5.0 ENVIRONMENTAL CONSEQUENCES

5.1 Alternatives Eliminated from Further Consideration

In addition to the six alternatives evaluated in this document, the USACE and PRT developed several alternatives that were eliminated from further consideration based on the results of modeling analyses. These eliminated alternatives included long groin construction with nourishment, long groin construction without nourishment, short groin construction with nourishment and inlet channel relocation, short groin construction without nourishment, and Eastern Channel dredging. The Eastern Channel dredging alternative is not the same as the recently constructed Lockwoods Folly River Habitat Restoration: Phase I Eastern Channel project completed in spring 2015 (Figure 5.1). The modeling results for these alternatives are described in detail in the East End Shore Protection Project Engineering and Modeling Report by ATM (ATM 2013, Appendix F).

The two long groin alternatives were eliminated based on model results showing significant downdrift (sediment transport) effects on the Holden Beach shoreline to the east of the groin structure (between the groin and LFI). Although the long groin under both alternatives effectively trapped sand to the west of the structure, adverse downdrift effects on the shoreline to the east were relatively high in comparison to the short and intermediate groin alternatives. Disproportionate downdrift erosional effects under the long groin alternatives were attributable to rapid westward migration of the inlet ebb channel and associated increases in current velocities along the groin structure. Associated shoreline erosion along the eastern margin of the groin resulted in projected annual downdrift impacts of approximately 32,000 cy/yr under both long groin alternatives.

Elimination of the short groin with nourishment and inlet channel relocation alternative was based on model results showing significant effects on inlet processes of erosion and accretion and an associated large increase in net sediment loss along the East End of Holden Beach. The projected effects are related to the expanded depth and width of the relocated outer inlet channel which substantially increase the inlet tidal prism. As a result, the inlet throat ebb channel is highly unstable throughout the four-year simulation period. The principal ebb channel response is one of westward migration and associated increases in erosion along the inlet shoreline of Holden Beach. Westward migration of the ebb channel also affects shoal attachment along the inlet shoulder of Holden Beach, resulting in additional relative sediment loss along the east end beach.

Elimination of the short groin without nourishment alternative was based on a projected substantial increase in erosion along the East End inlet shoulder.

.

Figure 5.1. Lockwoods Folly River Habitat Restoration Project, Phase I – Eastern Channel

The Eastern Channel dredging alternative was eliminated based on model results indicating no significant mitigative effects on East End shoreline erosion. The relocated Eastern Channel maintains its depth and shifts the main inlet channel more towards the center of LFI. Furthermore, the modeling results show a northward shift in the AIWW towards the mouth of the newly dredged Eastern Channel at the northwestern corner of Sheep Island. However, the Eastern Channel modeling results do not show any significant effects on the adjacent shorelines of Holden Beach or Oak Island.

Additional sand borrow sites were also evaluated and eliminated from further consideration: two AIWW spoil islands (Monks Island and Sheep Island) and three upland sources (Turkey Trap Road, Smith, and Tripp sites). The AIWW spoil islands contain a mix of beach-compatible and non-compatible sediment which would be costly to