation use.	4.5 acres of land converted to transportation use.
Potential Impacts	Human Environment	Cultural Resources	No change anticipated	The expansion of the existing ferry terminal could have potential impacts to the Ocracoke Historic District, depending on design.	No change anticipated
Potential Impacts	Human Environment	Bike & Pedestrian	No change anticipated	If the ferry terminal is relocated and NC 12 north of the new terminal is not maintained, could impact bike and pedestrian use of northern Ocracoke Island.	No change anticipated
Potential Impacts	Human Environment	Section 4(f)	Permanent use likely because berm and dune nourishment would be outside of the existing NC 12 easement.	Access to a 4(f) site would change, since NC 12 would no longer pass through Seashore.	Permanent use of approximately 4.5 acres north of new terminal for new transportation facility. Access changes to Seashore expected with new terminal.
Potential Impacts	Human Environment	Visual Considerations	Minor potential to impact based on height increase of dunes over existing conditions in some lower dune areas	Additional ferry infrastructure could cause a moderate change in visual character. Access changes to Seashore expected with new terminal.	New ferry terminal could be viewed from NC 12 and could cause moderate changes to views from the Sound
Potential Impacts	Human Environment	Socio Economic	No change anticipated	Longer ferry routes could potentially affect delivery times and costs for goods and services; Depending on whether NC 12 is maintained north of the ferry terminal, public access could be lost to parts of the Seashore.	Longer ferry routes could potentially affect delivery times and costs for goods and services. Depending on how much of NC 12 is maintained north of Ocracoke Village, public access could be lost to parts of the Seashore.
Potential Impacts	Natural Environment	Significant Natural Heritage Areas (SNHA)	0 acres	0 acres	Unknown because exact location undetermined.
Potential Impacts	Natural Environment	Protected Species[2]	Minor potential to impact sea turtles, but impact minimized if beach fill occurs outside of the nesting season. Minor potential temporary impact to piping plover and red knot during construction.	No change.	Unknown for NCNHP impact. No impacts to sea turtle. Little potential for other NPS species impacts.
Potential Impacts	Natural Environment	Wetlands	No change anticipated	No change.	Unknown because location is undetermined.
Potential Impacts	Natural Environment	SAVs & EFHs	Potential impacts to EFH present in the surf zone sand placement areas.	Dredging for new ferry route would potentially disrupt SAV and EFH habitats.	Dredging for new ferry route would potentially disrupt SAV and EFH habitats.

[1]Protected species refers to species listed as threatened or endangered by the USFWS. NPS species refers to species that either are proposed for listing (Rufa red knot) or are species of high concern (American oyster catcher). Because of agency concern for these species, their impacts were considered in this evaluation.

8.0 Summary of Agency Coordination

8.1 Merger Team Meetings

Aside from NCDOT, the following State and Federal agencies were included in the project Merger Team:

- Albemarle Regional Planning Organization (RPO)
- National Park Service (NPS)
- North Carolina Division of Water Resources (NCDWR)
- North Carolina Division of Coastal Management (NCDCM)
- National Marine Fisheries Service (NMFS)
- North Carolina State Historic Preservation Office (SHPO)
- North Carolina Wildlife Resources Commission (NCWRC)
- United States Army Corps of Engineers (USACE)
- Federal Highway Administration (FHWA)
- United States Environmental Protection Agency (USEPA)
- United States Fish and Wildlife Service (USFWS)

A project scoping meeting was held on May 8, 2014 with the Merger Team. The purpose of this meeting was to show the project to all Merger Team agencies and get their input prior to moving forward. Based on the meeting discussion, the concerns expressed by the agencies present included the following:

- USFWS expressed a preference that any nourishment activities occur outside of the nesting season for protected species known to use the area, including red knot, which is listed as threatened, and piping plover.
- USACE wanted assurance that they would be consulted along with the NPS when decisions start to be made about obtaining sand resources, stating that it would be best to make arrangements for permits with a lead time that considers the potential for regulatory delays and minimizes the need for "emergency actions." USACE was concerned that beach fill would have the potential to impact sea turtle species if done during nesting season. USACE also commented that sand color would also be a concern because of species preferences in color.
- NCDCM and NMFS wanted to be assured that SAV would be considered in the project feasibility study.

- NPS was concerned that sand resources will not be enough for the project because of competition from Dare and Hyde Counties, NCDOT and USACE. NPS was also concerned about wetland impacts, stating that no wetland banking opportunities exist on Ocracoke Island. NPS wants USACE to be involved in the sand resources discussion when sources are sought.

8.2 Individual Agency Coordination Meetings

During the development of this feasibility study, NCDOT held meetings with the National Park Service, Dare County and Hyde County officials.

A meeting was held with the National Park Service at NPS headquarters in Manteo. The April 22, 2014 meeting was to present the project and discuss items that would be important to NPS prior to moving forward. NPS expressed the following concerns at the meeting:-

- Process for obtaining sand resources
- The viability of 50 year options
- Impacts to sea turtles, migratory birds and other species of concern.

A joint local officials meeting was held with officials from Dare and Hyde Counties on June 11, 2014 at the Dare County Government Offices in Manteo. The purpose of the meeting was to present the project and discuss items that would be important to local government officials. Local officials had few comments since project alternatives had not yet been determined. The local officials requested to be involved in decisions affecting Ocracoke Village, especially from an economic standpoint. They also had an interest in a rerouted ferry from Hatteras Island coupled with a local transit system.

Since the meeting with the Dare and Hyde County local officials in 2014, NCDOT completed *The Ocracoke-Hatteras Passenger Ferry Feasibility Study* (June 2016). The study recommends two 100-passenger ferries making eight round-trips a day between Hatteras and Ocracoke Village. It also recommends a $15 round-trip toll, as well as a transit loop run by Hyde County, to take visitors from the terminal through Ocracoke Village and to various island attractions, such as Ocracoke Lighthouse and the National Park Service's Pony Pens.

.

9.0 Next Steps

If this project receives funding and is programmed in the STIP, the next step would be to initiate the NEPA process. Preliminary designs would be developed, a detailed impact assessment would be undertaken, and the information would be recorded in an environmental document. Factors to consider as the project advances to the NEPA study phase include:

<u>Short-Term Alternatives</u>

- Natural Environment
    - Beach/dune nourishment sources
    - Protected species impacts
    - Habitat modification
- Constructability
    - Easement requirements
    - Beach/dune nourishment volumes
    - Construction material transport to site, staging (especially for in-easement alternatives)
    - Durability through short-term timeframe
- Recreation
    - Section 4(f) applicability and impacts
    - Access maintenance during construction

<u>Long-Term Alternatives</u>

- Costs
    - Ferry acquisition and maintenance
    - New harbor facility development and maintenance
    - Channel development and maintenance
    - Long term nourishment costs

- Constructability
    - Construction methodology
    - Material transport requirements, construction staging within Seashore
    - Permit/ new easement requirements

- Nourishment
    - Costs of template nourishment maintenance
    - Continued availability of suitable sand sources

- Natural Environment
    - Essential Fish Habitat (EFH) and Submerged Aquatic Vegetation (SAV)

- Recreation and Access
    - Section 4(f)- access to NPS recreation facilities (if determined to be applicable)
    - Bike and pedestrian access
    - Off road vehicles (ORV)
    - Economic impact
        - Travel convenience

Investigations and studies that may need to be conducted include:

- Natural environment studies
- Economic impact studies
- Section 4(f) Evaluation
- Detailed sand sediment analysis
- Storm surge analysis to determine bridge height, design
- Offshore surveys to determine sand source availability if nourishment is considered a preferred alternative
- If ferry options are considered likely, studies to determine extent of dredging and potential for shoaling if ferry terminal is moved
- Shoreline studies to determine likelihood of a breach in the study area

If the project moves forward with federal funds, it is important to have an early coordination meeting with NPS and FHWA to determine the applicability of Section 4(f) as it relates to the Cape Hatteras National Seashore.

To help prepare for an emergency situation, potential options include: Stockpiling temporary bridges that can accommodate an appropriate set of spans. This would allow NCDOT to react swiftly in an emergency storm situation. Also, depending on the specific span length ranges of temporary bridges that may be required during the aftermath of a storm event, cored slab units could also be stockpiled for the purposes of constructing emergency temporary bridges.

Stockpiling precast prestressed concrete piles for the purposes of building the foundations for temporary bridges. This would also allow help prepare NCDOT in the event that a temporary bridge is needed during a storm event.

10.0 Works Cited

Atkins (Formerly PBS&J). Natural Resources Technical Report. Atkins, February 2010.

Conversation notes from NCDOT and PB's National Park Service Coordination Meeting – in Manteo, NC on April 22, 2014.

Holland Consulting Partners. Hyde County, NC CAMA Core Land Use Plan. Holland Consulting Partners, March 2008.

Hyde County. Ocracoke Development Ordinance (2nd Amendment thereto). Hyde County, November 2006.

Moffatt and Nichol. 2010 Update of Vulnerability Analysis & Coastal Engineering Evaluation. Moffatt and Nichol, April 2010.

Moffatt and Nichol. Update Shoreline and Erosion for Ocracoke Island. Moffatt and Nichol, August 2014.

NCDOT. Comprehensive Transportation Plan Hyde County. NCDOT, October 2012.

NCDOT. Around Pamlico Sound, Bicycling North Carolina's Outer Banks Region. NCDOT, May 1994.

NCDOT. Deposition of Dredge Material at the Hatteras Inlet Ferry Terminal on Ocracoke Island, Hyde County, North Carolina. NCDOT, January 2003.

NCDOT. Essential Fish Habitat Assessment for the Emergency Fill Along Highway 12 in Rodanthe, Dare County, NC. NCDOT (2013).

NCDOT. NCDOT Bid Abstract for Solicitation WPM912-14-B-0004, NCDOT, May 19, 2014.

North Carolina Natural Heritage Program GIS Information available at: http://portal.ncdenr.org/web/nhp/gis-download. July 2014.

Overton, M. and Fisher, J. NC 12 Vulnerability Analysis. Overton, M. and Fisher, J., June 2002.

Parsons Brinckerhoff. Traffic Estimate, NC 12 Ocracoke Island Hot Spot, Ocracoke Island, Hyde County. PB, August 2014.

Stone, J., Overton, M. and Fisher, J., December 1991 Options for North Carolina Coastal Highway Vulnerable to Long Term Erosion. 1991

United Stated Department of Transportation. U.S. Department of Transportation Act of 1966 (Section 4[f] thereto). United Stated Department of Transportation, 1966.

US Fish and Wildlife Service National Wetlands Mapper GIS Data Download Site: http://www.fws.gov/wetlands/Data/Data-Download.html. July 2014.Traffic Estimate Methodology

11.0 APPENDIX

Traffic Analysis

2014 Shoreline and Erosion Update

2010 Vulnerability Analysis Update

Traffic Analysis

1.0 Traffic Estimate Scenario Years and Inputs

1.1 Estimated Scenario Years

This traffic estimate is developed for present conditions, five year future conditions, and a future scenario terminating in 2040, which unlike the feasibility study's 50 year horizon, is 28 years into the future. The reason for the differing horizons is that developing a 50 year estimate exceeds the limits for a standard traffic forecast.

1.2 Inputs

The traffic estimate for this study was developed using existing data. No tube counts or turning movements were performed. The inputs for the analysis include the following:

- Published population and housing data
- Existing average annual daily traffic (AADT)
- Peak hour design percentages
- Truck percentages
- Conversion factors for extrapolating summer traffic volumes
- Consideration of traffic and land use trends over the past 10 years

2.0 Trends and Data Review

In preparing this estimate of future volumes, multiple sources were examined including land use data, roadway traffic data, and ferry data sources.

2.1 Population and Land Use Data

Traffic volume increases result from population growth. Population growth is directly tied to land use development and tourism, if an area is a tourism-based economy. Given this, a review of historical, existing, and forecast population and land use on Ocracoke Island was conducted, with emphasis on peak tourism season numbers.

Historical Population and Land Use

Historical population and land use data were gathered from the US Census, Hyde *County CAMA Core Land Use Plan* (2008) (LUP), and interviews with local planners. This data is presented in the traffic report. This feasibility study summarizes key findings of the analysis. These findings include:

- Population Growth – Annual population growth rates between 1970 and 2010 fluctuated slightly, but averaged approximately 1.4 percent growth. Annual growth rates between 2000 and 2010 demonstrated higher growth, averaging approximately 2.1 percent.

- Housing Unit Use and Growth – There are currently 983 housing units on Ocracoke Island. Approximately 269 housing units are owner occupied, with the remainder presumably being rental properties. An analysis of the data indicated a decline in owner occupancy and an approximate 3.8 increase in rentals between 2000 and 2010.

Projected Population and Land Use

A review of data in the *Hyde County LUP* indicates the following for Ocracoke Island:

- Population Growth – The forecast annual growth rates between 2000 and 2030 show population increase, with an anticipated acceleration in growth between 2010 and 2030.

- Housing Unit Growth – Although housing unit growth is anticipated through 2030, the rate is expected to be slower than the pre-2010 timeframe. Hyde County planners indicated that development restrictions associated with environmental conditions (primarily wetlands) and the Cape Hatteras National Seashore substantially limit continued growth in the undeveloped areas in and around Ocracoke Village. Given this constraint, most growth will likely occur as the result of replacing and expanding older structures. However, since more than 65 percent of structures in Ocracoke Village are 50 years old or older, their replacement or expansion may also be limited by the potential for them to be designated as historic structures. Based on the land development restrictions and potential restrictions on structural replacements or expansions, it is reasonable to assume that a maximum annual increase in housing units of 0.5 percent may occur. This assumption is consistent with the Hyde County LUP.

2.2 Summer Peak Population

The summer season is the time of greatest population on Ocracoke Island. Summer weekends are the peak times for short term population increase. In general, the summer population makeup is approximately 90 percent tourists and 10 percent permanent residents (Hyde County LUP). Of the 90 percent tourist population, approximately 20 percent are overnight visitors and 70 percent are day trippers. Detailed data are presented in the traffic report. Key findings regarding the summer population include:

- Seasonal Population Growth – Similar to the growth of Ocracoke permanent residents, seasonal populations are anticipated to grow. However, the anticipated 2010 to 2030 tourist population growth rate is less than the permanent population growth rate by 0.3 percent.

- Statistical Distribution of Tourist Population – Day trippers have historically made up the bulk of the seasonal population increase, and this trend is expected to continue. The growth rate of 0.7 percent for this population is anticipated to continue through 2030.

- Day Trips – The number of day trippers spikes on the summer weekends with tourists utilizing the ferry system to access Ocracoke Island, park in limited public parking locations or along NC 12, and enjoy the beach for the day. These volumes indicate that close to 2,000 cars already require parking at certain times (compared with less than 200 public parking spots provided in the National Seashore). The majority of parking on a summer weekend occurs on the beach and along NC 12.

2.3 Traffic Data

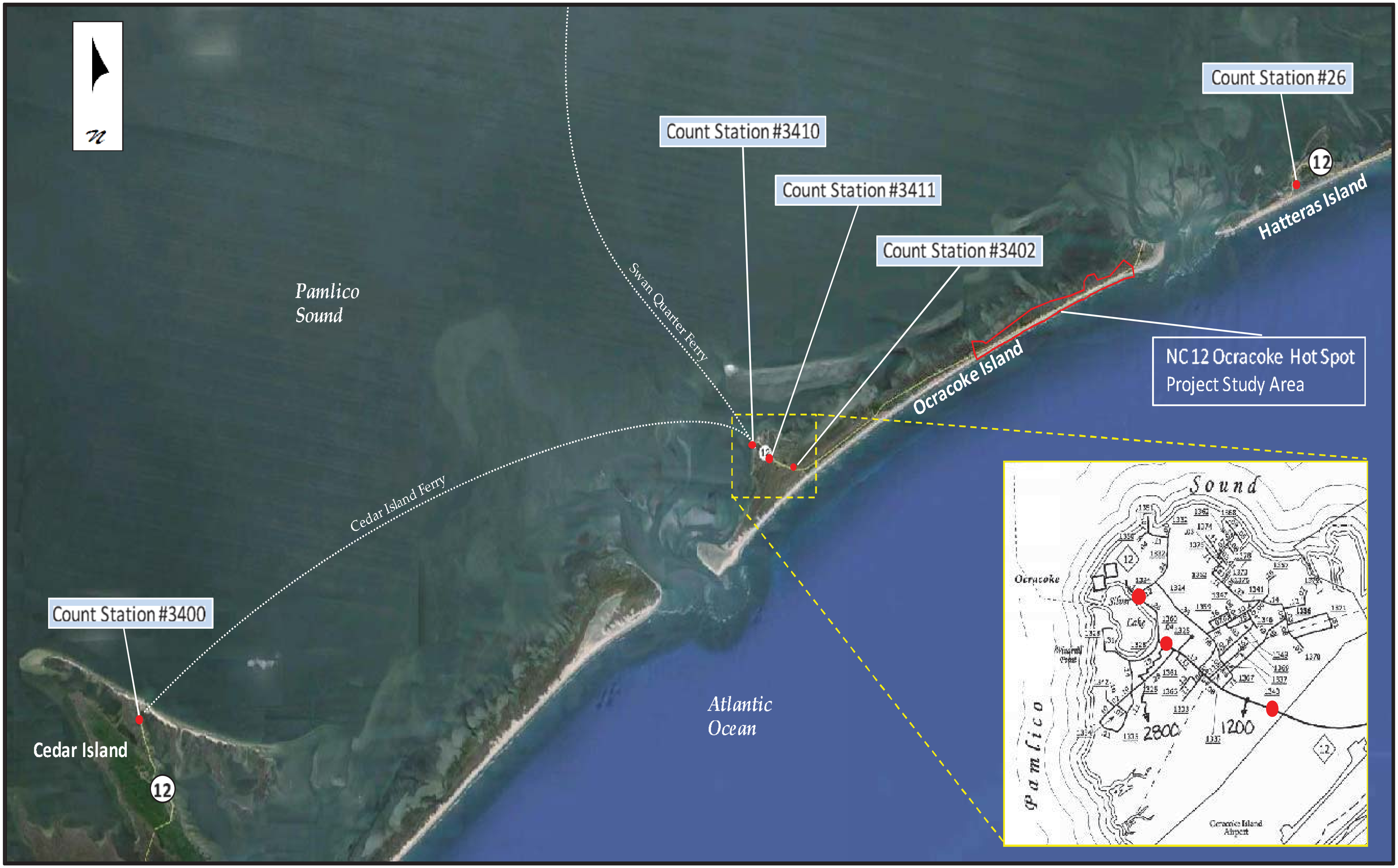
Roadways

As stated earlier, no traffic counts were performed. Additionally, since the project area is relatively remote, some data that would normally be available for urban areas is not available. This information includes published hourly and/or daily traffic counts and summer traffic counts. Instead, historical traffic data were reviewed for this study. Using the historical AADT records, it is possible to get an understanding of historical traffic growth rates. The locations of the NCDOT AADT map count stations used in this analysis are listed in Table -1 and shown graphically in **Error! Reference source not found.**1-1. The table indicates that:

- The highest AADT volume reported is on Ocracoke Island and occurs in Ocracoke Village near the Silver Lake Ferry terminal. No AADT count stations are located on the north end of Ocracoke Island. Because of this, historical data from the Hatteras Inlet Ferry were extrapolated to establish AADT on the northern part of Ocracoke Island on the segment of NC 12 near the Hatteras Inlet Ferry Terminal.

- NC 12 near the Hatteras Inlet Ferry Terminal on Ocracoke typically has less AADT than NC 12 near the Hatteras Inlet Ferry Terminal on Hatteras Island. This segment also shows a decreasing trend in the years following 2002.

- Traffic volumes on all links fluctuate each year. However, volumes on all sections of NC 12 have generally decreased over the past 10 years. The highest volumes were reported in 2002 (5,300 vpd). Since then, traffic volumes decreased at an annual rate of nearly 5 percent each year.



NC 12 IMPROVEMENTS PROJECT
FEASIBILITY STUDY

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
PROJECT DEVELOPMENT AND ENVIRONMENTAL ANALYSIS BRANCH

Hyde County
NCDOT Div. 1

NCDOT AADT Count Station Locations

Figure 1-1

Table 1-1. Historical Average Annual Daily Traffic (Roadways)

Section	Vehicles Per Day (VPD)										
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
NC 12 Near Hatteras Inlet Ferry Terminal on Hatteras Island in Dare County (Count Station 26)	4,200	1,600	3,000	4,100	2,900	3,800	3,100	2,600	2,700	3,200	2,600
NC 12 just south and east of Ocracoke Village (Count Station 3402)	5,300[1]	--	--	2,100	1,600	2,000	1,500	1,100	1,500	1,400	1,200
NC 12 within Ocracoke Village (Count Station 3411)	--	--	--	--	1,800	2,300	1,900	1,600	1,500	2,100	2,100
NC 12 Near Silver Lake Ferry Terminal in Ocracoke Village (Count Station 3410)	--	--	--	--	3,000	3,400	3,000	2,500	2,500	--	2,800
NC 12 on Cedar Island (Count Station 3400)	1,000	880	730	900	740	750	520	700	830	570	600

Source: NCDOT AADT program. Notes: 1.) Largest AADT for years surveyed. General Notes: Grey shading indicates NC 12 segments on Ocracoke Island. Two dashes (--) indicate no data available

Ferry Data

All vehicles accessing Ocracoke Island must use a ferry. Because of this, ferry data are a good indicator of traffic patterns. Daily ferry data were obtained to compare weekend and weekday traffic volumes. Monthly ferry traffic data were obtained from the NCDOT Ferry Division dating back to 1998 for the three ferry routes serving Ocracoke Island. The Hatteras Inlet Ferry and Cedar Island Ferry provide north-south linkage for NC 12. The AADT equivalents for these ferry routes are shown below in Table 2-2. Key findings from the ferry data include:

- The Hatteras Inlet Ferry carries the greatest volume of traffic to and from Ocracoke Island (75 percent and 80 percent during the summer). This usage peaked between the years 2001 and 2002.
- The Swan Quarter Ferry provides east-west access to mainland Hyde County and is the longest ferry route. It, therefore, has a lower percentage of tourism-related trips than the north-south ferries serving NC 12.
- Summer weekend traffic is not substantially higher than summer weekday traffic on Ocracoke Island. Wednesday and Thursday are high volume days for the ferries. Weeklong visitors tend to use the Hatteras Inlet Ferry for trips to Ocracoke Island returning the same day.
- During peak summer conditions, the Hatteras Inlet Ferry has high volume intervals during which not all vehicles can be served by the ferry.
- The Cedar Island Ferry and Swan Quarter Ferry have a familiar tourist pattern of weekly flows with the weekend volumes being greater due to the turnover of rental units.

Table 2-2. Ferry Route AADT Equivalents

Ferry	Crossing	Connecting	Number of Summer Departures/ Crossing Time	2012-2013 AADT Equivalent (vpd)	2012-2013 Summer (vpd)
Hatteras Inlet Ferry	Hatteras Inlet	NC 12 on Hatteras Island to NC 12 on Ocracoke Island.	30 per day per direction/ 55 minutes	735	1,486
Cedar Island Ferry	Pamlico Sound	NC 12 on Ocracoke Island to NC 12 on Cedar Island.	6 per day per direction/ 2 hours 15 minutes	150	244

Swan Quarter Ferry	Pamlico Sound	NC 12 on Ocracoke Island to US 264 on the mainland.	6 per day per direction/ 2 hours 30 minutes	94	134

Notes:

1. The historical ferry data in Table 8 was developed by computing an AADT from the total annual trips.
2. NCDOT reports ferry data on a non-standard fiscal year. It is assumed that the first year identified in the range correlates with the AADT years reported by NCDOT for roadways (e.g., ferry data for 2012–2013 is assumed as comparable to the 2012 AADT data for roads.

3.0 Forecast Methodology

The historical land use, roadway, and ferry data were evaluated and compared with the Hyde County Land Use Plan to estimate both existing 2013 and future 2040 volumes. Due to unique issues specific to developing future traffic estimates in an area subject to high levels of seasonal tourist traffic, the methodology examined multiple issues not typical for a traditional roadway facility.

3.1 Existing Conditions

Establishing existing traffic volumes is a typically standard procedure because existing traffic counts are relatively consistent, both day-to-day and throughout the year. In an area with a high number of seasonal tourists, such as Ocracoke Island, traffic volumes vary significantly based on the time of year, day of the week, the economy, and weather. In addition to variances throughout the year, the annual AADT for NC 12 on Ocracoke Island varies considerably from year to year.

As shown in Table , the AADT on the project segment has fluctuated between 1,200 vpd and 2,100 vpd over the past ten years based upon Count Station 3402 south of the project study area. In addition, 2002 had a reported AADT of 5,300 vpd. To the north of the study area at the Hatteras Ferry terminal, vehicles using the ferry have fluctuated between approximately 700 vpd and 1,200 vpd, with 1,400 vpd recorded in 2002.

Based on a review of the growth rates on both NC 12 and the ferries, it was determined that the best indicator of the baseline volume would be the historical data from 2002 through 2013. The 2002-2013 range was selected because it provides at least 10 years of trends and because 2002 was the earliest year that highway AADT volumes were available to directly compare with the ferry-based AADT equivalents. The traffic analysis further determined that the 85^{th} percentile value of 2,100 vpd is an appropriate estimate for the baseline AADT (see the full traffic report for a detailed description of the analysis). The 85^{th} percentile value was used because it incorporates both the overall reduction in traffic volumes since 2002 (5,300 vpd on Sta. 3402), while also accounting for the fact that the infrastructure is already in place to serve a higher volume than observed since the 2008 recession.

3.2 Future Growth Rate

Despite some downward trends in growth rates for traffic and ferry use over the past 10 years, the land use and tourism infrastructure in place is capable of, and has in the past, supported much higher average annual daily traffic. Therefore, the historical traffic decline is not a prudent single assumption for future growth. Review of housing data (discussed in Section 0) showed a 2.3 percent annual increase in total housing units in Ocracoke Village between 2000 and 2010. However, it is recognized that this growth may be constrained.

Day trippers using the ferry system to access Ocracoke Island are the primary source of summer traffic volumes, both during the week and on weekends. Hyde County anticipates an increase to a maximum of 10,000 day trippers in 2030 (the future year indicated in the Hyde County Land Use Plan). On Saturday July 6, 2013 the ferry system carried 3,600 vehicles and 9,800 passengers. Given that some of the passengers are full time residents, it is estimated that there were 4,400 day trippers who both accessed and left the island (8,800 ferry passengers). If it is assumed that there will be 10,000 day trippers by 2030, an annual increase of 3.1 percent is required. Similarly, it was computed that for 8,000 day trippers in 2030, an annual growth rate of 2.2 percent was required. Based on a combination of these two growth rates, it is estimated that AADT would increase by 2.5 percent per year.

2014 Shoreline and Erosion Update

moffatt & nichol

MEMORANDUM

To: Bill Rice

From: Moffatt & Nichol

Date: 26 June 2014

Subject: Update Shoreline and Erosion for Ocracoke Island

Under the current contracted effort, Moffatt & Nichol (M&N) provides an update to the vulnerability of the stretch of NC12 along Ocracoke Island. This memo provides a summary of the current work by M&N to update the existing shoreline based December 2013 aerials and projected 5-year and 50-year shorelines based on background erosions rates; a discussion of beach fill sources is also presented. This work builds on prior investigations, most recently documented by M&N in the 2010 Draft Vulnerability Analysis & Coastal Engineering Evaluations (VA&CEE).

2013 Shoreline Update

M&N loaded the December 2013 aerial photography into ArcMap and digitized the shoreline, defined by the wet/dry line, at a scale of 1:1,000 (NAD83 US ft). Table 1 identifies the setback distance measured at each of the transects based on the 2013 aerials and compared this shoreline to the shoreline established by the 2009 cross-section surveys presented in the 2010 Vulnerability Analysis & Coastal Engineering Evaluations (VA&CEE). It should be noted that the 2009 shoreline was based on the surveyed Mean High Water Line (MHWL).

The estimated setback distance from the shoreline to the road centerline is most notably changed at stations 585 and 605 where there has been 118 ft and 55 ft of shoreline recession. As identified in the VA&CEE, this reach of the roadway (specifically at station 605) is the most vulnerable to damage and requires regular maintenance to rebuild a protective dune.

Table 1. Setback Distance from the Road Centerline

Station	2009 Setback Distance (ft)	2013 Setback Distance (ft)
430	420	397
475	384	357
505	295	266
540	287	271
565	226	197
585	216	98
605	124	69
620	145	132
650	251	163
685	421	331

Figure 1 and Figure 2 illustrate the cross-section as surveyed at stations 585 and 605 in 2009 (VA&CEE, Draft 2010).

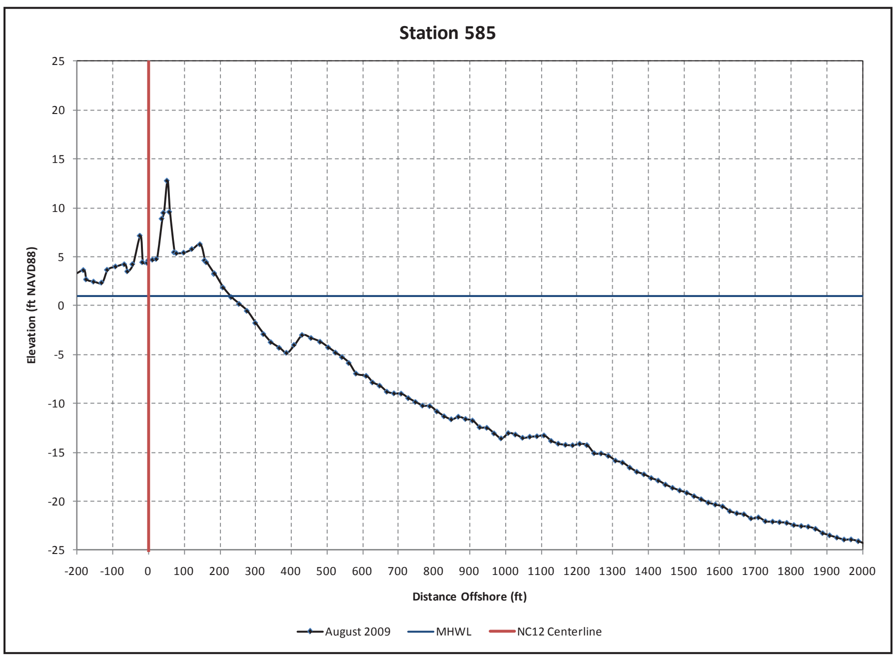


Figure 1. Station 585 cross-section survey performed in 2009

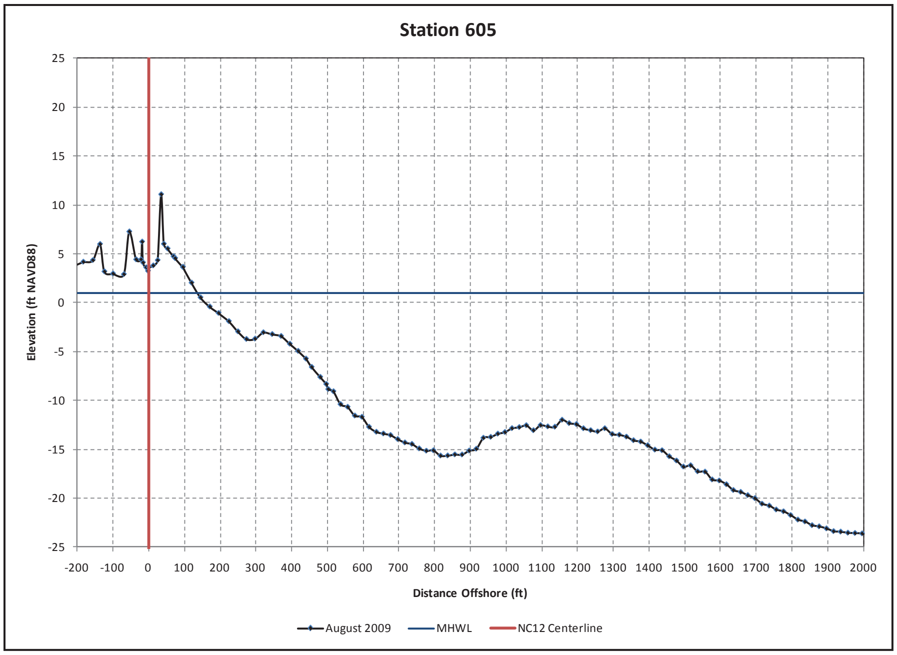


Figure 2. Station 605 cross-section survey performed in 2009

Projected 5 Year and 50 Year Shorelines

Ten survey transects were used as the basis for the 2010 Draft VA&CEE analysis. These transects were imported into ArcMap to define the extents of the project area and the midpoint in between adjacent transects was determined. The midpoint on either side of each transect was used to define the extents for which the erosion rate for that transect was applied. The background erosion rates previously calculated by Professor Overton of North Carolina State University as identified in the Draft VA&CEE (M&N, 2010) were used to approximate the amount of erosion that would occur in 5 years and 50 years (Table 2).

Spatially, the segment of the shoreline to which the erosion rate for each transect was applied (defined by the midpoints on either side of the transect) was shifted landward for both the 5 year and 50 year time periods. The individual segments were then connected at each midpoint location to form a single predicted shoreline position for the 5 year and 50 year time periods. Figures 3 through 6 illustrate the digitized 2013 shoreline and the projected 2018 and 2063 shorelines.

Table 2. 5 Year and 50 Year Erosion Rate Analysis

Station	Annual Erosion Rate (ft/yr)	5 Year Erosion (ft)	50 Year Erosion (ft)
430+00	2.9	14.5	145.0
475+00	5.2	26.0	260.0
505+00	6.0	30.0	300.0
540+00	7.5	37.5	375.0
565+00	8.2	41.0	410.0
585+00	8.6	43.0	430.0
605+00	8.6	43.0	430.0
620+00	9.4	47.0	470.0
650+00	8.3	41.5	415.0
685+00	3.1	15.5	155.0

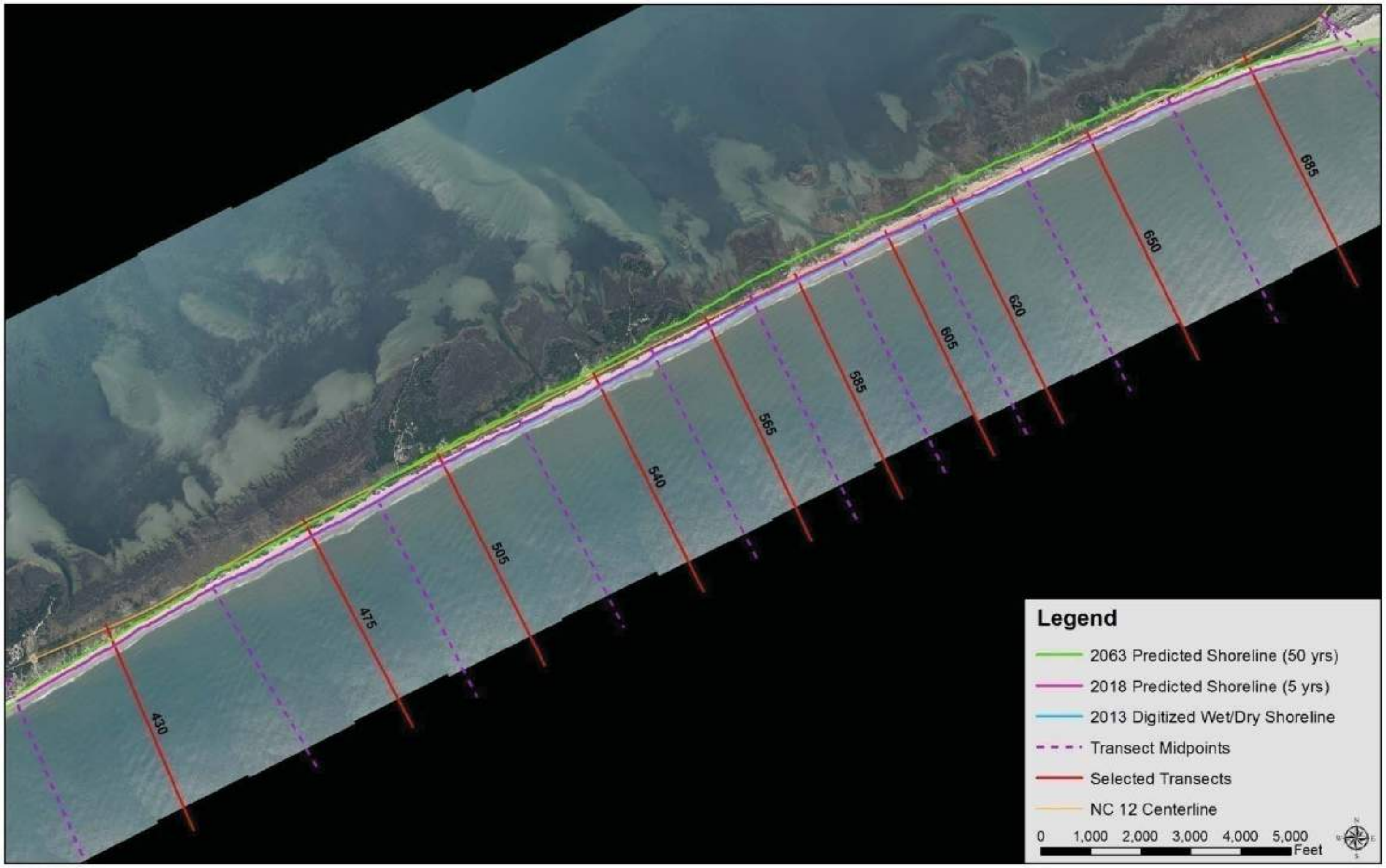


Figure 3. Project area with projected shorelines

Figure 4. Shorelines – Southwest Reach

Figure 5. Shorelines - Central Reach

Figure 6. Shorelines – Northeast Reach

The following discussion of alternatives and dune and beach fill sources and strategies for mitigation of erosion is provided as an excerpt from the 2010 Draft VA&CEE.

Development of Alternatives

Engineering and planning mitigation strategies including beach nourishment, dune nourishment and roadway relocation to reduce the vulnerability of NC12 were reviewed. Key considerations for defining the specific engineering alternatives included: guidelines by the National Parks Service (NPS), the potential impact to natural resources, the availability of sand resources and anticipated costs for implementation.

The project area lies within the Cape Hatteras National Seashore. Therefore NPS guidelines for emergency roadway repair were taken into consideration. NPS guidelines do not allow for a traditional “beach nourishment” project. The guidelines identify an acceptable emergency fill template with: the maximum crest elevation at +10 ft NAVD 88, a maximum width of 10 ft at the crest; the landward and seaward slopes are identified as 5:1 and 3:1 respectively and the material be placed above MHW. However, based on prior investigations by Moffatt & Nichol (2003, 2004) this template yields minimal benefit for roadway protection. Therefore an attempt is made to define alternatives which afford protection to NC12 while adhering to the spirit of the NPS guidelines.

With consideration to the above, the following alternatives were defined for evaluation and are further described below:

- *Alternative 1: Baseline (Do Nothing)*
- *Alternative 2: Large Scale Beach Nourishment*
- *Alternative 3: Small Scale Dune Nourishment*
- *Alternative 4: Roadway Relocation and Dune Nourishment*

Alternative 1: Baseline

The Baseline scenario is, by definition, the “Do Nothing” alternative. The profiles of the existing conditions scenario were taken from the August of 2009 Ocracoke Island survey data provided by McKim & Creed. For this study, the nourishment cycle for the alternatives is assumed to be 4 years; therefore in order to assess the effectiveness of the alternatives, the baseline conditions after 4 years are also evaluated for comparison.

Figure 7 illustrates an example of the baseline conditions and after four years at station 605+00. The profile at the end of four years is translated landward 34.4 ft based on the average annual erosion rate (8.6 ft/year); after four years the frontal dune was predicted to erode as the shoreline recession occurs.

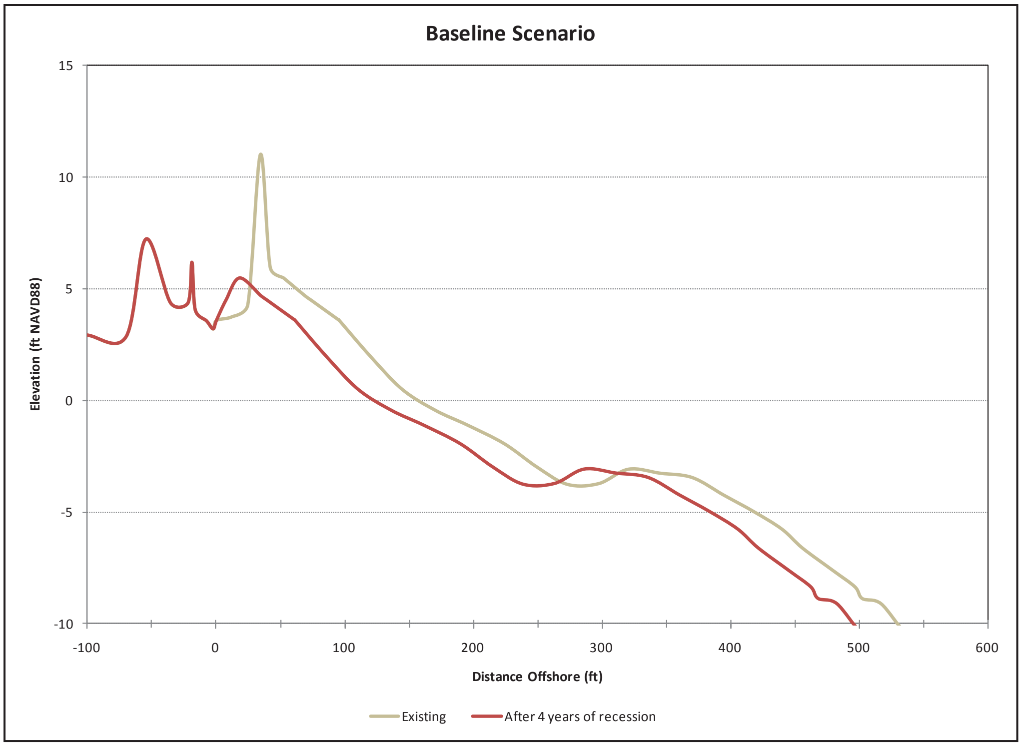


Figure 7. Alternative 1 – Existing profile and after 4 years at Station 605+00

Alternative 2: Large Scale Beach Nourishment

The large scale beach nourishment scenario is defined to maintain a setback of 230 ft and withstand up to a 50-yr return period storm. The template includes nourishment of a dune and berm. As illustrated in Figure 8 the dune crest elevation was established at +15 ft NAVD 88, the landward and seaward slopes are identified as 5:1 and 3:1 respectively. The berm was set at an elevation of +4 ft NAVD88 and extended 230 ft from the center of the roadway to the 1 ft NAVD contour (MHW).

It was assumed that the beach nourishment project would be conducted at a 4 year interval. The template was designed following an iterative method with the application of SBEACH and EST models using the 34 tropical and the 18 extratropical storms. Iterations were performed to achieve a 50-yr return period for dune area loss above the 4 ft NAVD contour equal to 50 % of the total material. The profile at Station 605+00 was used to develop the design template (Figure 8); station 605+00 was selected because it is the most vulnerable profile and a limiting constraint in the nourishment design.

The minimum design template was compared to each of the existing profiles for the length of the project area. At locations where a large quantity of material exists above the 4 ft NAVD (Station 430+00, 475+00, 540+00, 565+00), no additional material is required to achieve the dune and berm template. Material would be required at profile 505+00 and from Stations 585+00 to 685+00.

Table 3 identifies the quantity of material required to achieve the design template and pre-nourishment requirements to hold the existing shoreline in place. Pre-nourishment requirements are estimated as a function of the historical erosion rates. Based on prior studies, it is assumed that 1.37 cy of erosion occurs per 1 lf of shoreline recession. Additionally, a factor of 1.3 is applied to account for an anticipated accelerated rate of erosion post-nourishment.

To achieve the initial design template, approximately 226,600 cy would be required along 14,250 lf of shoreline (Station 490+00 to 522+50 and Station 575+00 to 685+00). In addition, to maintain the proposed template (or existing shoreline) in place for a 4 year period would require approximately 1,227,800 cy; under this scenario the pre-nourishment is assumed to be applied along the entire 25,500lf of the project area to maintain the existing shoreline position.

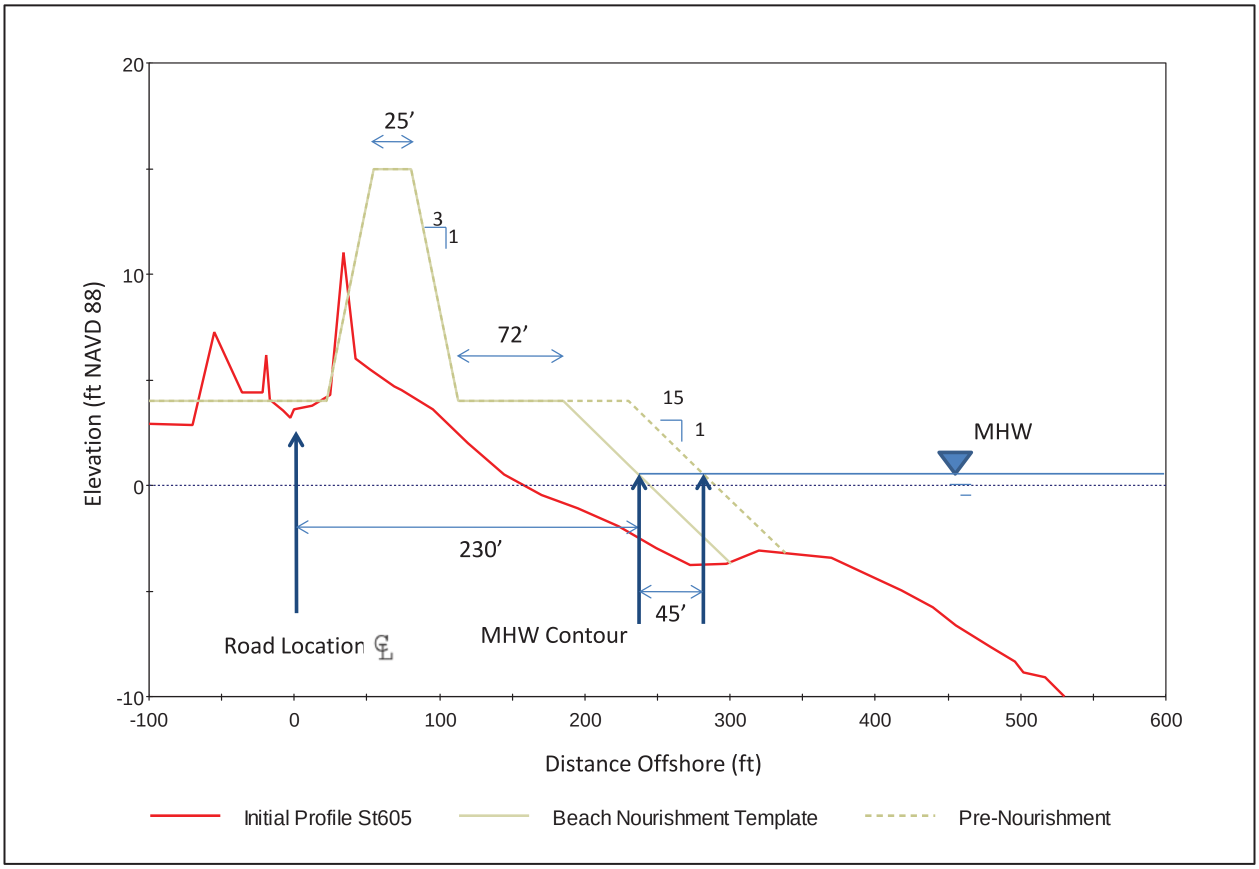


Figure 8. Alternative 2 - Beach Nourishment template at Station 605+00

Table 3. Alternative 2 –Beach Nourishment Design Template and Pre-nourishment Requirements

Station	Background Erosion rate (ft/yr)	Erosion After 4 years [ft]	Template Volume (cy)	Pre-Nourishment Volume (cy)
430+00	2.9	11.6	-	46,500
475+00	5.2	20.8	-	139,000
505+00	6.0	24.0	33,600	139,000
540+00	7.5	30.0	-	160,300
565+00	8.2	32.8	-	131,500
585+00	8.6	34.4	13,000	122,600
605+00	8.6	34.4	54,100	107,300
620+00	9.4	37.6	56,100	150,700
650+00	8.3	33.2	59,400	192,200
685+00	3.1	12.4	10,400	38,700
Total			**226,600**	**1,227,800**

Alternative 3: Small Scale Dune Nourishment

The dune nourishment scenario was developed with consideration given to the NPS guideline that restricts the location of placed material to the dune and the portion of the beach profile above MHW. The dune geometry developed under Alternative 2 was also used as the template for this scenario (Figure 9). The dune crest elevation was established at +15 ft NAVD 88, a maximum width of 25 ft at the crest; the landward and seaward slopes are identified as 5:1 and 3:1.

The design template was superimposed onto the existing August 2009 survey profile to assess the volume of material required to construct the dune. At profiles 430+00, 475+00, 540+00, 565+00 and 685+00, no material is required. Additional material is required at stations 505+00, 585+00, 605+00, 620+00 and 650+00.

Table 4 identifies the required material above the 4 ft NAVD contour for the construction of the dune nourishment template in each station. The total volume needed to construct the dune for the dune nourishment scenario is 132,700 cy over 12,500 lf of shoreline (from Station 490+00 to 522+50 and 575+00 to 667+50). There would be adequate material available every 4 years to renourish the dunes, with approximately 220,000 cy estimated to be available from the NC Ferry dredging operations and an additional 80,000 cy of material available from USACE operations.

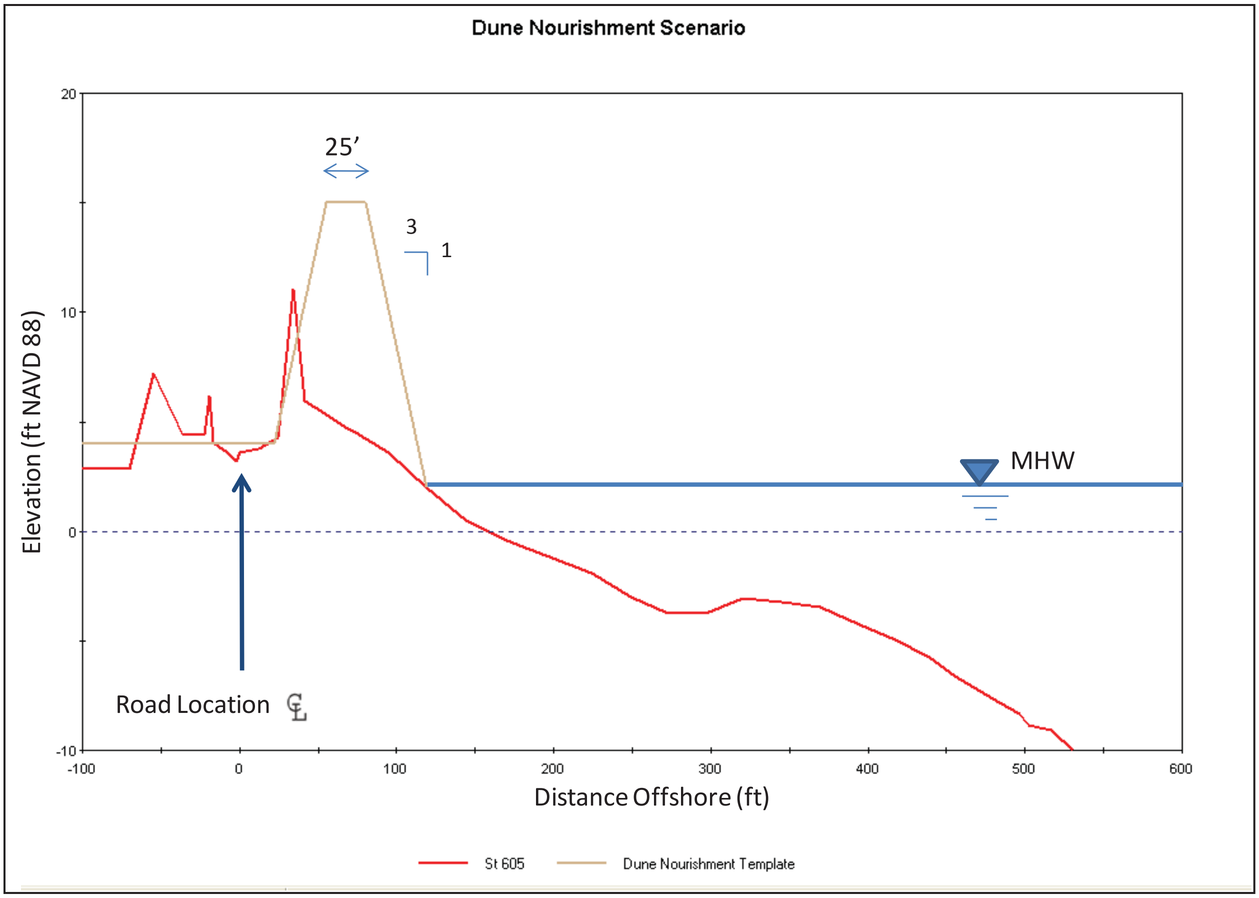


Figure 9. Alternative 3 - Dune Nourishment template at Station 605+00

Table 4. Alternative 3 – Dune Nourishment Design Template Requirements

Station	Required Volume (cy/ft)	Required Volume (cy)
430+00	-	-
475+00	-	-
505+00	10.46	34,000
540+00	-	-
565+00	-	-
585+00	12.92	13,000
605+00	19.44	32,400
620+00	9.84	22,000
650+00	5.03	22,400
685+00	-	8,900
Total		**132,700**

Alternative 4: Roadway Relocation and Dune Nourishment

Under this scenario, NC 12 would be relocated. The proposed roadway alignment was developed by Parsons Brinkerhoff (PB) by shifting the roadway as far landward as possible, without encroaching on wetlands. Table 5 identifies the proposed roadway realignment setback; from St 565+00 to 620+00, the proposed alignment is 140 ft landward of the existing roadway.

Table 5. Alternative 4 Roadway Relocation – Proposed Setback

Station	Existing Setback (2013)	Proposed Setback w/ Roadway Relocation	Offset
	(ft)	(ft)	(ft)
430+00	397	447	50
475+00	357	492	135
505+00	266	406	140
540+00	271	411	140
565+00	197	337	140
585+00	98	238	140
605+00	69	209	140
620+00	132	267	135
650+00	163	291	128
685+00	331	451	120

In addition to relocation of the road, a dune would be constructed using a design template similar to that identified in Alternatives 2 & 3 (Figure 10). Figure 10 illustrates the location of the existing and proposed roadway realignments.

For the vulnerability analysis it is conservatively assumed that the additional protection afforded by the existing vegetated dunes would not be accounted for in the SBEACH model. For the simulations, the berm was extended (at an elevation of 4 ft NAVD) to intersect the existing profile (Figure 10).

The initial dune nourishment template in 2010 will require a total of approximately 490,000 cy. A portion of this material will come from the existing dunes (non-vegetated). The additional material would be provided from USACE and NCDOT dredging operations (as noted above, approximately 300,000 cy is available every four years). Every four years the dunes will be rebuilt with material from USACE and NCDOT dredging operations.

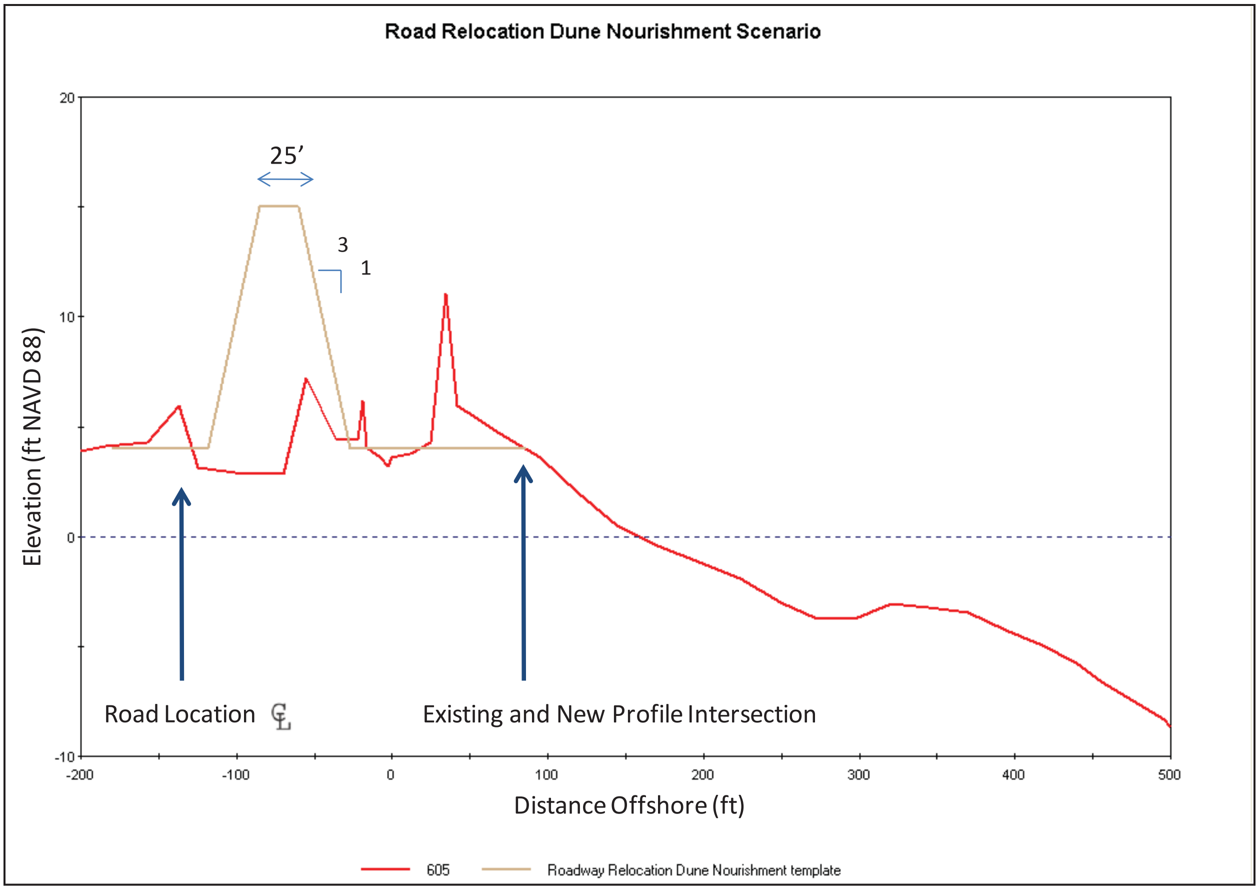


Figure 10. Alternative 4 - Roadway relocation and Dune Nourishment profile at Station 605+00

Table 6. Alternative 4 Roadway Relocation – Required Volume (above 4 ft NAVD)

Station	Required Volume (cy/ft)	Required Volume (cy)
430+00	17.79	40,100
475+00	30.63	114,900
505+00	6.61	21,500
540+00	9.79	29,400
565+00	20.82	46,900
585+00	26.31	52,700
605+00	23.41	41,000
620+00	16.85	38,000
650+00	14.91	48,500
685+00	32.33	56,600
Total		**489,600**

Dredging Operations - Potential Sand Resources

As previously documented by Moffatt & Nichol (May 2003), the dredging work of the existing channel between the ferry terminals at Ocracoke and Hatteras Islands and crossing Hatteras Inlet, results in a potential source of sediment which is close to the study area. The USACE is responsible for dredging operations between the Hatteras ferry terminal and the Hatteras Inlet channel. The NCDOT Ferry Division is responsible for the remainder of the channel across Hatteras Inlet to the Ocracoke ferry terminal. Figure 11 shows the location of this channel and the division of USACE and NCDOT responsibility for maintenance.

Within the years from 2002 to 2009, a total of 135,000 cy was dredged from Hatteras Channel and Rollinson Channel and placed upland onto Cora June Island by the USACE. An additional approximately 30,000 cy of material was sidecast to either side of the channel during the seven year period (2002 – 2009) (USACE, 2009). Based on communication with USACE staff, the material historically dredged from Hatteras channel is beach compatible. A report by Ardaman and Associates (September 2009) documents the characteristics of material found in Rollinson channel; the material was generally characterized as silt and silty sand that is not beach compatible. Overall, dredging operations by the USACE yield on average approximately 80,000 cy of beach compatible material every four years.

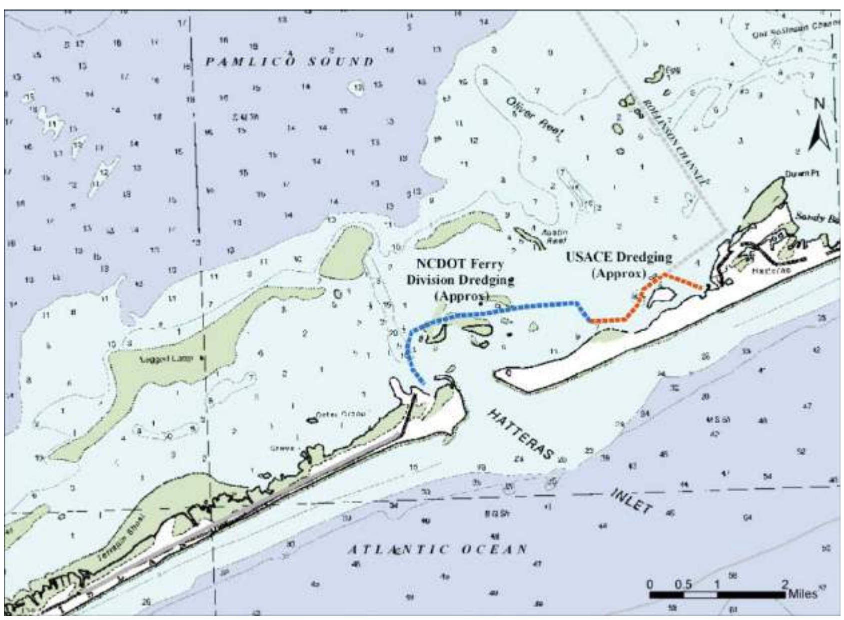


Figure 11. Dredging Extents - Hatteras/Ocracoke Ferry Channel

The remainder of the Hatteras/Ocracoke ferry terminal channel is maintained by the NCDOT Ferry Division. Typically the ferry channel from Hatteras Inlet to the Ocracoke terminal is dredged annually; however, dredging quantities and frequencies have varied historically with the occurrence of storm events (Moffatt & Nichol, 2005). The material is dredged using a hydraulic dredge and is typically placed at an upland disposal site adjacent to the Ocracoke ferry terminal (Figure 12). Following major storm events resulting in significant overwash and loss of dunes, this upland material has typically been used to rebuild the small frontal dune system along the Ocracoke Island hotspot.

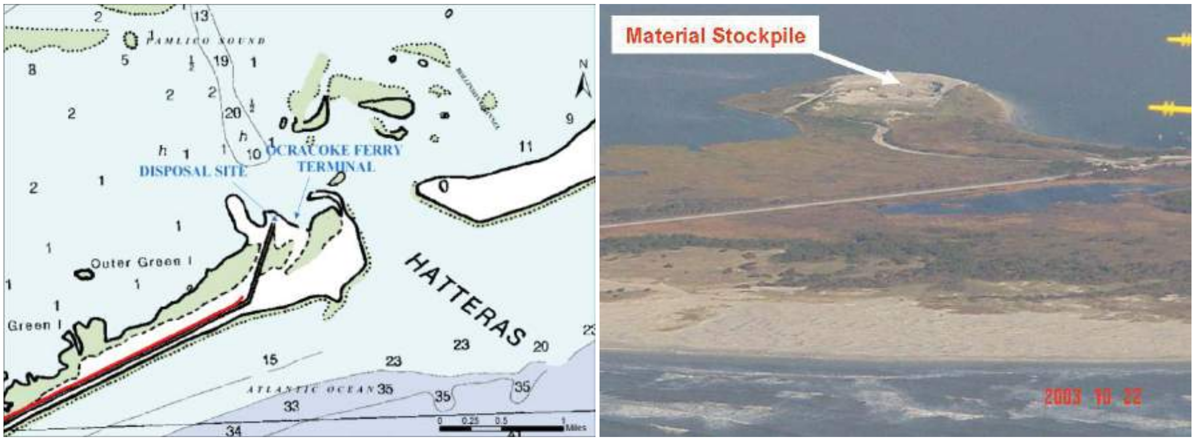


Figure 12. Upland Disposal Site Adjacent to Ocracoke Ferry Terminal

Figure 13 shows the total annual dredging quantities computed from weekly dredging reports. Based on communication with NCDOT (NCDOT, 2009), reliable dredging records from 2005 to 2010 were not available; records were incomplete or otherwise missing. The average annual dredging quantity from 1975-2004 was computed as approximately 55,000 cy.

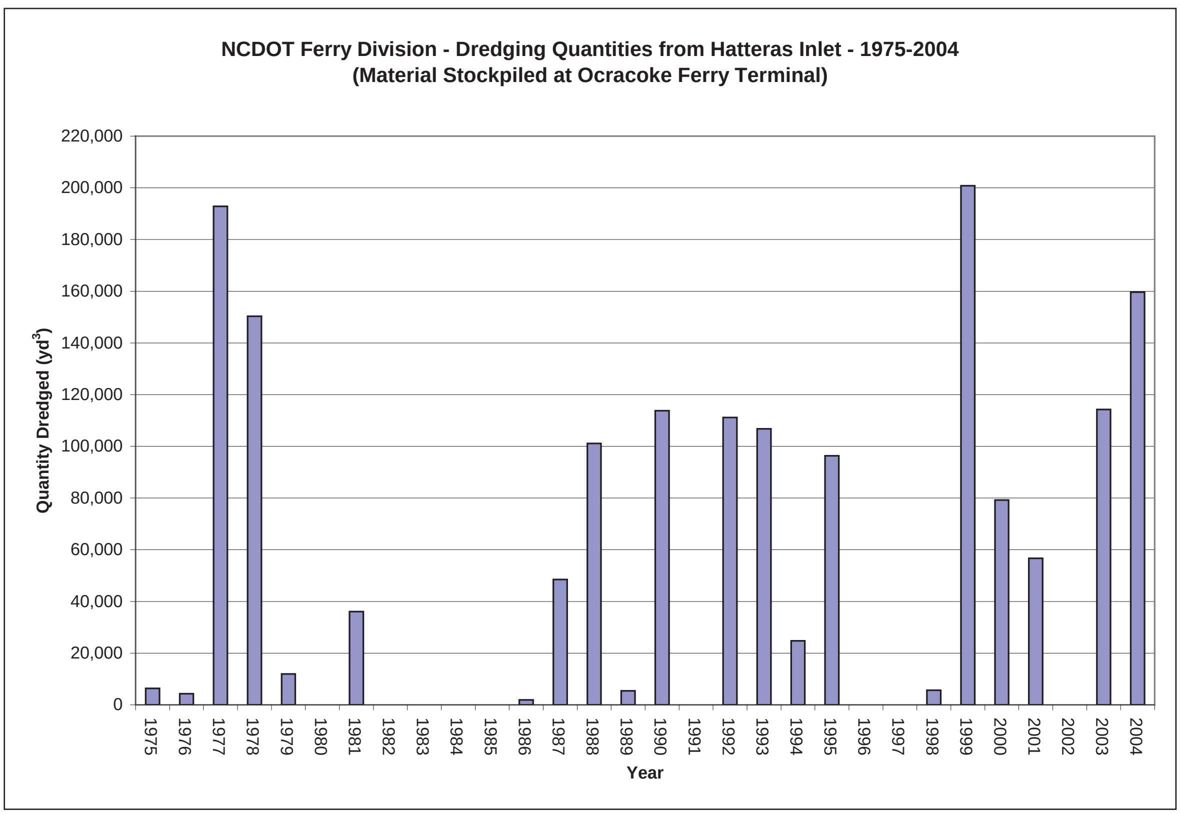


Figure 13. NCDOT Ferry Division Historical Dredging Quantities at Hatteras Inlet

Nearshore/Offshore Sediment Sources

A sand resource study developed by the North Carolina Geological Survey (NCGS) (funded by the North Carolina Department of Transportation (NC DOT)), provides nearshore/offshore sediment availability information in the surroundings of the study area. The availability of newer, significantly higher resolution Compressed High Intensity Radar Pulse (CHIRP) seismic, side scan sonar, and bathymetric data were presented as having a potentially significant impact on a reinterpretation of the existing dataset and refining the previously defined potential sand resource target areas.

Twelve potential sand resource areas were identified from the geophysical data. South of Diamond Shoals, five target areas were identified for the fine-grained beaches of Ocracoke, one potential area for the medium-grained scenario applicable to Hatteras, and one compatible for both scenarios (Figure 14 and Table 7). The closest potential target area is Ocracoke 3, sited within 1 to 3 miles of the “hotspot”. Based on the NCGS analysis, approximately 45.8 Million cubic yards (Mcy) of beach compatible material would be available from the Ocracoke 3 area; the material is characterized as fine grain sands which is generally compatible with size sediments on the Ocracoke Island beaches.

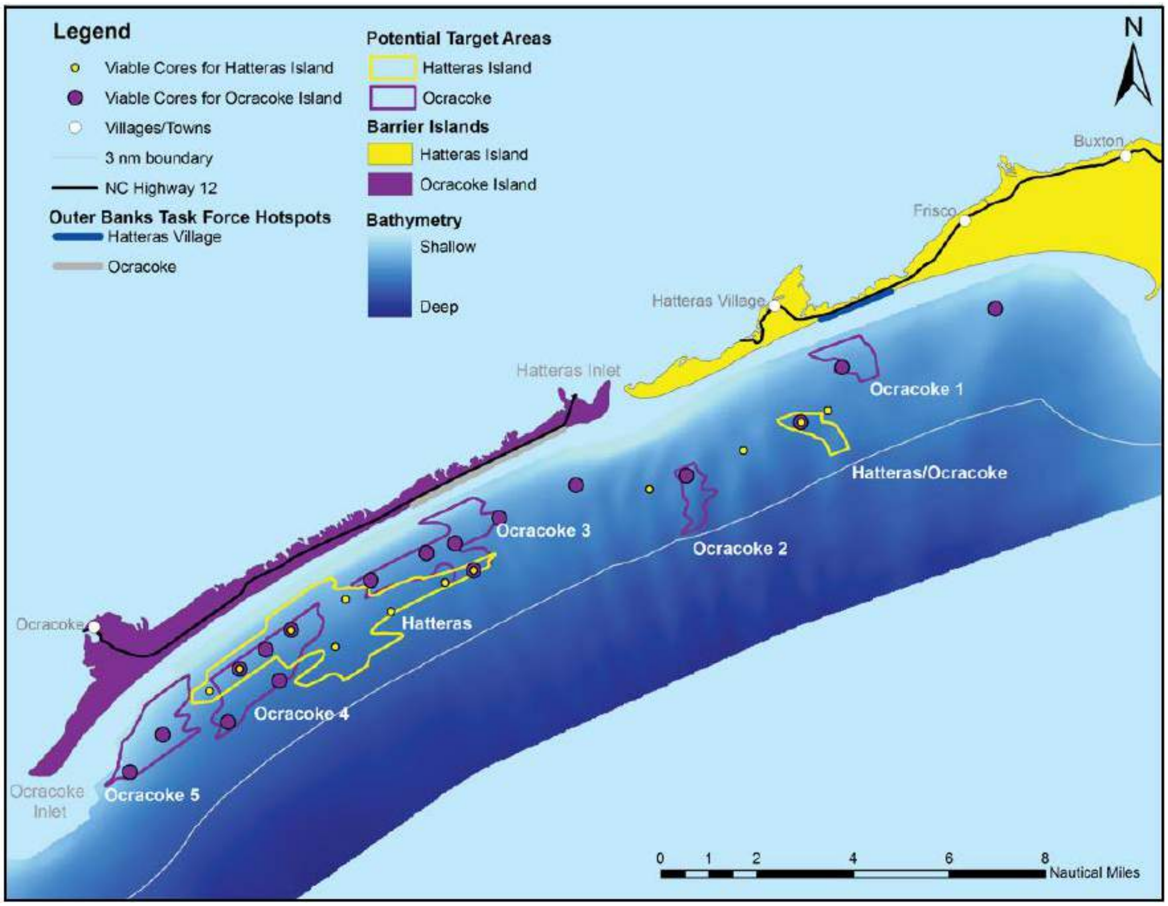


Figure 14. Locations of Potential Target Areas Identified in the Southern Portion of the Study Area (NCGS, 2009).

Table 7. Summary Table for Potential Sand Resource Target Areas

Potential Target Area	Water Depth Range (ft)	Beach Target	Grain Size	Volume (M cy)
Hatteras	34.8 -59.4	Hatteras Island	Medium	113.3
Hatteras/Ocracoke	51.5 - 56.7	Hatteras & Ocracoke Island	Medium & Fine	6.9
Ocracoke 1	38.0 - 50.2	Ocracoke Island	Fine	13.1
Ocracoke 2	48.5 - 62.3	Ocracoke Island	Fine	7.9
Ocracoke 3	32.1 - 54.8	Ocracoke Island	Fine	45.8
Ocracoke 4	42.6 - 55.8	Ocracoke Island	Fine	44.6
Ocracoke 5	31.5 - 51.5	Ocracoke Island	Fine	42.3

2010 Vulnerability Analysis Update

Update of Vulnerability Analysis and Coastal Engineering Evaluation for NC12 at Ocracoke Island

April 2010

Prepared for Parsons Brinkerhoff

Moffatt & Nichol

EXECUTIVE SUMMARY

The objectives of this current study were to: (1) refine the definition of vulnerability and identify methods so that they may be consistently applied by NCDOT; (2) assess the vulnerability of NC12 on Ocracoke Island over a 15 year planning horizon; (3) identify alternatives for reducing the vulnerability of the NC 12 hotspot on Ocracoke Island and (4) evaluate the potential benefits and costs.

Vulnerability of NC12 was defined with respect to (a) maintenance requirements and (b) storm damage. Where the setback from the centerline of the road to MHW was less than 230 ft, the roadway was considered vulnerable to increased maintenance. Vulnerability with respect to storm damage was assessed based on the area of erosion above the +4 ft contour (between the edge of the roadway and the beach) for a series of storm events. The following alternatives were evaluated:

- *Alternative 1: Baseline (Do Nothing)*
- *Alternative 2: Large Scale Beach Nourishment*
- *Alternative 3: Small Scale Dune Nourishment*
- *Alternative 4: Roadway Relocation and Dune Nourishment*

Under existing conditions, the most vulnerable section of NC12 is along Station 585+00 to 620+00; with imminent damage pending along the reach from Station 605+00 to 620+00. Within 4 years, it is estimated that an additional 4500 lf of the roadway will become vulnerable to storm damage. If erosion were to go unmitigated, by 2025 there would be no setback at Stations 605+00 and 630+00; the length of roadway that would require frequent maintenance would increase to 14,500 lf.

Implementation of a Beach Nourishment project (Alternative 2) is a viable but expensive management strategy to protect NC12. To achieve the initial design template 226,600 cy would be placed along 14,250 lf of shoreline. Additionally, to maintain a 230 ft setback, approximately 704,000 cy of pre-nourishment would be required for the initial four year cycle. The total cost of the initial nourishment project is estimated to be between $11 million and $14 million. During the fifteen year planning horizon it is estimated that a total of approximately 4.5 Mcy of material (to maintain at a minimum the design template) would be required at a cost of $54 Million to $67.5 Million.

Dune Nourishment (Alternative 3) was evaluated following general guidelines of the NPS. Under this scenario, approximately 132,000 cy of sand would be placed to build the initial template at total cost of approximately $528,000 to $792,000. To the extent possible, the dune will be rebuilt every four years. This scenario affords only a limited amount of additional protection of NC12 (as compared to the baseline conditions).

If NC12 were relocated (Alternative 4) there would be a substantial reduction in risk of storm damage over the 15 year planning horizon. At the end of the 15 year period, NC12 will be vulnerable to frequent maintenance at Stations 585+00, 605+00 and 620+00; the vulnerability at these location after 15 years will be similar to what it is today under Baseline Conditions. The total cost for Alternative 4, roadway relocation and dune nourishment, was not evaluated as part of this assessment.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

1.0 BACKGROUND

The North Carolina Department of Transportation (NCDOT) sponsored this study to assess the vulnerability of NC12 highway along Ocracoke Island. This work builds on prior investigations by Moffatt & Nichol (May 2003, May 2004 and April 2005).

Prior evaluations completed by Moffatt & Nichol, revealed that a large portion of the NC 12 highway along Ocracoke Island was vulnerable to damage and/or maintenance from the impact of even a high frequency (2-Year) storm event. Approximately 5.4 miles (28,500 linear feet) of NC12 was characterized as a “hotspot” (Figure 1). A critical area of erosion was identified along 2.6 miles of shoreline (13,500 feet from Station 530+00 to 665+00). For this study the project area to be evaluated is defined by 25,500 lf of roadway extending from Station 430+00 to Station 685+00 (Figure 2).

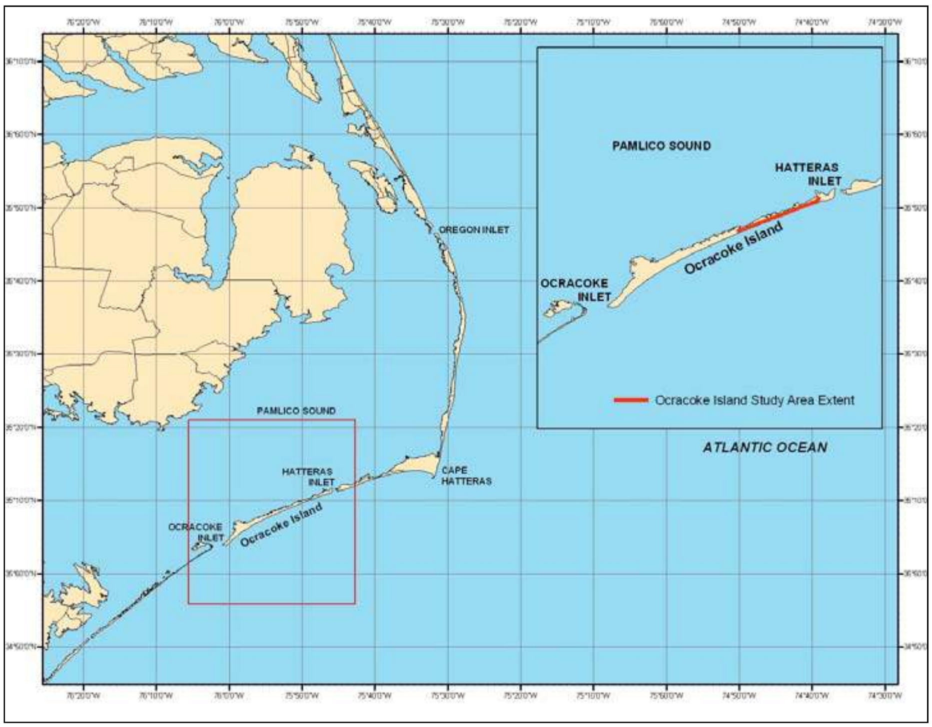


Figure 1. Location of Ocracoke Island Study Area

In prior investigations Moffatt & Nichol (2003, 2004 and 2005) defined vulnerability and employed an approach that differed slightly from that adopted by Overton and Fisher (June 2005). Moffatt & Nichol defined vulnerability of the roadway to increased maintenance based on the setback of the +4ft contour from the roadway centerline (setback < 150 ft was considered vulnerable); vulnerability to storm damage was evaluated based on the area of dune loss above a specified contour (+3 ft NAVD or +4 ft NAVD). Overton and Fisher (June 2005) defined vulnerability in terms of a setback from the edge of pavement to the MHWL; no volumetric threshold was employed. Additionally, Overton and Fisher defined a design criteria for dune construction that was based on a 50% chance that 50% of the dune may be eroded during a 12 year period.

Figure 2. Project Area

The objectives of this current study are to: (1) refine the definition of vulnerability and identify methods for evaluating vulnerability so that they may be consistently applied by NCDOT; (2) assess the vulnerability of the "hotspot" area of NC12 on Ocracoke Island through a 15 year planning horizon; (3) identify alternatives for reducing the vulnerability of the NC 12 hotspot on Ocracoke Island (including dune/beach nourishment and roadway relocation) and (4) evaluate the potential benefits and costs offered by each alternative.

2.0 DATA COLLECTION

Survey

Topographic and hydrographic surveys were performed along 10 transect lines in August of 2009 by McKim & Creed from Station 430+00 to 685+00 (Figure 2). The upland survey transects extended from approximately 200 feet landward of NC 12 seaward to an elevation of approximately -5 ft NAVD. An offshore hydrographic survey was completed, extending the profiles to a depth of approximately -30 ft NAVD. Upland and nearshore survey data was combined to develop profiles for each of the 10 stations as illustrated in Appendix A.

Figure 3 presents a comparison between the 2009 and 2003 surveys; as illustrated at Station 540+00, both the crest elevation and width of the frontal dune has been increased since 2003.

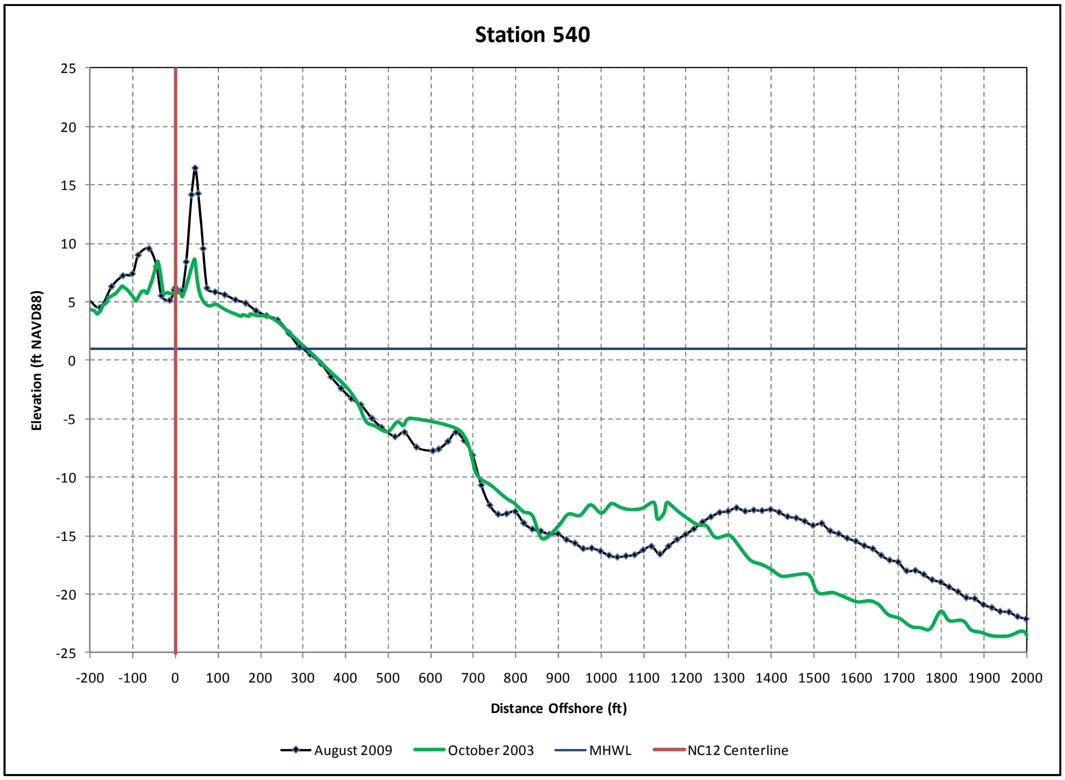


Figure 3. Survey Comparison 2004 and 2009 at Station 540+00

Setback

For this study the setback will be defined as the distance from where Mean High Water (MHW) intersects the shoreline to the center of the roadway (Figure 4). The profile at station 620+00 illustrates "typical" conditions of the project area with a limited setback (Figure 5); there is an artificially constructed dune with a crest elevation of 14 ft NAVD dropping to an elevation of approximately 8ft NAVD at a 3:1 slope.

Table 1 summarizes the setback distances from the roadway centerline to MHW based on the 2009 survey for all the profiles. Within the study area, the shoreline is closest to the highway along stations 605+00 to 620+00, where the existing setback is less than 150 feet.

Figure 4. Plan View Illustrating Setback of Roadway Centerline from the MHW at station 620+00

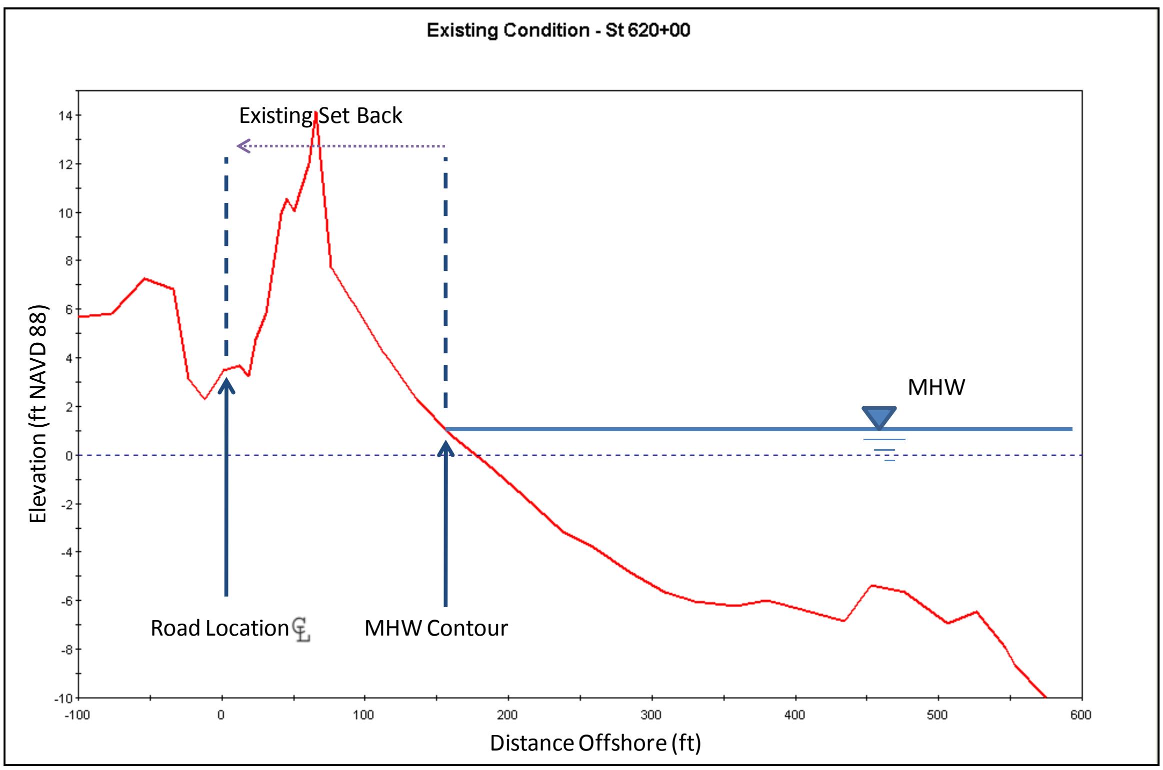


Figure 5. Example Profile at Station 620+00 Based on 2009 Survey

Table 1. Setback Distance based on 2009 Survey

Transect	Distance (ft)
430+00	420
475+00	384
505+00	295
540+00	287
565+00	226
585+00	216
605+00	124
620+00	145
650+00	251
685+00	421

Background Erosion Rates

Historical shoreline erosion rates were evaluated for the project area by Professor Overton of North Carolina State University (2009). Prior estimates of the long term shoreline erosion rates along Ocracoke Island were updated by including the most recent shoreline delineation (2008) in the shoreline database. Table 2 summarizes the estimated average historical erosion rates for the project area. The highest erosion rates (8.6 to 9.4 feet/year) correspond to the area with the least setback distance from Station 585+00 to 620+00.

Table 2. Estimated Average Annual Erosion Rates

Station	Erosion Annual rate (ft/yr)
430+00	2.9
475+00	5.2
505+00	6.0
540+00	7.5
565+00	8.2
585+00	8.6
605+00	8.6
620+00	9.4
650+00	8.3
685+00	3.1

Current Dredging Operations - Potential Sand Resource

As previously documented by Moffatt & Nichol (May 2003), the dredging work of the existing channel between the ferry terminals at Ocracoke and Hatteras Islands and crossing Hatteras Inlet, results in a potential source of sediment which is close to the study area. The USACE is responsible for dredging operations between the Hatteras ferry terminal and the Hatteras Inlet channel. The NCDOT Ferry

Division is responsible for the remainder of the channel across Hatteras Inlet to the Ocracoke ferry terminal. Figure 6 shows the location of this channel and the division of USACE and NCDOT responsibility for maintenance.

Within the past seven years, a total of 135,000 cy was dredged from Hatteras Channel and Rollinson Channel and placed upland onto Cora June Island by the USACE. An additional approximately 30,000 cy of material was sidecast to either side of the channel during the seven year period (2002 – 2009) (USACE, 2009). Based on communication with USACE staff, the material historically dredged from Hatteras channel is beach compatible. A report by Ardaman and Associates (September 2009) documents the characteristics of material found in Rollinson channel; the material was generally characterized as silt and silty sand that is not beach compatible. Overall, dredging operations by the USACE yield on average approximately 80,000 cy of beach compatible material every four years.

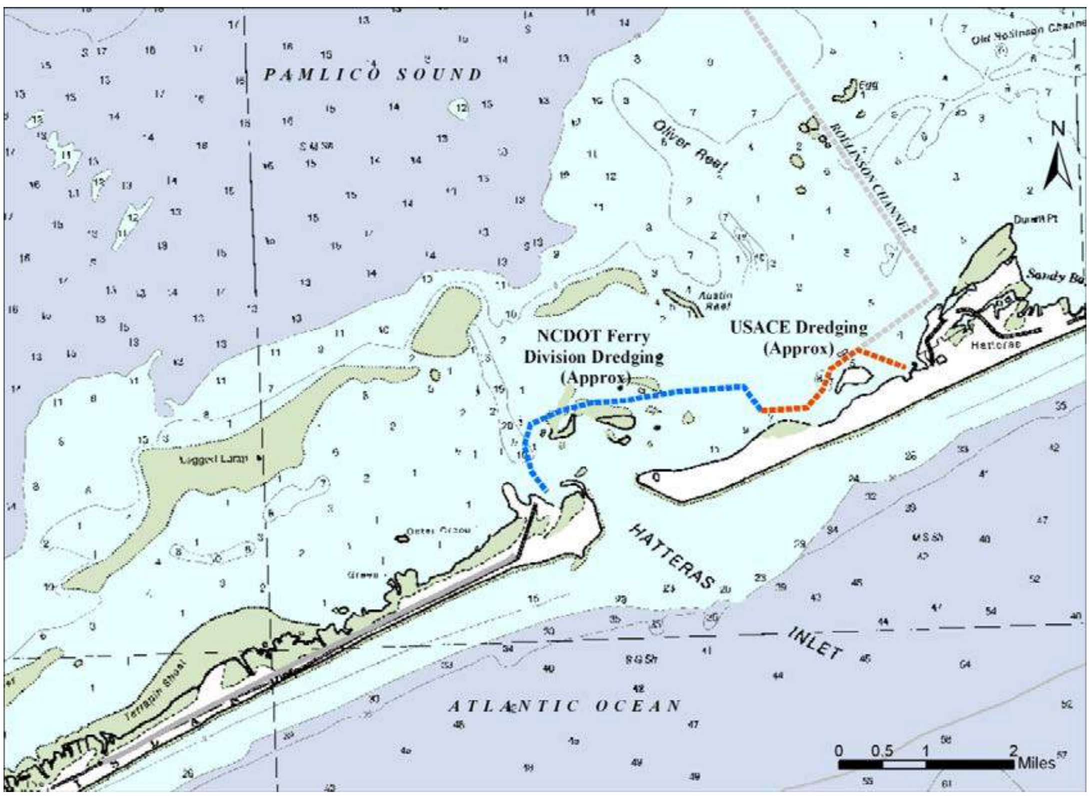


Figure 6. Dredging Extents – Hatteras/Ocracoke Ferry Channel

The remainder of the Hatteras/Ocracoke ferry terminal channel is maintained by the NCDOT Ferry Division. Typically the ferry channel from Hatteras Inlet to the Ocracoke terminal is dredged annually; however, dredging quantities and frequencies have varied historically with the occurrence of storm events (Moffatt & Nichol, 2005). The material is dredged using a hydraulic dredge and is typically placed at an upland disposal site adjacent to the Ocracoke ferry terminal (Figure 7). Following major storm events resulting in significant overwash and loss of dunes, this upland material has typically been used to rebuild the small frontal dune system along the Ocracoke Island hotspot.

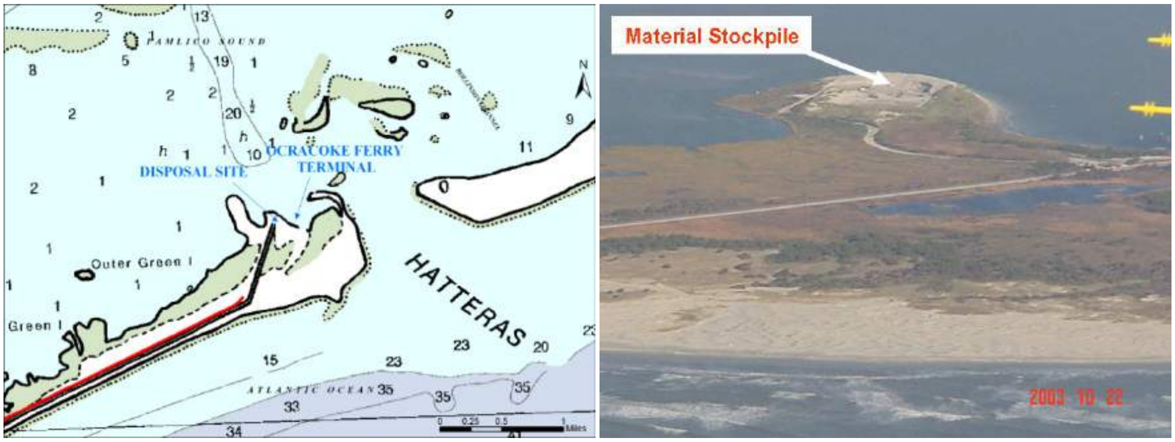


Figure 7. Upland Disposal Site Adjacent to Ocracoke Ferry Terminal

Figure 8 shows the total annual dredging quantities computed from weekly dredging reports. Based on communication with NCDOT (NCDOT, 2009), reliable dredging records from 2005 to 2010 were not available; records were incomplete or otherwise missing. The average annual dredging quantity from 1975-2004 was computed as approximately 55,000 cy.

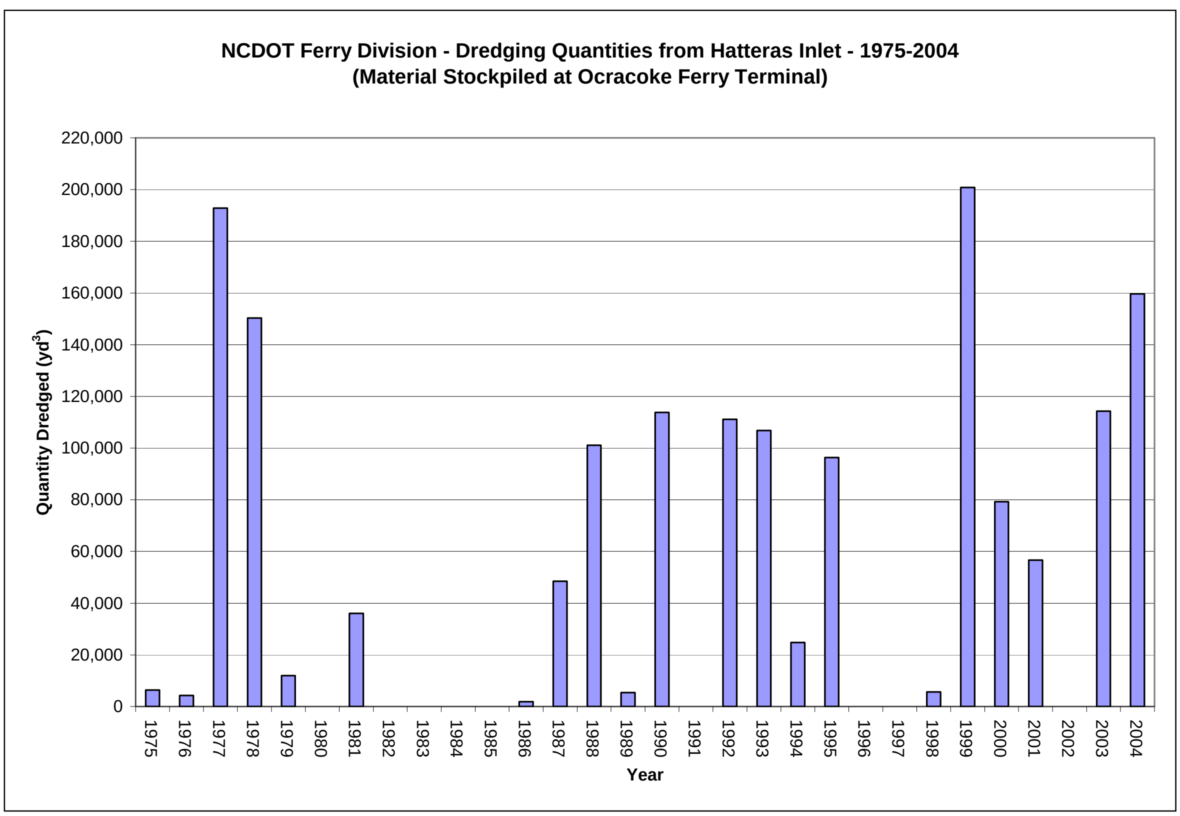


Figure 8. NCDOT Ferry Division Historical Dredging Quantities at Hatteras Inlet

Nearshore/Offshore Sediment Sources

A sand resource study developed by the North Carolina Geological Survey (NCGS) (funded by the North Carolina Department of Transportation (NC DOT)), provides nearshore/offshore sediment availability information in the surroundings of the study area. The availability of newer, significantly higher resolution Compressed High Intensity Radar Pulse (CHIRP) seismic, side scan sonar, and bathymetric data were presented as having a potentially significant impact on a reinterpretation of the existing dataset and refining the previously defined potential sand resource target areas.

Twelve potential sand resource areas were identified from the geophysical data. South of Diamond Shoals, five target areas were identified for the fine-grained beaches of Ocracoke, one potential area for the medium-grained scenario applicable to Hatteras, and one compatible for both scenarios (Figure 9 and Table 3). The closest potential target area is Ocracoke 3, sited within 1 to 3 miles of the "hotspot". Based on the NCGS analysis, approximately 45.8 Million cubic yards (Mcy) of beach compatible material would be available from the Ocracoke 3 area; the material is characterized as fine grain sands which is generally compatible with size sediments on the Ocracoke island beaches.

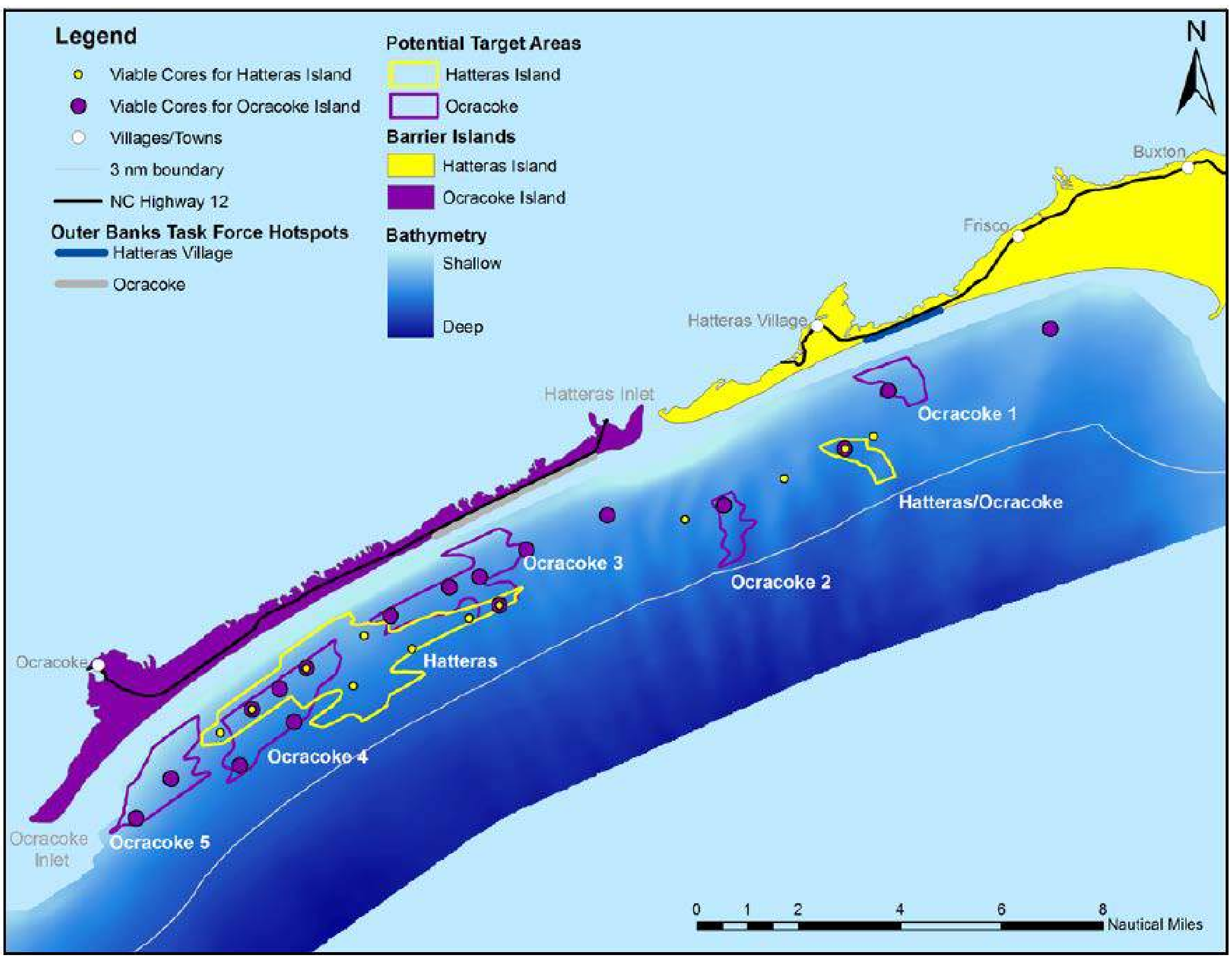


Figure 9. Locations of Potential Target Areas Identified in the Southern Portion of the Study Area (NCGS, 2009).

Table 3. Summary Table for Potential Sand Resource Target Areas

Potential Target Area	Water Depth Range (ft)	Beach Target	Grain Size	Volume (M cy)
Hatteras	34.8 -59.4	Hatteras Island	Medium	113.3
Hatteras/Ocracoke	51.5 - 56.7	Hatteras & Ocracoke Island	Medium & Fine	6.9
Ocracoke 1	38.0 - 50.2	Ocracoke Island	Fine	13.1
Ocracoke 2	48.5 - 62.3	Ocracoke Island	Fine	7.9
Ocracoke 3	32.1 - 54.8	Ocracoke Island	Fine	45.8
Ocracoke 4	42.6 - 55.8	Ocracoke Island	Fine	44.6
Ocracoke 5	31.5 - 51.5	Ocracoke Island	Fine	42.3

Water Levels and Storm Surge

For this study, the Cape Hatteras fishing pier tide gage (Station 8654400) served as the basis for water levels at the project site (Table 4).

Table 4. Tidal Elevations

Datum	Feet Above MLLW
MEAN HIGHER HIGH WATER (MHHW)	3.46
MEAN HIGH WATER (MHW)	3.11
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD)	2.06
MEAN SEA LEVEL (MSL)	1.61
MEAN TIDE LEVEL (MTL)	1.61
MEAN LOW WATER (MLW)	0.12
MEAN LOWER LOW WATER (MLLW)	0.00

Storm Data

The database of 34 tropical and 18 extratropical storms developed in prior investigations (Moffatt & Nichol 2003 and 2005) was employed for this study to evaluate erosion and vulnerability. Under prior investigations a time series of water level elevation, wave height and winds was compiled for each event. Summary characteristics for the storms are provided in Appendix B.

3.0 APPROACH

Definition of Vulnerability & Methods for Evaluation

For this study, vulnerability of NC12 was redefined with respect to (a) maintenance requirements and (b) storm damage as described below. It should be noted that the approach and the alternatives to be evaluated were revised from the original scope based on a meeting held between the NCDOT and its project consultants (NCDOT Team Meeting, November 2010).

Maintenance Requirements

Maintenance requirements are considered excessive when NC12 becomes vulnerable to repetitive overwash and sand deposits. Potential for increased maintenance is evaluated based on a single parameter – the setback distance of the roadway centerline from the MHWL. Consistent with previous studies done for NCDOT by Fisher and Overton (1991, 2005), when the setback is less than 230 ft the roadway is by definition considered vulnerable to increased maintenance. The projected shoreline position was evaluated based on the assumption that the average historical shoreline recession rate (Table 2) is representative of the erosion that will occur over the 15 year planning horizon.

Storm Damage

Vulnerability with respect to storm damage (damage to or undermining of the road) is evaluated following general methods outlined in prior studies by Moffatt & Nichol (2003, 2004 and 2005). Storm damage was assessed based on the area of erosion above the +4 ft contour (between the edge of the roadway and the beach) for a series of storm events. Volumes are computed before and after a storm in order to determine the material loss due to the wave climate generated by the storm. If the dune area loss above the 4 ft NAVD contour is more than 50 % of the total material, then the profile is considered vulnerable to that storm. For this study it is assumed that an acceptable level of risk of storm damage is a 50-yr return period storm event.

The SBEACH (Storm-induced BEAch CHange) cross-shore sediment transport model was used to calculate erosion under storm water levels and wave action. SBEACH was run for 34 tropical and 18 extratropical storms as identified in Appendix B. Each storm was run for two tide conditions (high and low). Survey data, storm data (water elevation, wave height and winds) and sediment grain size characteristics were input variables in the SBEACH analysis. Assumptions for SBEACH model input parameters are identified in Appendix B.

The Empirical Simulation Technique (EST) model was applied to assess the recurrence interval (probability of erosion), following methods previously employed by Moffatt & Nichol (2003, 2004 and 2005). EST is a statistical analysis package used for simulating multiple life-cycle sequences of stochastic multivariate systems. The model employs a “boot-strap” technique in which random sampling of a finite length database is used to generate a larger database of events. The EST model uses input and response parameters to generate life-cycle simulations of events with the corresponding impacts. Input parameters were defined to include: (1) tide condition, (2) storm duration, (3) maximum storm surge elevation, (4) maximum significant wave height, (5) maximum wave period, (6) maximum water elevation on beach, and (7) maximum wave runup. The response parameters are based on the SBEACH model output. For this study, the response variables are defined as (a) dune area eroded above the 4 ft NAVD-88 contour and (b) the percentage of total material above the 4 ft NAVD-88 contour that eroded.

Development of Alternatives

Engineering and planning mitigation strategies including beach nourishment, dune nourishment and roadway relocation to reduce the vulnerability of NC12 were reviewed. Key considerations for defining the specific engineering alternatives included: guidelines by the National Parks Service (NPS), the potential impact to natural resources, the availability of sand resources and anticipated costs for implementation.

The project area lies within the Cape Hatteras National Seashore. Therefore NPS guidelines for emergency roadway repair were taken into consideration. NPS guidelines do not allow for a traditional "beach nourishment" project. The guidelines identify an acceptable emergency fill template with: the maximum crest elevation at +10 ft NAVD 88, a maximum width of 10 ft at the crest; the landward and seaward slopes are identified as 5:1 and 3:1 respectively and the material be placed above MHW. However, based on prior investigations by Moffatt & Nichol (2003, 2004) this template yields minimal benefit for roadway protection. Therefore an attempt is made to define alternatives which afford protection to NC12 while adhering to the spirit of the NPS guidelines.

With consideration to the above, the following alternatives were defined for evaluation and are further described below:

- *Alternative 1: Baseline (Do Nothing)*
- *Alternative 2: Large Scale Beach Nourishment*
- *Alternative 3: Small Scale Dune Nourishment*
- *Alternative 4: Roadway Relocation and Dune Nourishment*

Alternative 1: Baseline

The Baseline scenario is, by definition, the "Do Nothing" alternative. The profiles of the existing conditions scenario were taken from the August of 2009 Ocracoke Island survey data provided by McKim & Creed, as illustrated in Appendix A. For this study, the nourishment cycle for the alternatives is assumed to be 4 years; therefore in order to assess the effectiveness of the alternatives, the baseline conditions after 4 years are also evaluated for comparison.

Figure 10 illustrates an example of the baseline conditions and after four years at station 605+00. The profile at the end of four years is translated landward 34.4 ft based on the average annual erosion rate (8.6 ft/year); after four years the frontal dune will erode as the shoreline recession occurs.

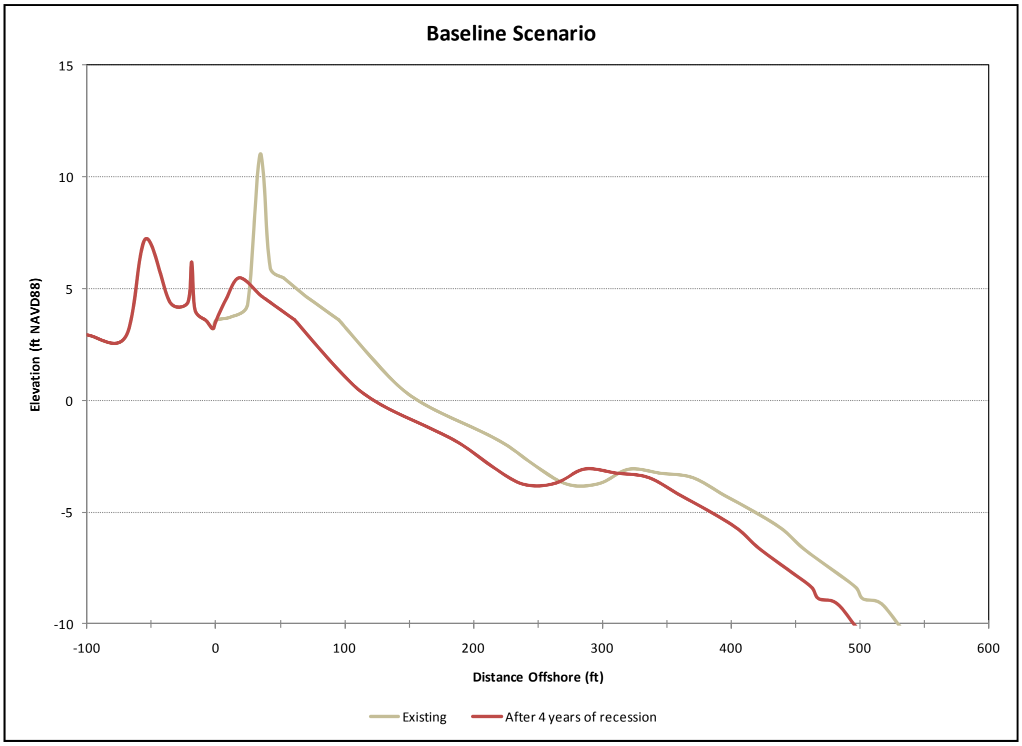


Figure 10. Alternative 1 – Existing profile and after 4 years at Station 605+00

Alternative 2: Large Scale Beach Nourishment

The large scale beach nourishment scenario is defined to maintain a setback of 230 ft and withstand up to a 50-yr return period storm. The template includes nourishment of a dune and berm. As illustrated in Figure 11 the dune crest elevation was established at +15 ft NAVD 88, the landward and seaward slopes are identified as 5:1 and 3:1 respectively. The berm was set at an elevation of +4 ft NAVD88 and extended 230 ft from the center of the roadway to the 1 ft NAVD contour (MHW).

It was assumed that the beach nourishment project would be conducted at a 4 year interval. The template was designed following an iterative method with the application of SBEACH and EST models using the 34 tropical and the 18 extratropical storms. Iterations were performed to achieve a 50-yr return period for dune area loss above the 4 ft NAVD contour equal to 50 % of the total material. The profile at Station 605+00 was used to develop the design template (Figure 11); station 605+00 was selected because it is the most vulnerable profile and a limiting constraint in the nourishment design.

The minimum design template was compared to each of the existing profiles for the length of the project area. At locations where a large quantity of material exists above the 4 ft NAVD (Station 430+00, 475+00, 540+00, 565+00), no additional material is required to achieve the dune and berm template. Material would be required at profile 505+00 and from Stations 585+00 to 685+00.

Table 5 identifies the quantity of material required to achieve the design template and pre-nourishment requirements to hold the existing shoreline in place. Pre-nourishment requirements are estimated as a function of the historical erosion rates. Based on prior studies, it is assumed that 1.37 cy of erosion occurs per 1 lf of shoreline recession. Additionally, a factor of 1.3 is applied to account for an anticipated accelerated rate of erosion post-nourishment.

To achieve the initial design template, approximately 226,600 cy would be required along 14,250 lf of shoreline (Station 490+00 to 522+50 and Station 575+00 to 685+00). In addition, to maintain the proposed template (or existing shoreline) in place for a 4 year period would require approximately 1,227,800 cy; under this scenario the pre-nourishment is assumed to be applied along the entire 25,500lf of the project area to maintain the existing shoreline position.

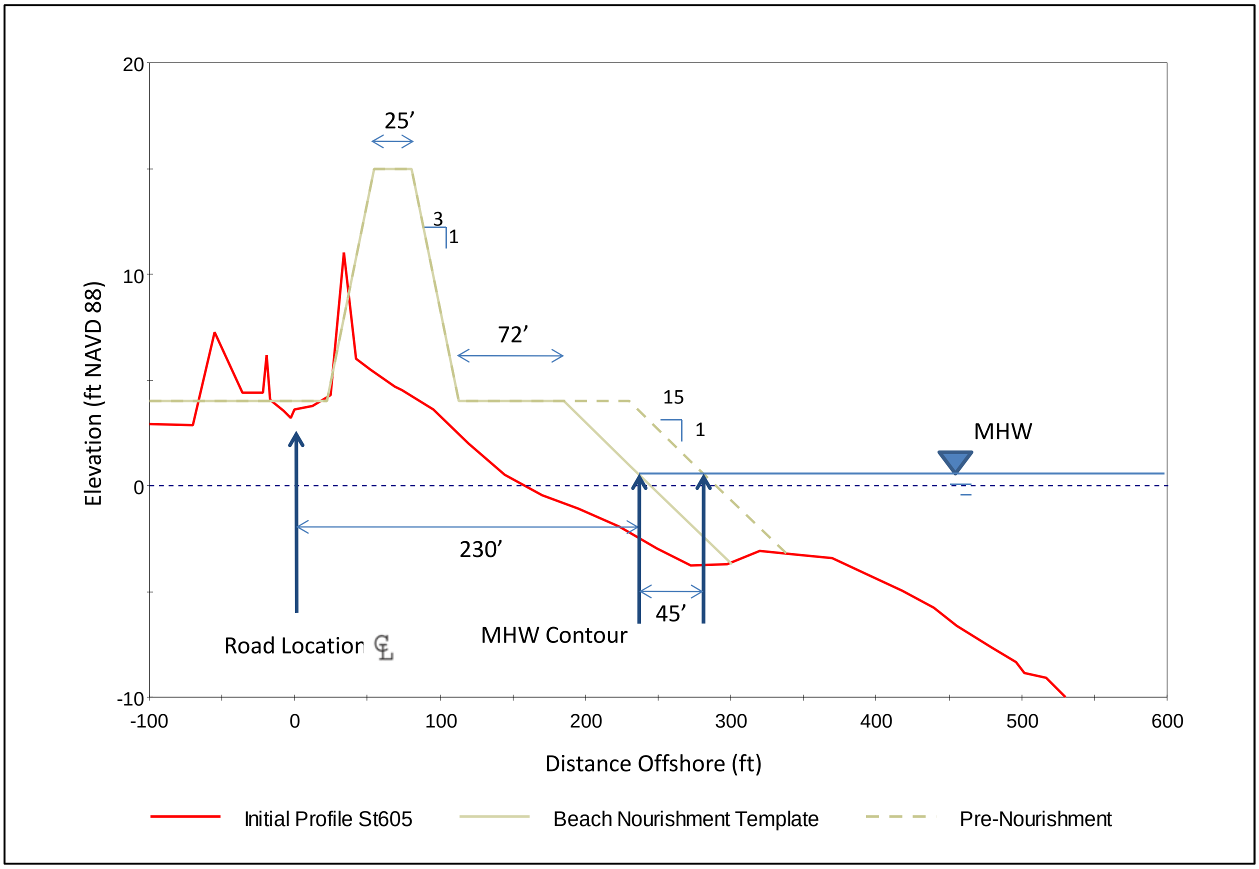


Figure 11. Alternative 2 - Beach Nourishment template at Station 605+00

Table 5. Alternative 2 –Beach Nourishment Design Template and Pre-nourishment Requirements

Station	Background Erosion rate (ft/yr)	Erosion Rate After 4 years [ft]	Template Volume (cy)	Pre-Nourishment Volume (cy)
430+00	2.9	11.6	-	46,500
475+00	5.2	20.8	-	139,000
505+00	6.0	24.0	33,600	139,000
540+00	7.5	30.0	-	160,300
565+00	8.2	32.8	-	131,500
585+00	8.6	34.4	13,000	122,600
605+00	8.6	34.4	54,100	107,300
620+00	9.4	37.6	56,100	150,700
650+00	8.3	33.2	59,400	192,200
685+00	3.1	12.4	10,400	38,700
Total			**226,600**	**1,227,800**

Alternative 3: Small Scale Dune Nourishment

The dune nourishment scenario was developed with consideration given to the NPS guideline that restricts the location of placed material to the dune and the portion of the beach profile above MHW. The dune geometry developed under Alternative 2 was also used as the template for this scenario (Figure 12). The dune crest elevation was established at +15 ft NAVD 88, a maximum width of 25 ft at the crest; the landward and seaward slopes are identified as 5:1 and 3:1.

The design template was superimposed onto the existing August 2009 survey profile to assess the volume of material required to construct the dune. At profiles 430+00, 475+00, 540+00, 565+00 and 685+00, no material is required. Additional material is required at stations 505+00, 585+00, 605+00, 620+00 and 650+00.

Table 6 identifies the required material above the 4 ft NAVD contour for the construction of the dune nourishment template in each station. The total volume needed to construct the dune for the dune nourishment scenario is 132,700 cy over 12,500 lf of shoreline (from Station 490+00 to 522+50 and 575+00 to 667+50). As identified in Section 2.0, there would be adequate material available every 4 years to renourish the dunes, with approximately 220,000 cy estimated to be available from the NC Ferry dredging operations and an additional 80,000 cy of material available from USACE operations.

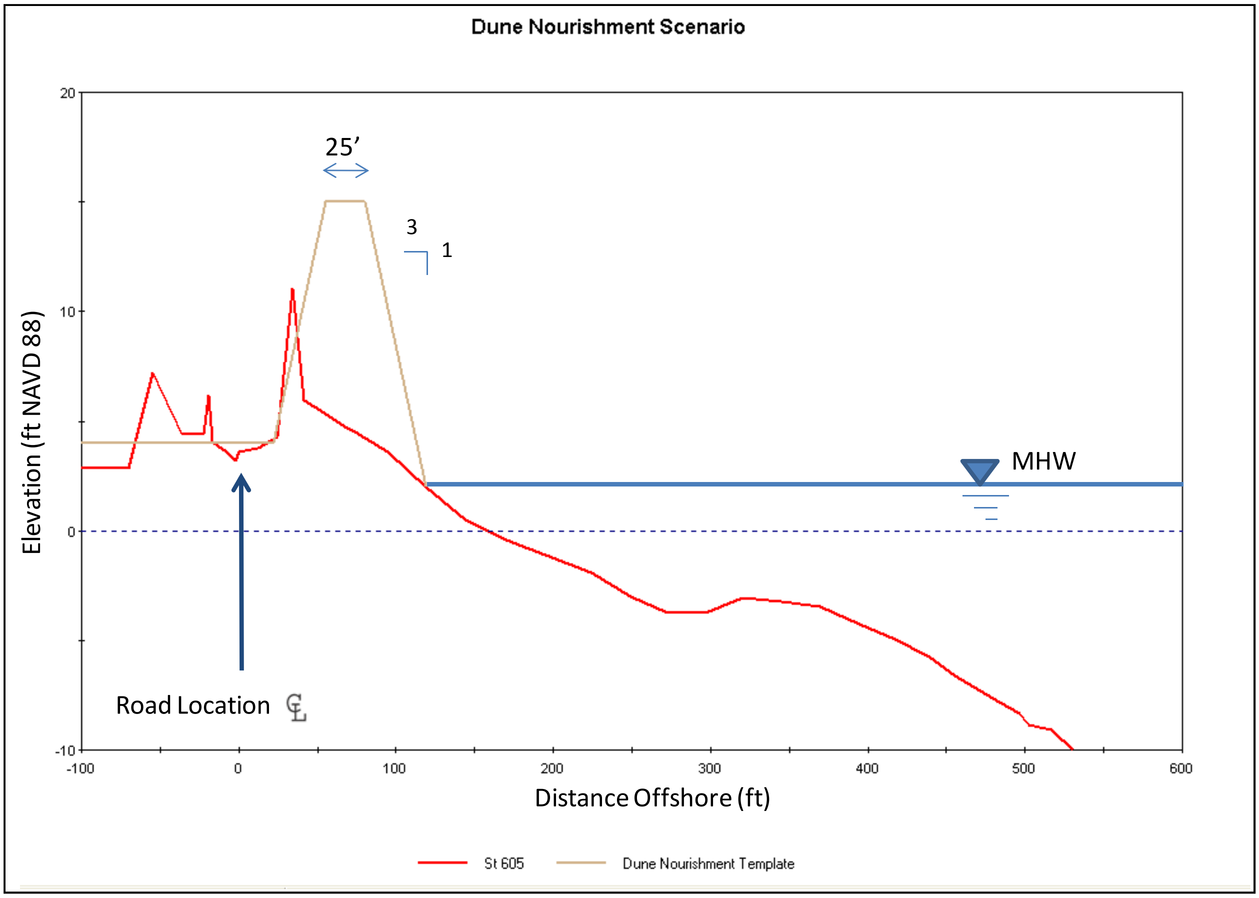


Figure 12. Alternative 3 - Dune Nourishment template at Station 605+00

Table 6. Alternative 3 – Dune Nourishment Design Template Requirements

Station	Required Volume (cy/ft)	Required Volume (cy)
430+00	-	-
475+00	-	-
505+00	10.46	34,000
540+00	-	-
565+00	-	-
585+00	12.92	13,000
605+00	19.44	32,400
620+00	9.84	22,000
650+00	5.03	22,400
685+00	-	8,900
Total		**132,700**

Alternative 4: Roadway Relocation and Dune Nourishment

Under this scenario, NC 12 would be relocated. The proposed roadway alignment was developed by Parsons Brinkerhoff (PB) by shifting the roadway as far landward as possible, without encroaching on wetlands. Table 7 identifies the proposed roadway realignment setback; from St 565+00 to 620+00, the proposed alignment is 140 ft landward of the existing roadway.

Table 7. Alternative 4 Roadway Relocation – Proposed Setback

Station	Existing Setback	Proposed Setback w/ Roadway Location	Offset
	(ft)	(ft)	(ft)
430+00	417	467	50
475+00	379	514	135
505+00	289	429	140
540+00	280	420	140
565+00	218	358	140
585+00	208	348	140
605+00	116	256	140
620+00	135	270	135
650+00	243	371	128
685+00	418	538	120

In addition to relocation of the road, a dune would be constructed using a design template similar to that identified in Alternatives 2 & 3 (Figure 13). Figure 14 illustrates the location of the existing and proposed roadway realignments.

For the vulnerability analysis it is conservatively assumed that the additional protection afforded by the existing vegetated dunes would not be accounted for in the SBEACH model. For the simulations, the berm was extended (at an elevation of 4 ft NAVD) to intersect the existing profile (Figure 13).

The initial dune nourishment template in 2010 will require a total of approximately 490,000 cy. A portion of this material will come from the existing dunes (non-vegetated). The additional material would be provided from USACE and NCDOT dredging operations (as noted above, approximately 300,000 cy is available every four years). Every four years the dunes will be rebuilt with material from USACE and NCDOT dredging operations.

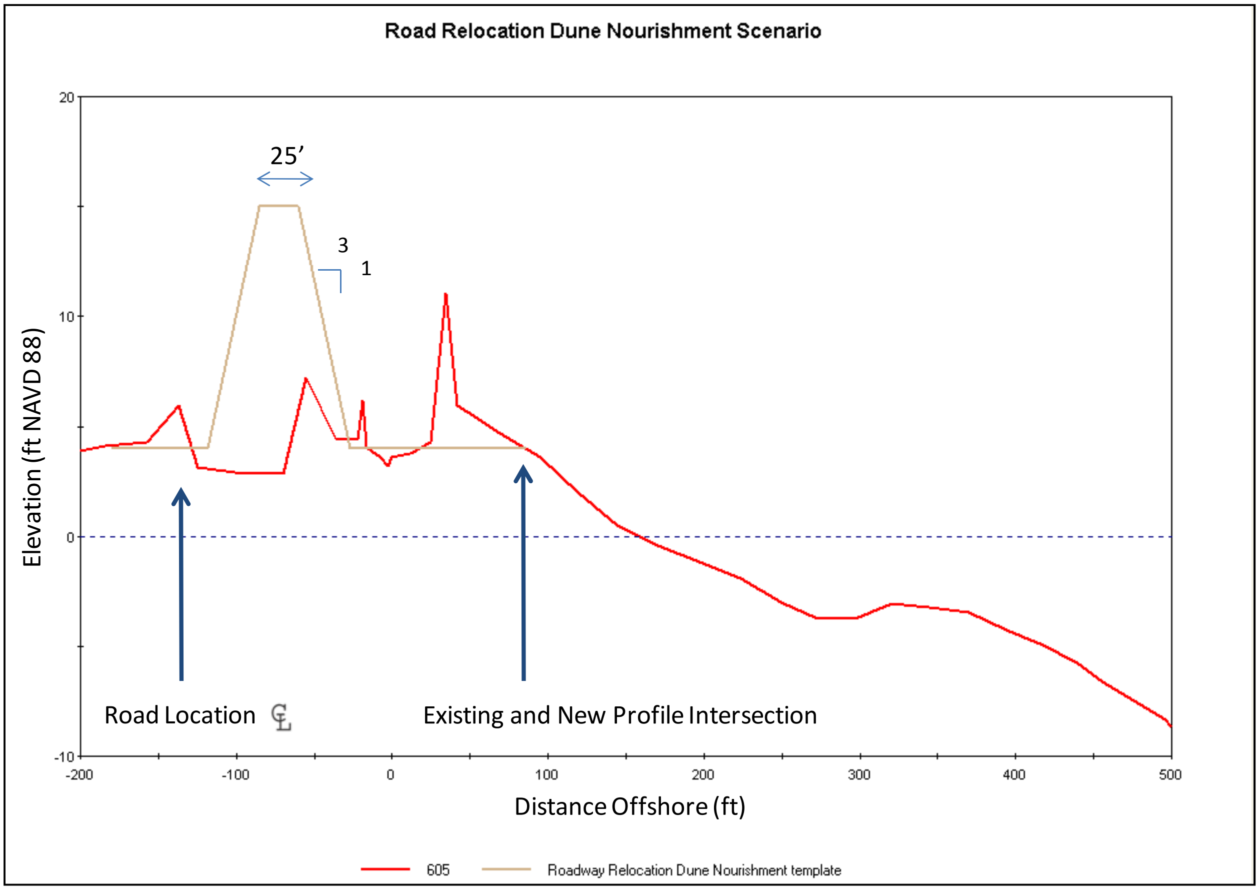


Figure 13. Alternative 4 - Roadway relocation and Dune Nourishment profile at Station 605+00

Table 8. Alternative 4 Roadway Relocation – Required Volume (above 4 ft NAVD)

Station	Required Volume (cy/ft)	Required Volume (cy)
430+00	17.79	40,100
475+00	30.63	114,900
505+00	6.61	21,500
540+00	9.79	29,400
565+00	20.82	46,900
585+00	26.31	52,700
605+00	23.41	41,000
620+00	16.85	38,000
650+00	14.91	48,500
685+00	32.33	56,600
Total		**489,600**

Figure 14. Proposed Roadway Realignment

5.0 EVALUATION OF ALTERNATIVES

Alternative 1: Baseline Conditions

The vulnerability of NC12 to storm damage and maintenance was evaluated at each of the ten profiles for existing conditions and after four years of shoreline recession.

Maintenance Requirements

Table 9 identifies the existing setback of the MHW line and the projected setback based on continued shoreline recession (assuming historical erosion rate) over the 15 year planning horizon. The grey cells indicated that the roadway is vulnerable to frequent maintenance (Setback <230 ft). Currently, the roadway is vulnerable from station 565+00 through Station 620+00. If recession continues at the historical rate, within 10 years, profiles at Stations 505+00, 540+00 and 650+00 will also become vulnerable to frequent maintenance.

Table 9. Alternative 1 Baseline Conditions - Vulnerability to Maintenance

Station	Erosion Annual rate (ft/yr)	Setback Distance from Road to MHW Line 2010 (ft)	2015 (ft)	2020 (ft)	2025 (ft)
430+00	2.9	417	402	388	373
475+00	5.2	379	353	327	301
505+00	6.0	289	259	229	199
540+00	7.5	280	242	205	167
565+00	8.2	218	177	136	95
585+00	8.6	208	165	122	79
605+00	8.6	116	73	30	-13
620+00	9.4	135	88	41	-6
650+00	8.3	243	201	160	118
685+00	3.1	418	402	387	371

Storm Damage

Table 10 presents the results of the volumetric vulnerability analysis upon application of SBEACH and EST. The grey cells indicate that the road is going to be vulnerable to less than a 50-year storm event. Under existing conditions, at stations 505+00, 585+00, 605+00, 620+00, the road is vulnerable to storm damage (<50 year return period storm event). The portion of NC12 along Stations 605+00 and 620+00 is vulnerable to damage in a 2-Year or 3-Year storm event; with continued shoreline recession, in four years, damage to this section of the roadway will be imminent. After four years, NC12 will be vulnerable to storm damage at additional locations including profiles 565+00 and 650+00.

Table 10. Alternative 1 Baseline Conditions – Vulnerability to Storm Damage (Recurrence Interval)

Station	Beginning of Cycle (Years)	After 4 years (Years)
430+00	150	150
475+00	85	75
505+00	38	18
540+00	150	120
565+00	78	44
585+00	18	13
605+00	3	<1
620+00	2	<1
650+00	55	37
685+00	150	150

Figure 15 provides an example of pre and post storm conditions illustrating the simulated profile change at station 565+00 if a storm were to make landfall at low tide with characteristics (i.e. significant wave height, surge, duration) comparable to those experienced during Hurricane Isabel.

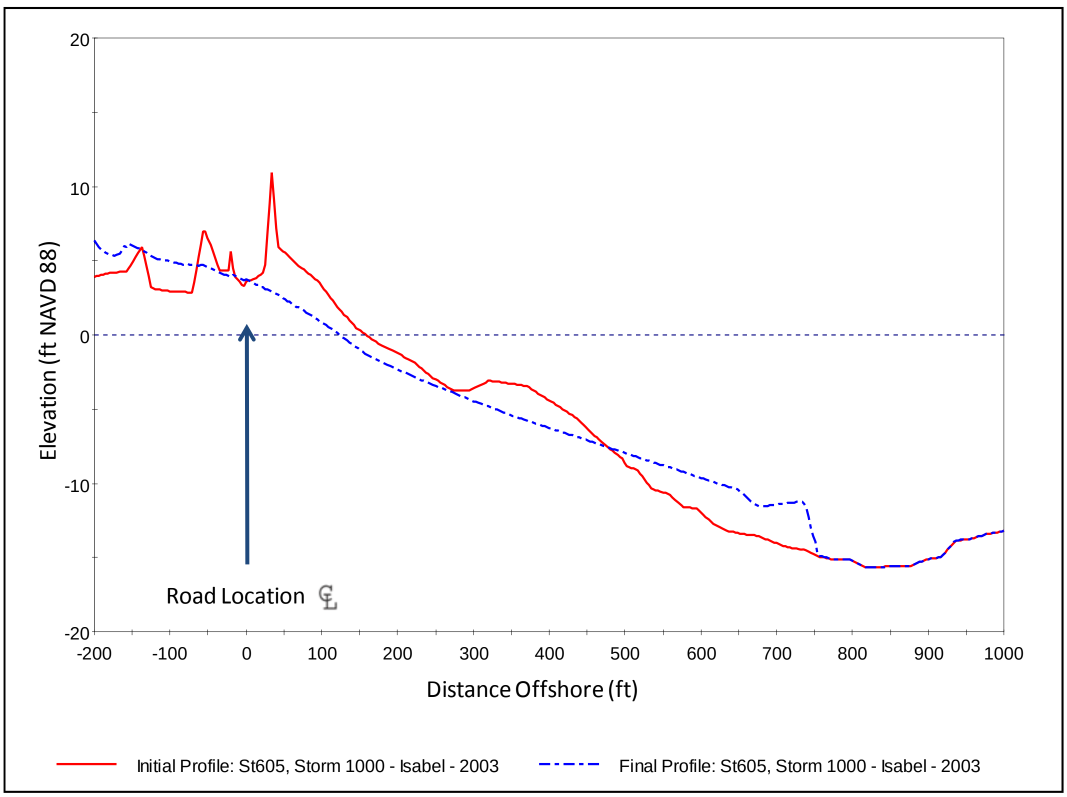


Figure 15. Alternative 1 -Existing Conditions pre and post storm profiles at Station 605+00

Alternative 2: Beach Nourishment

As described in Section 4.0 above, the beach and dune nourishment template for this alternative was designed following an iterative method of trial and error to achieve a minimum level of protection from storm damage and to minimize maintenance requirements. By design, the minimum setback will be 230 ft and at a minimum the risk of storm damage will be a 50-year return period event.

It was identified in Section 2.0 (Development of Alternatives) that 226,600 cy would be placed along 14,250 lf of shoreline to achieve the fill template. In addition, to maintain the proposed template in place for a 4 year period would require an additional 1,227,800 cy of pre-nourishment along 25,500 lf of shoreline. This is identified as Scenario A in Table 11.

To reduce pre-nourishment requirements the scenario could be modified. Rather than hold the existing or design template in place, pre-nourishment could be performed only as required to maintain a 230 ft setback. Where the roadway is not projected to be at risk within the 4 year nourishment cycle, pre-nourishment would not be performed. For the initial project cycle approximately 704,000 cy of pre-nourishment would be required over 11,000 lf (552+50 to 662+50); this is identified as Scenario B in Table 11. During subsequent cycles within the planning horizon, as the shoreline recedes, additional reaches will require pre-nourishment. The length of the shoreline requiring pre-nourishment requirement would increase; for example in 2018 and 2022, approximately 1M cy of pre-nourishment would be required over 17,750 lf (Table 11). A total of approximately 3.6 Mcy would be required in pre-nourishment over the planning horizon through 2025.

Table 11. Alternative 2: Beach Nourishment Design Template and Pre-nourishment Requirements

Station	Initial Required Material for Template 2010 (cy)	Pre-Nourishment Volume				
		Scenario A – Maintain Template	Scenario B – Minimum Vulnerability			
		Every 4 years (cy)	2010 (cy)	2014 (cy)	2018 (cy)	2022 (cy)
430+00	-	46,500	0	0	0	0
475+00	-	139,000	0	0	0	0
505+00	33,600	139,000	0	0	139,000	139,000
540+00	-	160,300	0	160,300	160,300	160,300
565+00	-	131,500	131,500	131,500	131,500	131,500
585+00	13,000	122,600	122,600	122,600	122,600	122,600
605+00	54,100	107,300	107,300	107,300	107,300	107,300
620+00	56,100	150,700	150,700	150,700	150,700	150,700
650+00	59,400	192,200	192,200	192,200	192,200	192,200
685+00	10,400	38,700	0	0	0	0
Total	226,600	1,227,800	704,300	864,600	1,003,600	1,003,600
Total 2010 - 2025	**226,600**	**4.9 Mcy**	**3.6 Mcy**			

Figure 16 illustrates the predicted response of the beach nourishment template at Station 605+00 after construction if a storm comparable to Hurricane Isabel were to strike at low tide.

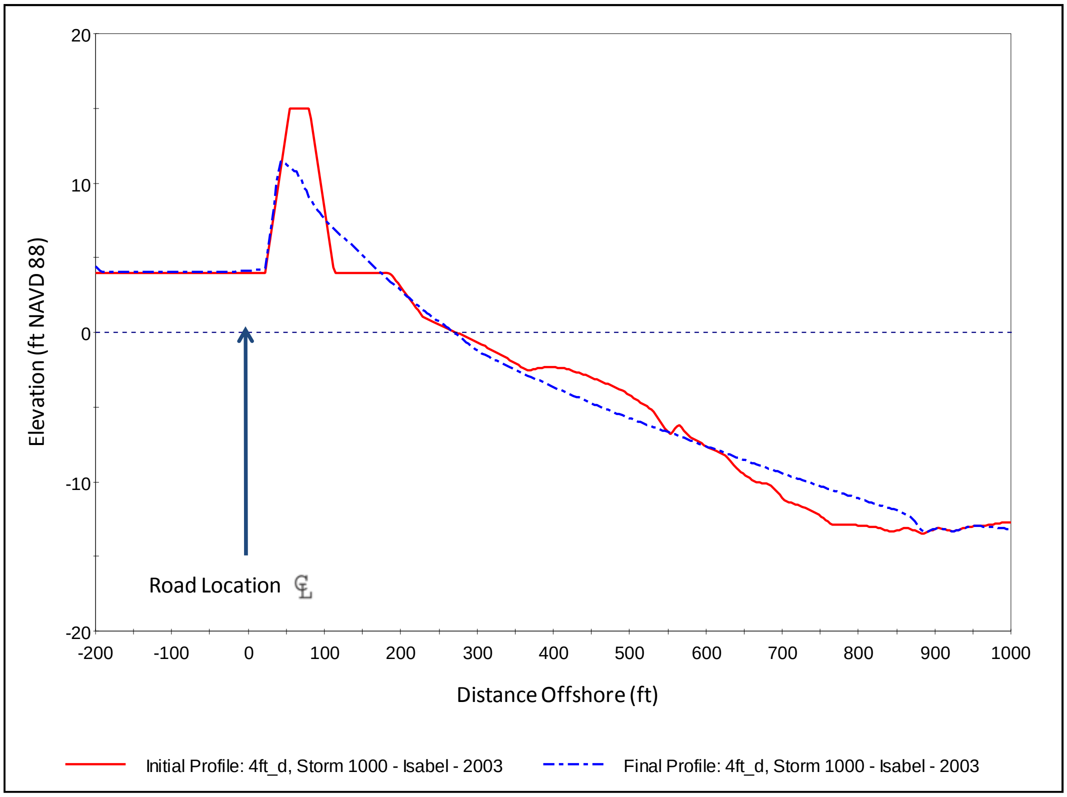


Figure 16. Alternative 2 - Beach Nourishment pre and post storm profiles at Station 605+00

Alternative 3: Dune Nourishment

Maintenance

The vulnerability of NC12 to increased maintenance is the same as the existing conditions scenario (Table 9).

Storm Damage

The vulnerability of the dune nourishment scenario was evaluated at two different time frames - (a) beginning of the dune nourishment (2010) and (b) after 4 years, at the end of the nourishment cycle. Table 12 presents the results of the storm damage analysis. Similar to the baseline scenario, at profiles 505+00, 585+00, 605+00, 620+00 the road is vulnerable to storm damage (<50 year). At Stations 605+00 and 620+00, immediately after nourishment, there is a likelihood that the road will be damaged in less than a 15-Year return period event; at this location at the end of the 4 year nourishment cycle there is little protection from storm damage. At the end of the cycle station 565+00 also becomes vulnerable to storm damage.

As shoreline recession continues, the setback will be reduced (Table 9). The size of the dune that may be rebuilt will therefore be limited based on the area available between NC12 right of way and the MHW line. To the extent possible, the dune will be rebuilt every four years.

Table 12. Alternative 3: Dune Nourishment – Vulnerability to Storm Damage (Recurrence Interval)

Station	2010 (Years)	2014 (Years)
430+00	150	150
475+00	85	75
505+00	44	19
540+00	150	120
565+00	78	44
585+00	40	30
605+00	11	2
620+00	6	1
650+00	58	51
685+00	150	150

Figure 17 illustrates the simulated response if the dune nourishment template after 2010 were impacted by a storm comparable to Hurricane Isabel.

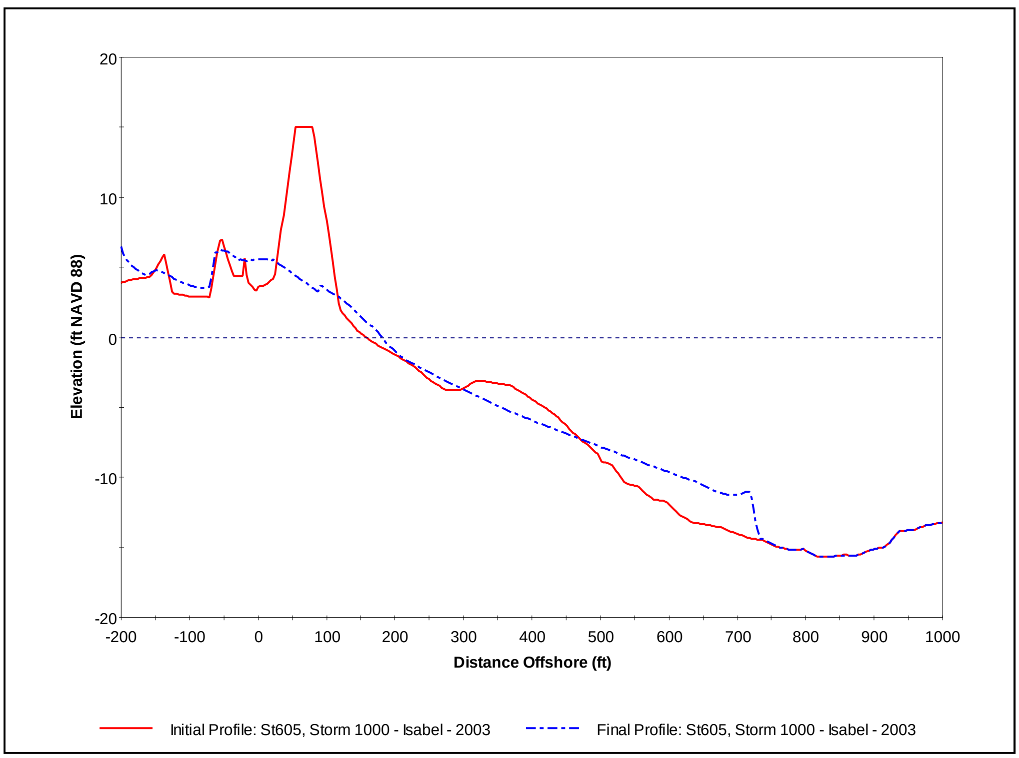


Figure 17. Alternative 3 - Dune Nourishment pre and post storm profiles at Station 605+00 (2010)

Alternative 4: Roadway relocation with Dune Nourishment

Maintenance

Table 13 presents the projected setback (assuming the historical erosion rate) and vulnerability to maintenance over the 15 year planning horizon. At the end of the 15 year period, Stations 585+00, 605+00 and 620+00, NC12 will be vulnerable to frequent maintenance; the vulnerability in 2015 will be similar to existing conditions at these locations.

Table 13. Alternative 4: Roadway Relocation - Vulnerability to Maintenance

Station	Erosion	Distance from Road to MHW Line			
	Annual rate (ft/yr)	2010 (ft)	2015 (ft)	2020 (ft)	2025 (ft)
430+00	2.9	467	452	438	423
475+00	5.2	514	488	462	436
505+00	6.0	429	399	369	339
540+00	7.5	420	382	345	307
565+00	8.2	358	317	276	235
585+00	8.6	348	305	262	219
605+00	8.6	256	213	170	127
620+00	9.4	270	223	176	129
650+00	8.3	371	329	288	246
685+00	3.1	538	522	507	491

Storm Damage

The vulnerability to storm damage was evaluated post-construction (2010), and at every 4 years thereafter. As noted above, starting in 2014 it was assumed that the material available from dredging by the USACE and NCDOT would be placed to rebuild the dunes as may be required. The results are identified in Table 14. In 2010 under the profile at station 620+00, even after roadway relocation and dune construction, will be vulnerable to storm damage. Under this scenario, with the exception of the section of roadway at near profiles 605+00 and 620+00, the roadway will not be vulnerable to storm damage during the 15 year planning horizon.

Table 14. Alternative 4: Roadway Relocation - Vulnerability to Storm Damage (Recurrence Interval)

Station	2010 (Years)	2014 (Years)	2018 (Years)	2022 (Years)
430+00	62	61	58	56
475+00	150	150	150	150
505+00	77	75	75	72
540+00	150	150	150	150
565+00	150	150	150	150
585+00	120	120	120	120
605+00	83	57	41	25
620+00	43	30	24	13
650+00	100	100	100	94
685+00	150	144	140	140

Figure 18 illustrates the simulated response of the dune nourishment and roadway relocation project if it were impacted by a storm similar to Hurricane Isabel at low tide.

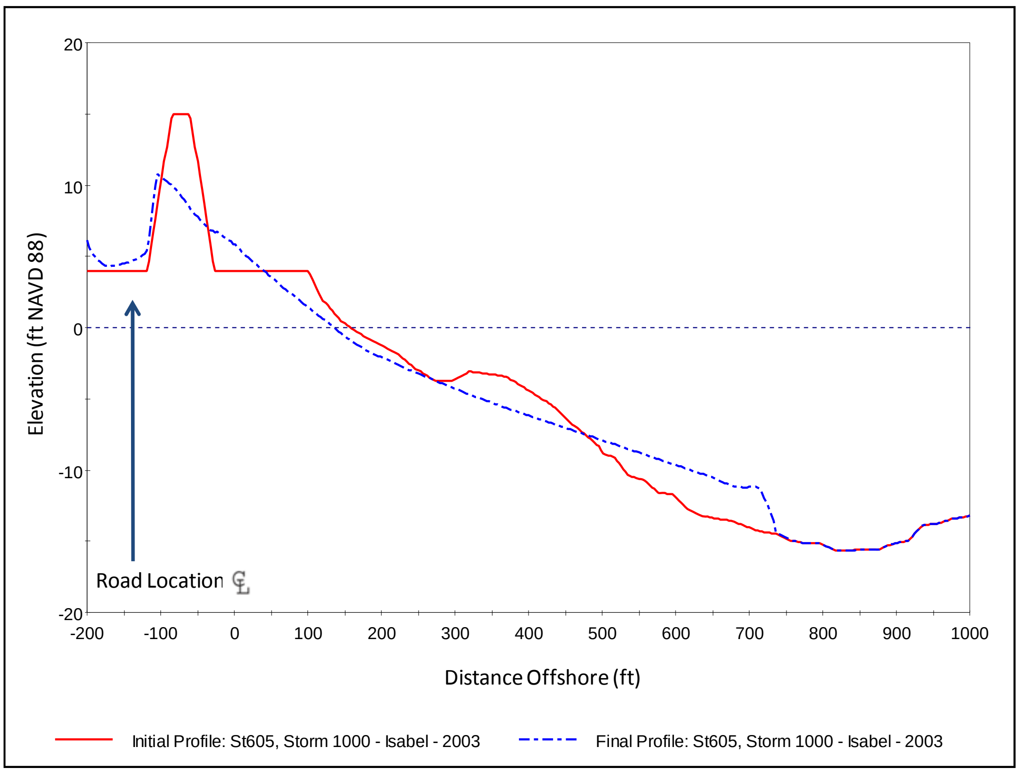


Figure 18. Roadway Relocation with Dune Nourishment Typical Cross Section – Pre and Post Storm Activity – Station 605+00 (After Construction)

6.0 OPINION OF PROBABLE COSTS FOR BEACH AND DUNE NOURISHMENT

An opinion of probable costs was developed for beach and dune nourishment scenarios (Alternatives 2 & 3) based on the volume of material to be placed and the potential borrow sources to be utilized for each alternative.

Alternative 2 consists of dredging nearshore borrow areas to obtain material for beach nourishment. It is assumed that the offshore dredging would utilize either a medium or large hopper dredge, given the potential haul distances. In developing the opinion of probable costs for Alternative 2, the planning level unit cost for beach nourishment is estimated to be $12 to $15 per cubic yard of material; this is based on similar projects which have been undertaken in the region. This assumes that a large scale (>500,000 cy) project will be undertaken and includes mobilization and demobilization.

For Alternative 2, to meet the initial design template, 226,600 cy would be placed along 14,250 lf of shoreline. Additionally, pre-nourishment material will be placed. If the pre-nourishment is limited to quantities required to maintain a 230 ft setback, approximately 704,000 cy would be required for the initial four year cycle. The total cost of the initial nourishment project is estimated to cost between $11 million to $14 million, including the additional costs for mobilization / demobilization. During the fifteen year planning horizon it is estimated that a total of approximately 4.5 Mcy of material would be required at a total estimated cost on the order of $54 Million to $67.5 Million, including the additional costs for mobilization / demobilization.

Under Alternative 3, approximately 132,000 cy of material from the stockpile adjacent to the Ocracoke Ferry Terminal to build the initial dune profile in 2010. The cost for transport and placement of the material along the critical area extent is estimated at approximately $6 to $8 per cubic yard of material, yielding a total cost of approximately $528,000 to $792,000 for the initial project. The amount of material required and cost for periodically rebuilding the dune throughout the planning period was not evaluated.

The total cost for Alternative 4, roadway relocation and dune nourishment, was not evaluated as part of this assessment.

7.0 SUMMARY AND CONCLUSIONS

For this study, vulnerability of NC12 was defined with respect to (a) maintenance requirements and (b) storm damage. Where the setback from the centerline of the road to MHW line was less than 230 ft, the roadway was considered vulnerable to increased maintenance. The projected shoreline position was evaluated based on the assumption that the average historical shoreline recession rate is representative of the erosion that will occur over the 15 year planning horizon. Vulnerability with respect to storm damage was assessed based on the area of erosion above the +4 ft contour (between the edge of the roadway and the beach). If the dune area loss above the 4 ft NAVD contour was more than 50 % of the total material, then the profile is considered vulnerable to that storm. For this study it was assumed that an acceptable level of risk is defined by a 50-yr return period storm event.

Key considerations for defining the specific engineering alternatives included: guidelines by the National Parks Service (NPS), the potential impact to natural resources, the availability of sand resources and anticipated costs for implementation. The following alternatives were evaluated:

- *Alternative 1: Baseline (Do Nothing)*
- *Alternative 2: Large Scale Beach Nourishment*
- *Alternative 3: Small Scale Dune Nourishment*
- *Alternative 4: Roadway Relocation and Dune Nourishment*

Table 15 and Table 16 summarize the vulnerability with respect to maintenance requirements. Table 17 presents the results of the storm damage vulnerability.

Under existing conditions, the most vulnerable section of NC12 is along Station 585+00 to 620+00 where the road is vulnerable to maintenance (<230 ft setback) and storm damage (<50 year). Within 4 years, it is estimated that an additional 4500 lf of the roadway will become vulnerable to storm damage (Table 17). If erosion were to go unmitigated (at rates greater than 9 ft/year), by 2025 there would be no setback at Stations 605+00 and 630+00; the length of roadway that would require frequent maintenance would increase to approximately 14,500 lf.

Implementation of a Large Scale Beach Nourishment Project (Alternative 2) is a viable but expensive management strategy to protect NC12. Under this scenario 226,600 cy would be placed along 14,250 lf of shoreline to achieve the initial design template. Additionally, to maintain a 230 ft setback, approximately 704,000 cy of pre-nourishment would be required for the initial four year cycle. The total cost of the initial nourishment project is estimated to cost between $11 million and $14 million. During the fifteen year planning horizon an additional 4.5 Mcy of material would be required, to maintain the design template, at an estimated cost of $54 Million to $67.5 Million.

Dune Nourishment (Alternative 3) was evaluated following general guidelines of the NPS. Under this scenario, approximately 132,000 cy of sand would be placed to build the initial template, equating to an average of 10.6 cy/lf at total cost of approximately $528,000 to $792,000. To the extent possible, the dune will be rebuilt every four years. The amount of material required and cost to rebuild the dune over the planning period was not quantified as part of this study. This scenario affords only a limited amount of additional protection of NC12 (as compared to the baseline conditions).

If NC12 were relocated (Alternative 4) there would be a substantial reduction in risk of storm damage over the 15 year planning horizon. At the end of the 15 year period, NC12 will be vulnerable to frequent maintenance at Stations 585+00, 605+00 and 620+00; the vulnerability at these location after 15 years will be similar to what it is today under Baseline Conditions. Under this scenario, only the profiles at stations 605+00 and 620+00 will be vulnerable to storm damage in 2025. The total cost for Alternative 4, roadway relocation and dune nourishment, was not evaluated as part of this assessment.

Table 15. Summary of Vulnerability Based on Setback - 2010

Station	Distance from Road to MHW Contour (year 2010)			
	Alt 1 - Base Line	Alt 2 - Beach Nourishment	Alt 3 - Dune Nourishment	Alt 4 - Roadway Relocation & Dune Nourishment
	(ft)	(ft)	(ft)	(ft)
430+00	417	230	417	467
475+00	379	230	379	514
505+00	289	230	289	429
540+00	280	230	280	420
565+00	218	230	218	358
585+00	208	230	208	348
605+00	116	230	116	256
620+00	135	230	135	270
650+00	243	230	243	371
685+00	418	230	418	538

Table 16. Summary of Vulnerability Based on Setback - 2025

Station	Background Erosion Rate (ft/yr)	Distance from Road to MHW Contour (year 2025)			
		Alt 1 - Base Line (ft)	Alt 2 - Beach Nourishment (ft)	Alt 3 - Dune Nourishment (ft)	Alt 4 - Roadway Relocation & Dune Nourishment (ft)
430+00	2.9	373	230	373	423
475+00	5.2	301	230	301	436
505+00	6.0	199	230	199	339
540+00	7.5	167	230	167	307
565+00	8.2	95	230	95	235
585+00	8.6	79	230	79	219
605+00	8.6	-13	230	-13	127
620+00	9.4	-6	230	-6	129
650+00	8.3	118	230	118	246
685+00	3.1	371	230	371	491

Table 17. Summary of Vulnerability Based on Potential Volumetric Erosion

Station	Estimated Recurrence Interval						
	Alt 1 - Baseline Conditions		Alt 2 -Beach Nourishment (years)	Alt 3 - Dune Nourishment		Alt 4 - Roadway Relocation & Dune Nourishment	
	2010 (years)	2014 (years)		2010 (years)	2014 (years)	2010 (years)	2014 (years)
430+00	150	150	> 50	150	150	76	66
475+00	85	75	> 50	85	85	150	150
505+00	38	18	> 50	44	19	90	79
540+00	150	120	> 50	150	120	150	150
565+00	78	44	> 50	78	44	150	150
585+00	18	13	> 50	40	30	140	130
605+00	3	0.5	> 50	11	1.5	82	56
620+00	2	0.5	> 50	6	1	37	30
650+00	55	37	> 50	58	51	110	88
685+00	150	150	> 50	150	150	150	150

7.0 REFERENCES

Ardaman & Assoc, September 2009. Rollinson Channel Soil Testing Report.

Fisher and Overton, June 2005. Bonner Bridge Replacement Parallel Bridge Corridor with NC12 Maintenance, Shoreline Change and Stabilization Analysis.

Moffatt & Nichol, "Vulnerability Analysis of NC 12, Ocracoke Island Hotspot", Raleigh, NC, May, 2003.

Moffatt & Nichol, "Post-Hurricane Isabel Vulnerability Analysis of NC 12, Ocracoke Island Hotspot", Raleigh, NC, May, 2004.

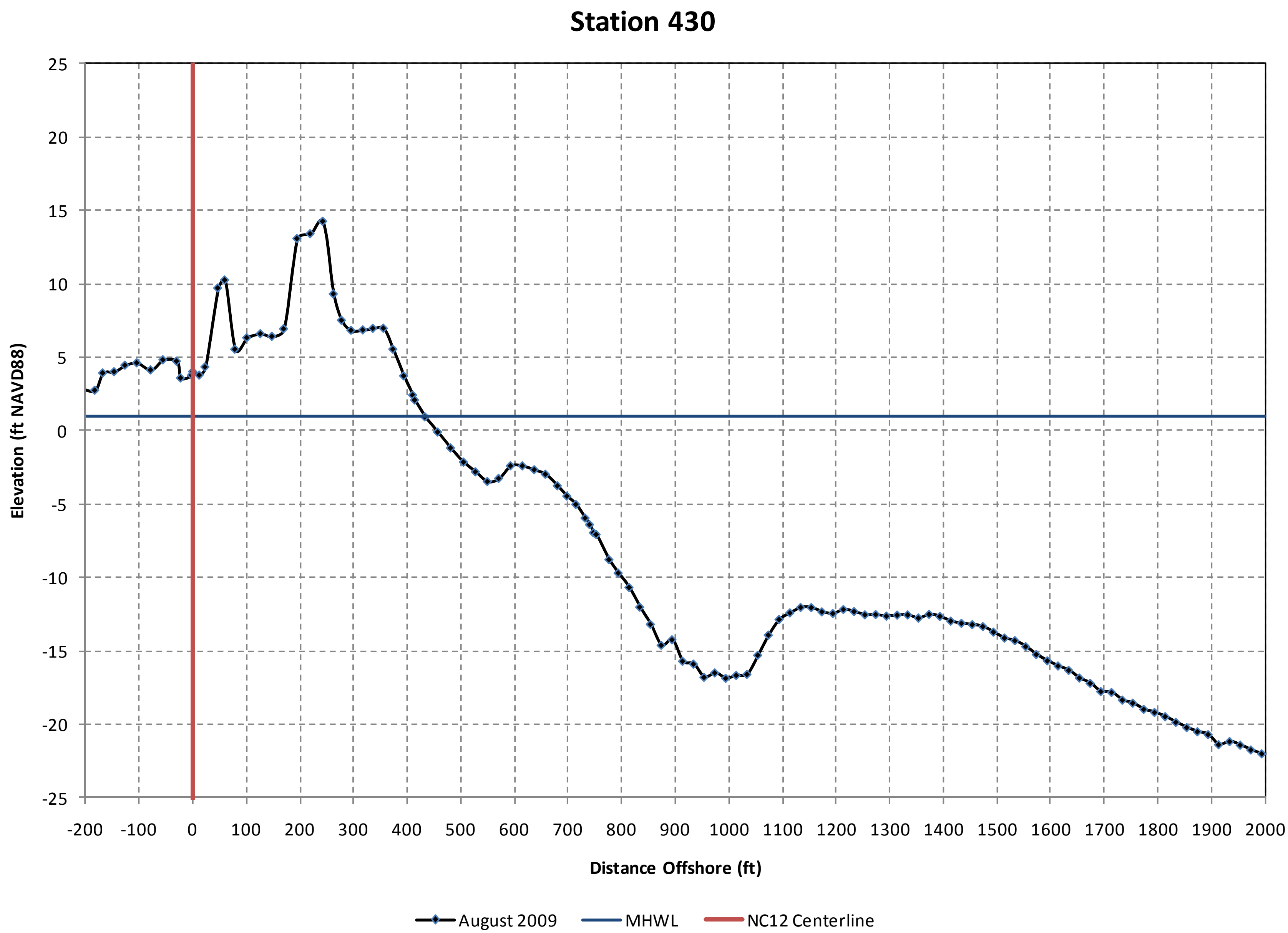
NCDOT Ferry Terminal, 2009. Communication with Norris Reed. of NC Ferry Division

NCDOT, November 2010. Meeting notes NC12 project team meeting. Participants included: NCDOT Project Manager Beth Smyre , Dr. Margery Overton and representatives from Moffatt & Nichol, PB, and URS.

NCGS, Revised August 4, 2009. Offshore Sand Resource Investigation, North Carolina Outer Banks: Ocracoke Inlet to Oregon Inlet.

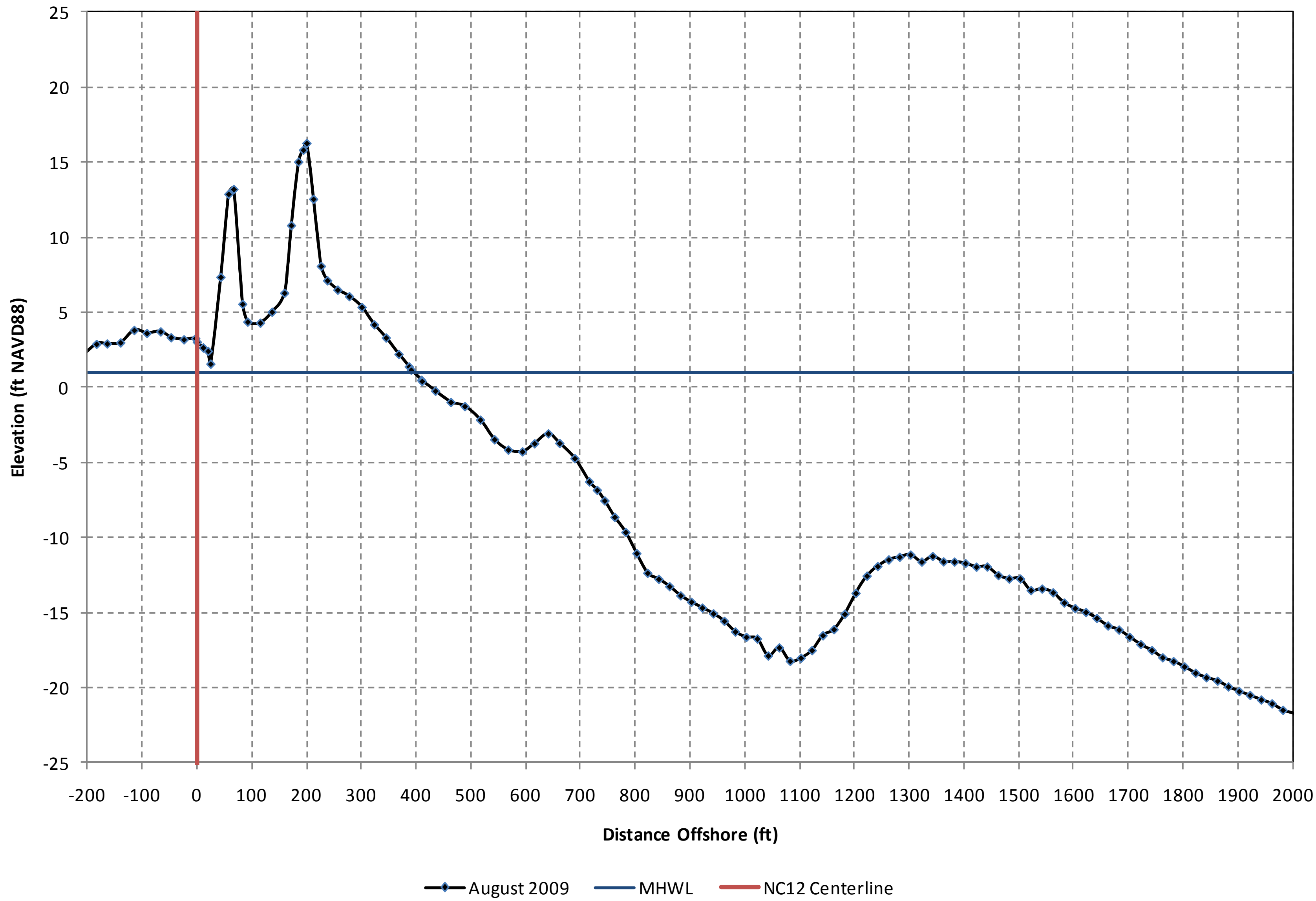
USACE, 2009. Communication with Chris Frabotta of USACE, Wilmington District.

APPENDIX A – AUGUST 2009 SURVEY

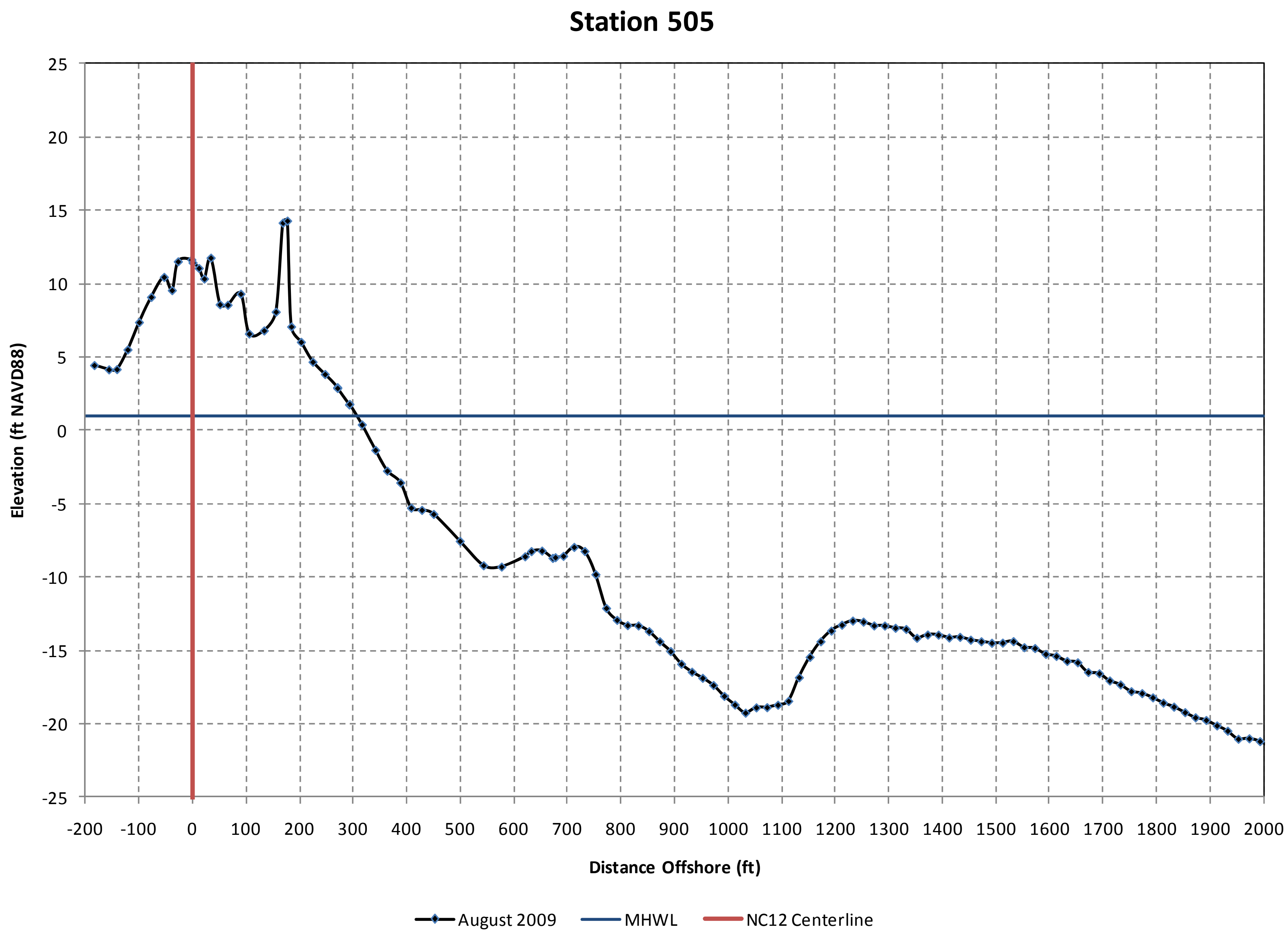


Station 430
25
20
15
10
5
0
-5
-10
-15
-20
-25
Elevation (ft NAVD88)
-200
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Distance Offshore (ft)
August 2009
MHWL
NC12 Centerline

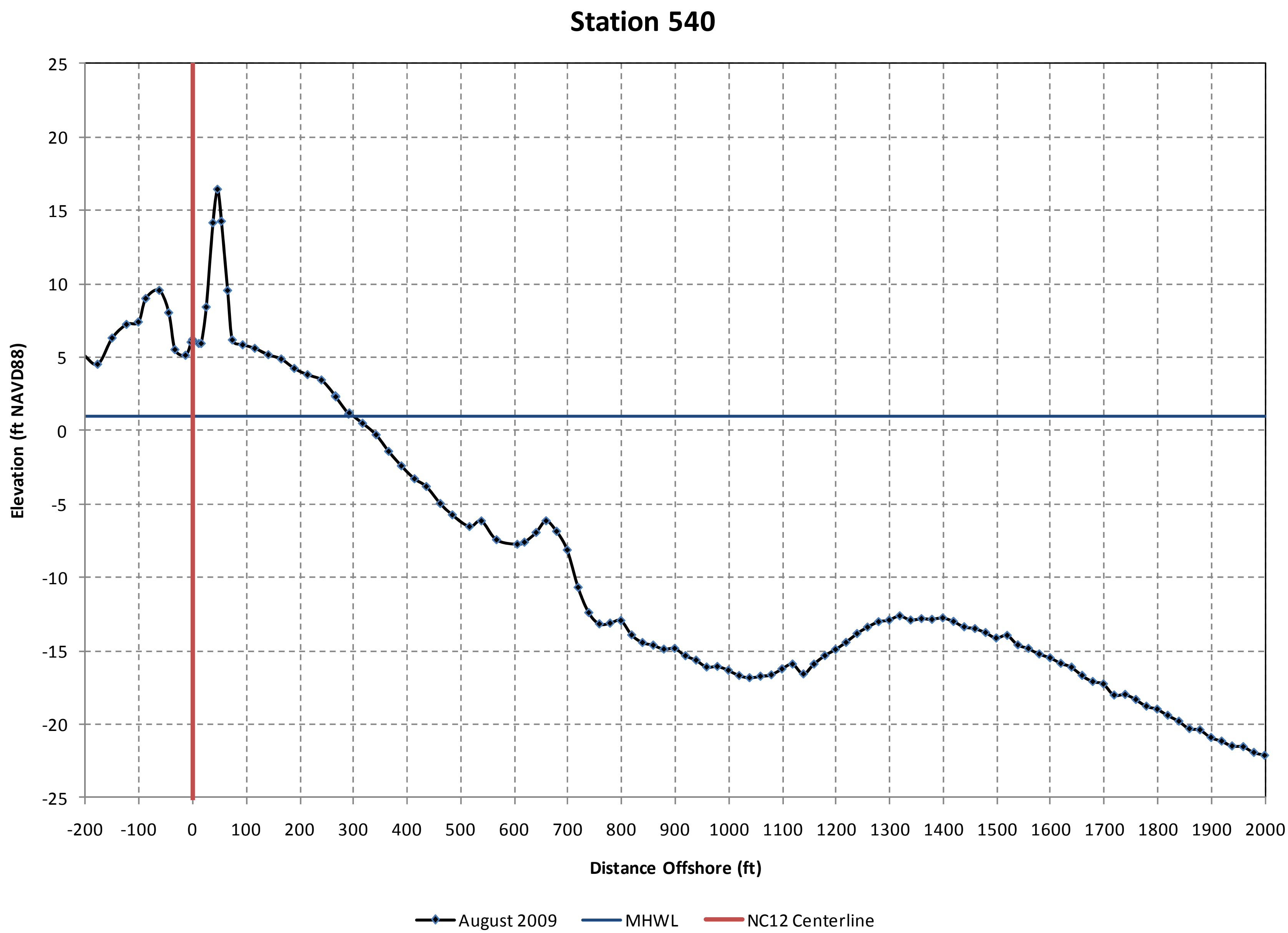
Station 475



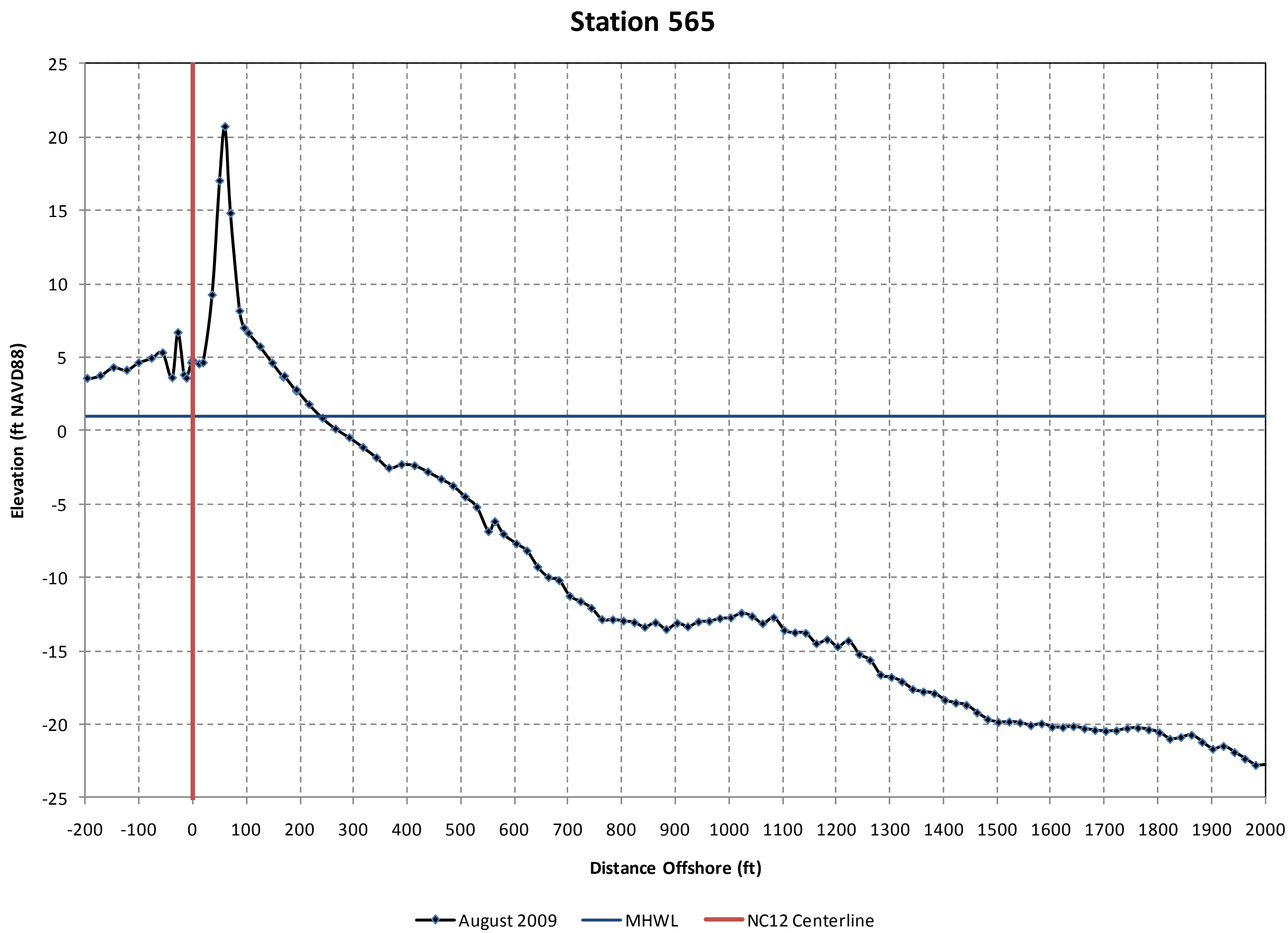
Elevation (ft NAVD88)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Distance Offshore (ft)
August 2009
MHWL
NC12 Centerline



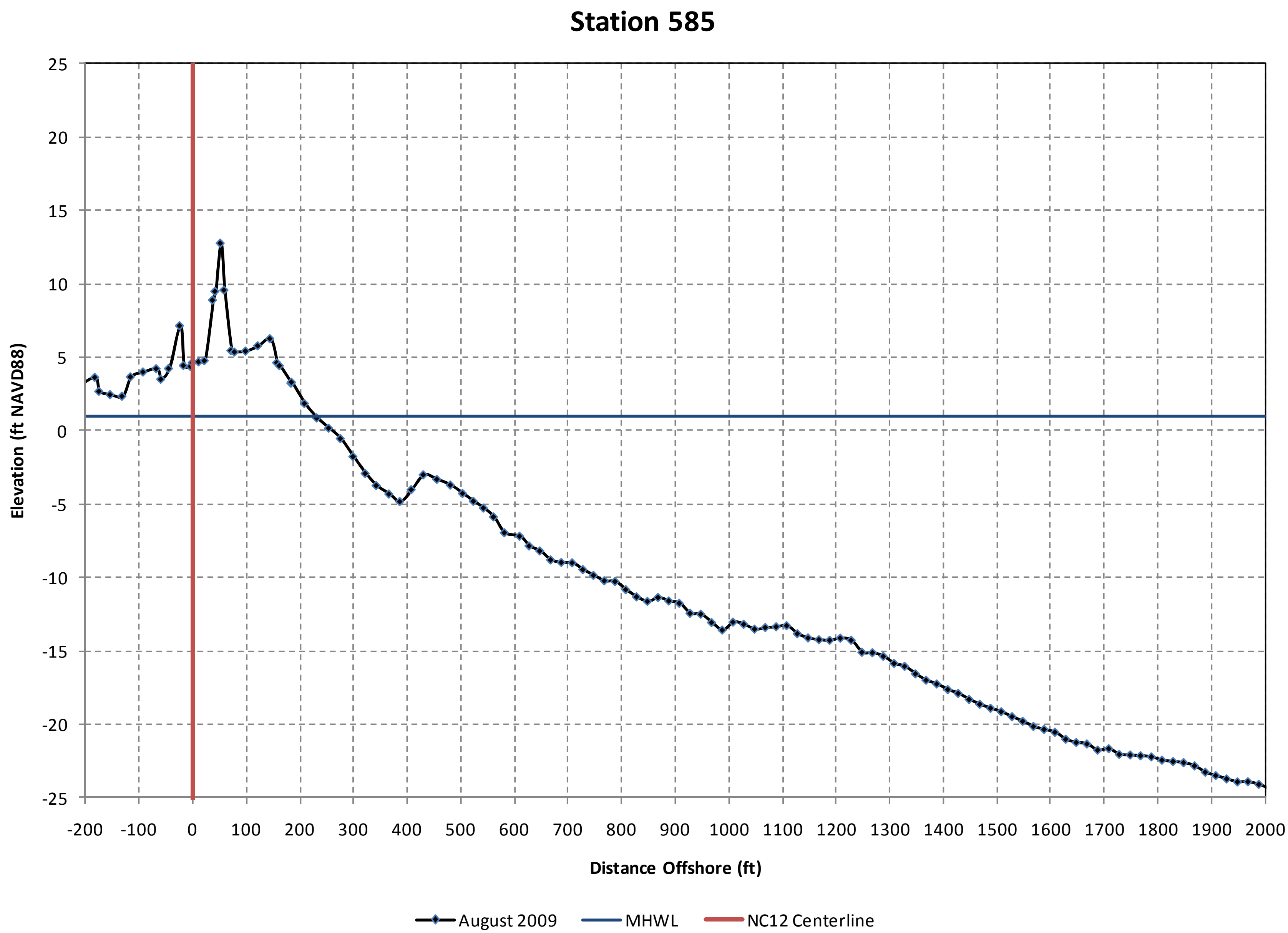
Station 505
Elevation (ft NAVD88)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Distance Offshore (ft)
August 2009
MHWL
NC12 Centerline



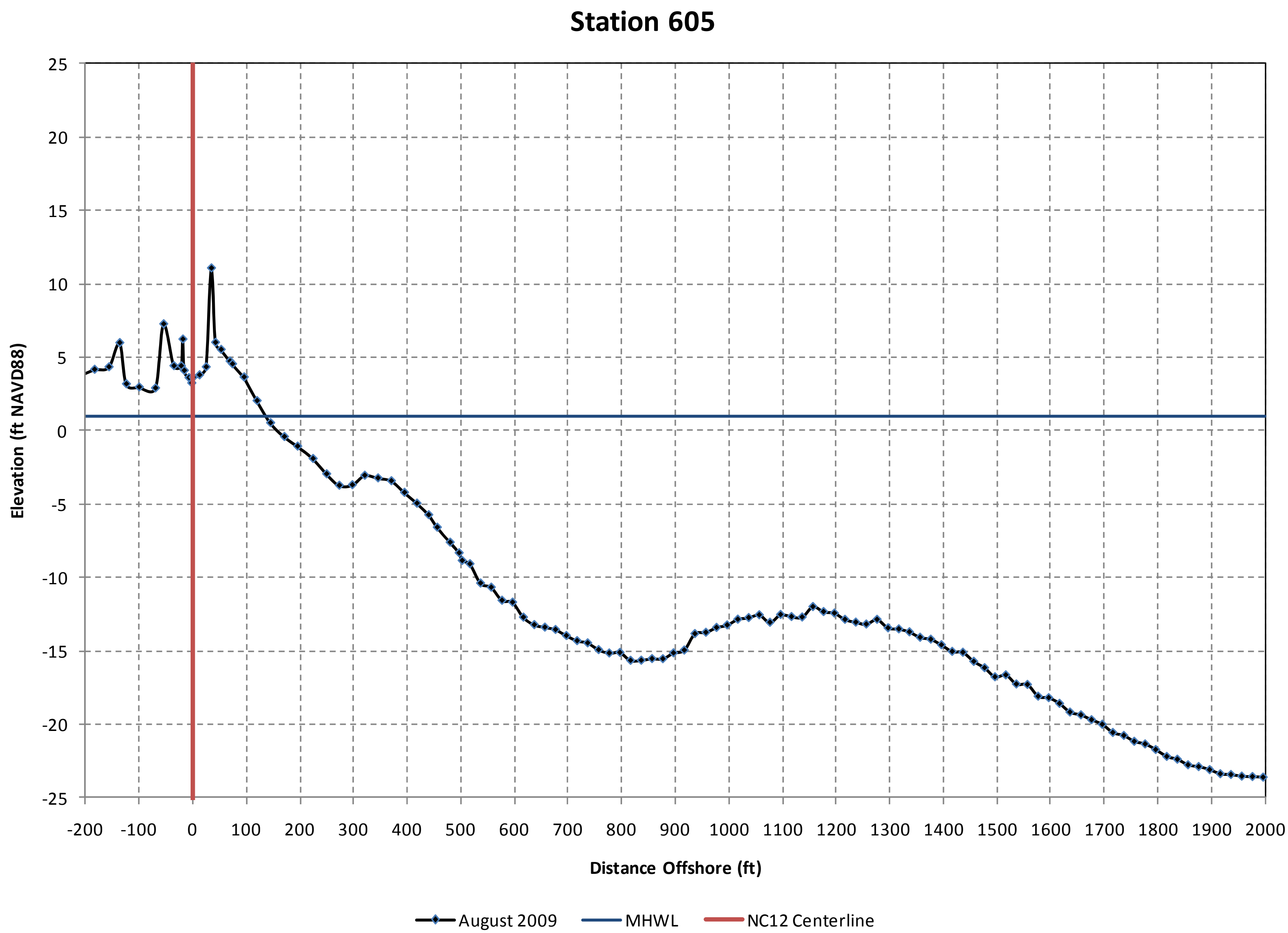
Station 540
Elevation (ft NAVD88)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Distance Offshore (ft)
August 2009
MHWL
NC12 Centerline

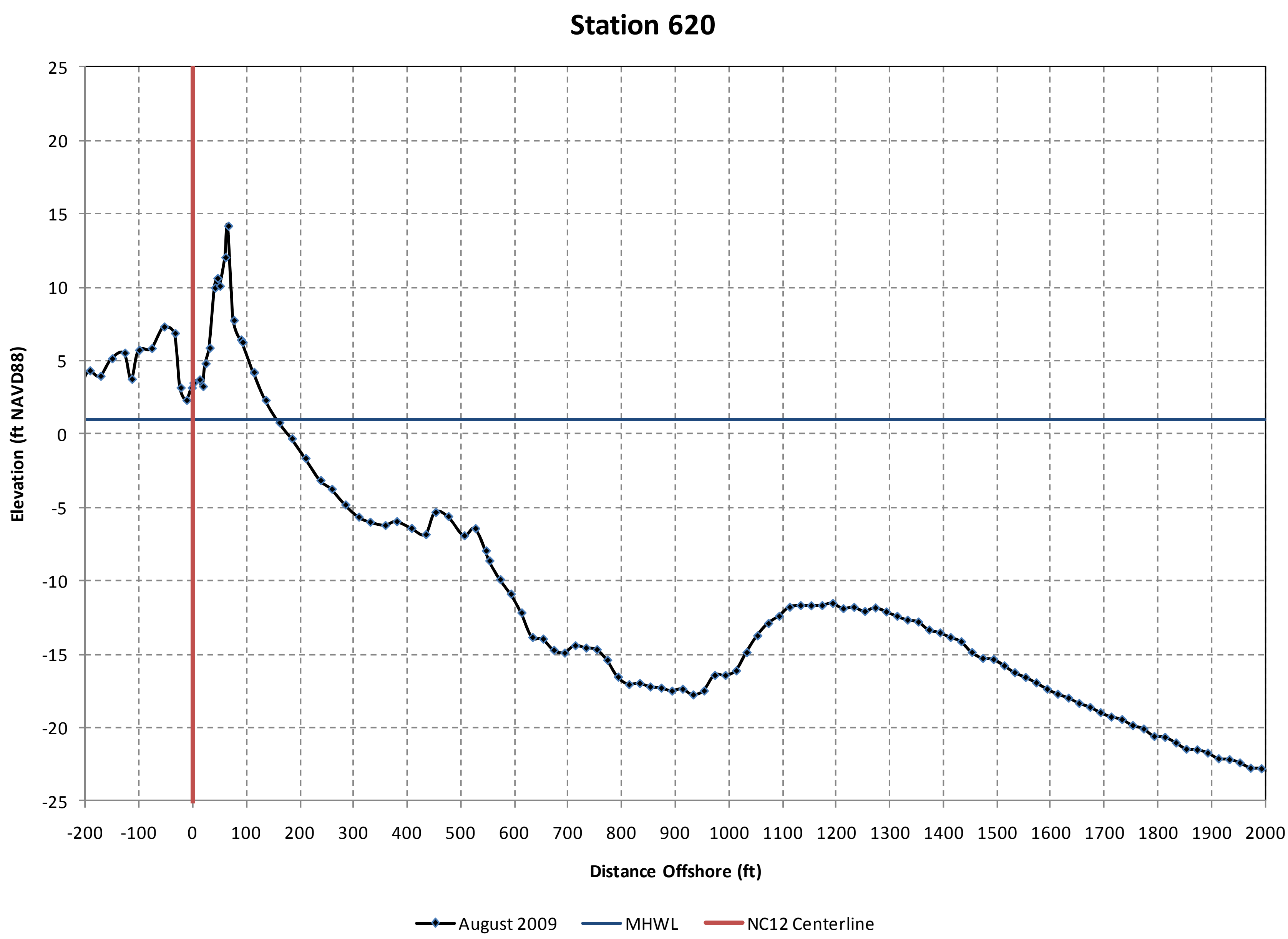


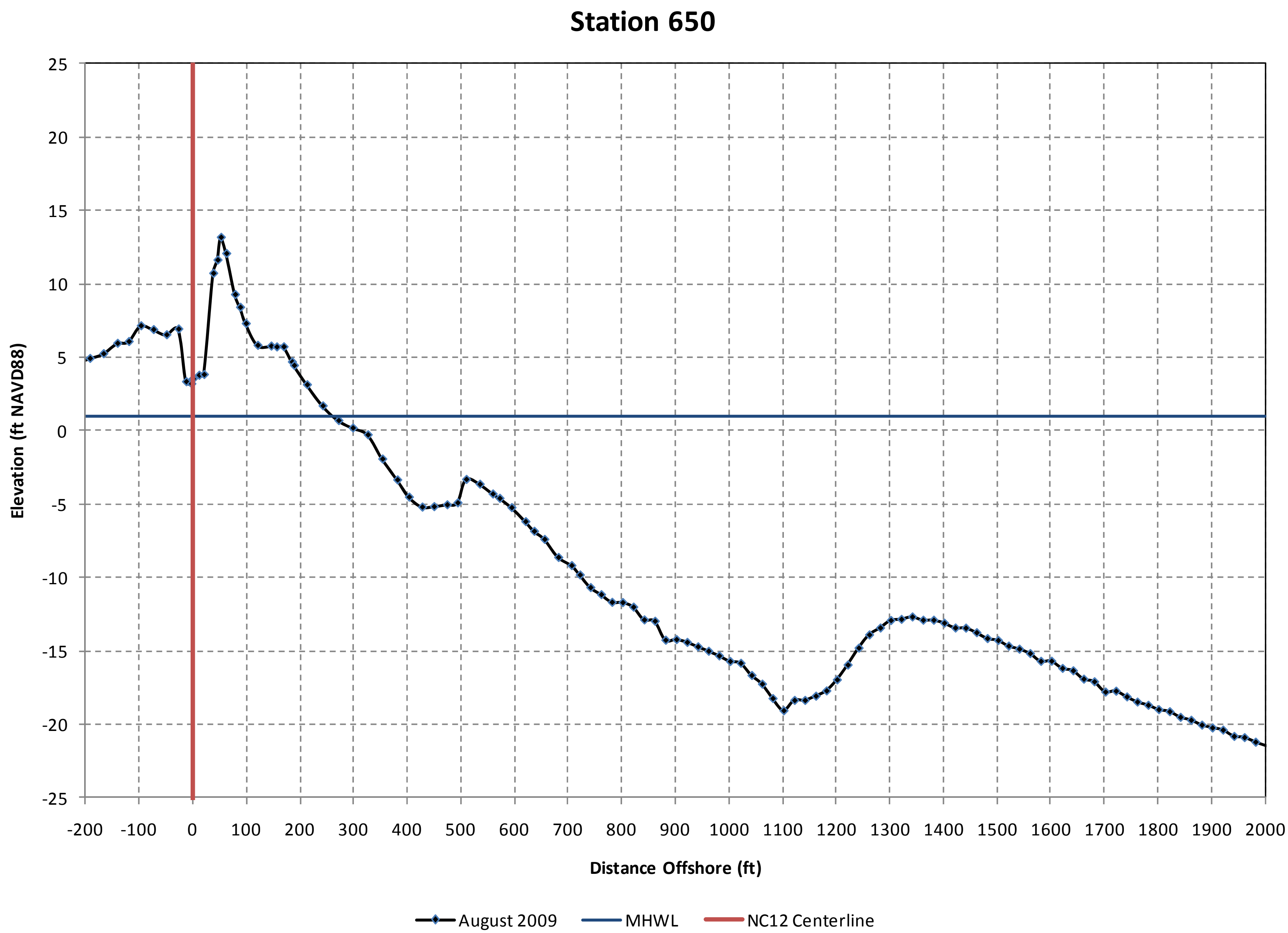
Station 565
Elevation (ft NAVD88)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Distance Offshore (ft)
August 2009
MHWL
NC12 Centerline



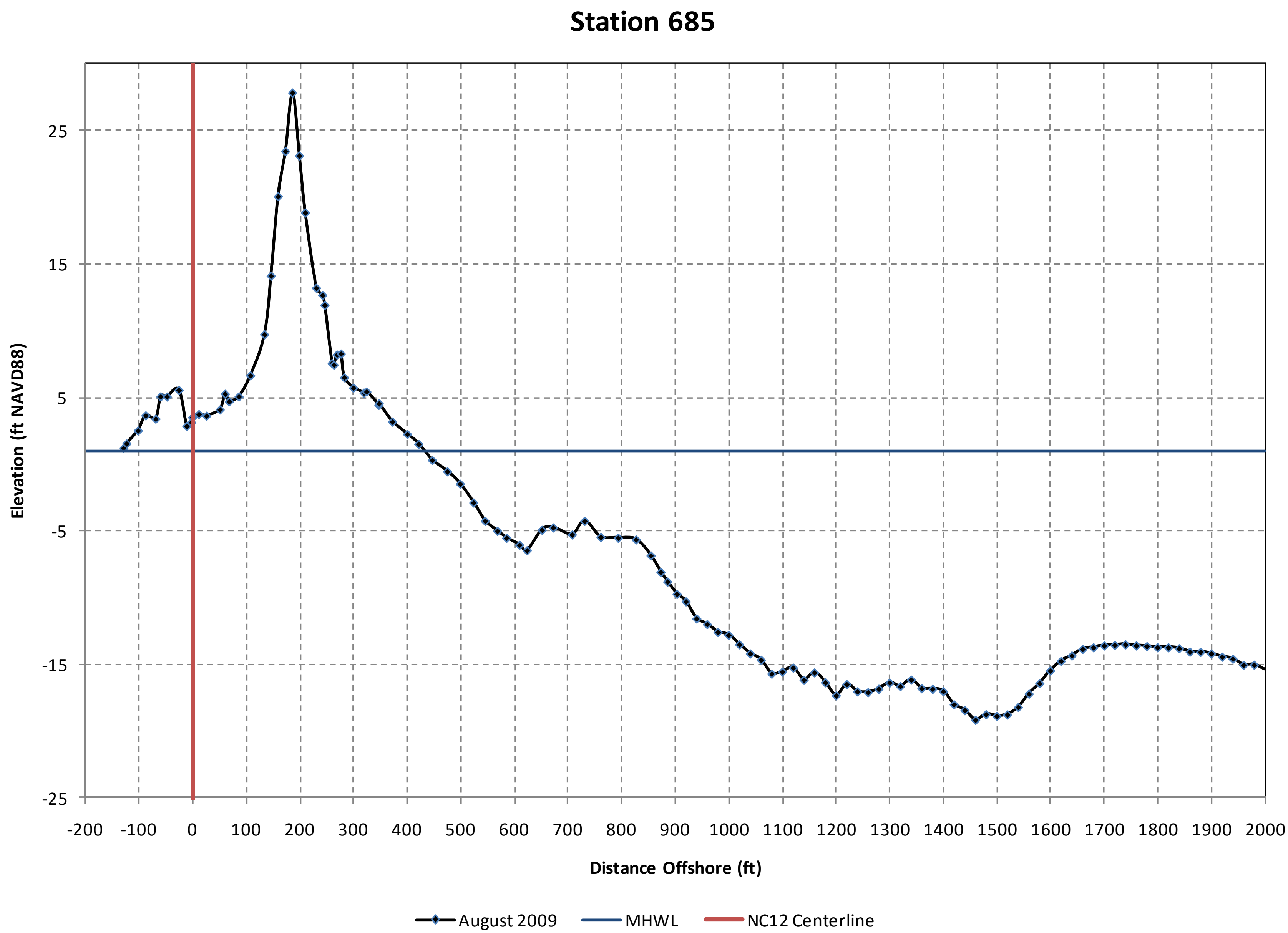
Station 585
Elevation (ft NAVD88)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Distance Offshore (ft)
August 2009
MHWL
NC12 Centerline


Station 605
Elevation (ft NAVD88)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Distance Offshore (ft)
August 2009
MHWL
NC12 Centerline


Station 620
25
20
15
10
5
0
-5
-10
-15
-20
-25
Elevation (ft NAVD88)
-200
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Distance Offshore (ft)
August 2009
MHWL
NC12 Centerline



Station 650
Elevation (ft NAVD88)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Distance Offshore (ft)
August 2009
MHWL
NC12 Centerline


Station 685
Elevation (ft NAVD88)
25
15
5
-5
-15
-25
-200
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Distance Offshore (ft)
August 2009
MHWL
NC12 Centerline

APPENDIX B – SBEACH MODEL INPUT PARAMETERS

Table B-1. Tropical Storms for SBEACH Analysis

Storm Name	HURDAT Storm #	Date	SBEACH Duration (hr)	Peak Storm Surge (ft NAVD)	Peak Wave Height (ft)
No Name	76	9/27/1893	96	1.78	*19.2*
No Name	112	8/3/1899	96	1.15	28.5
No Name	194	10/9/1910	72	4.84	17.2
No Name	292	9/6/1928	96	1.16	19.2
No Name	299	8/31/1930	96	*1.19*	19.2
No Name	332	9/8/1933	72	6.13	37.1
No Name	353	8/29/1935	72	2.41	17.7
No Name	386	9/10/1938	72	1.71	17.7
Great Atlantic	436	9/9/1944	72	3.80	37.1
Hurricane Barbara	520	8/11/1953	72	2.00	19.2
Hurricane Florence	526	9/23/1953	96	1.16	10.6
Hurricane Hazel	541	10/5/1954	96	2.16	21.9
Hurricane Connie Hurricane Diane Combined Storms	545 546	8/3/1955 8/7/1955	72 96 168	4.70	17.2
Hurricane Ione	552	9/18/1955	72	5.82	37.1
Hurricane Donna	597	8/29/1960	72	4.34	17.2
Hurricane Alma	611	8/26/1962	72	1.44	14.7
Hurricane Isbell	635	10/8/1964	72	1.44	19.7
Hurricane Gladys	669	10/13/1968	96	1.31	10.6
Tropical Storm Doria	702	8/20/1971	72	2.09	20.3
Hurricane Agnes	712	6/14/1972	96	1.67	19.2
Hurricane Dennis	797	8/7/1981	72	1.10	19.2
Subtropical Storm #1	807	6/18/1982	72	1.61	19.7
Hurricane Gloria	835	9/16/1985	72	5.77	37.1
Hurricane Emily	909	8/22/1993	96	2.03	28.5
Hurricane Allison	920	6/3/1995	72	1.06	14.1
Hurricane Bertha	925	7/5/1996	216	1.78	17.7
Hurricane Felix	940	8/23/1996	72	2.05	20.3
Hurricane Fran	944	10/4/1996	96	2.34	21.9
Tropical Storm Josephine	948	8/19/1998	72	2.08	17.7
Hurricane Bonnie	961	8/19/1998	120	1.75	17.7
Hurricane Earl	964	8/31/1998	72	1.45	14.7
Hurricane Dennis Hurricane Floyd Combined Storms	977 979	8/24/1999 9/7/1999	192 96 288	2.48	21.9
Hurricane Irene	982	10/12/1999	72	2.48	21.9
Hurricane Isabel	1000	9/18/2003	145	5.00	40.0

Table B-2. Extratropical Storms for SBEACH Analysis

Storm Date	Storm Class	Maximum Storm Surge Elevation (ft NAVD)	Maximum Significant Wave Height (ft)	SBEACH Duration (hr)	SBEACH Duration (days)
11/30/1986	V	1.75	23.6	102	4.25
2/17/1979	IV	1.79	20.3	216	9.00
10/10/1983	IV	0.96	10.8	102	4.25
2/15/1987	III	1.23	17.7	108	4.50
11/12/1981	III	1.39	13.8	96	4.00
3/9/1989	III	1.24	10.5	132	5.50
12/12/1983	III	0.99	10.5	228	9.50
11/8/1991	III	1.80	11.2	120	5.00
1/23/1992	III	1.24	13.5	78	3.25
2/12/1985	II	2.00	13.1	102	4.25
3/22/1989	II	1.24	9.8	72	3.00
12/29/1991	II	1.01	10.5	120	5.00
12/17/1982	II	1.51	9.2	78	3.25
10/10/1982	I	1.18	8.5	48	2.00
1/6/1980	I	1.52	8.2	147	6.125
12/12/1982	I	1.40	7.9	72	3.00
2/25/1986	I	1.01	7.2	84	3.50
1/4/1989	I	1.00	8.2	60	2.50

SBEACH input parameters

- Transport Rate Coefficient (m^4/N) = 1.75-e06
- Overwash transport parameter = 0.005
- Coefficient for slope-dependent term (m^2/N) = 0.002
- Transport rate decay coefficient multiplier = 0.5
- Water temperature in Degrees C = 20

Grain Size Distribution

Profile 430 = 0.29 mm
Profile 475 = 0.28 mm
Profile 505 = 0.28 mm
Profile 540 = 0.27 mm
Profile 565 = 0.27 mm
Profile 585 = 0.27 mm
Profile 605 = 0.27 mm
Profile 620 = 0.25 mm
Profile 650 = 0.24 mm
Profile 685 = 0.22 mm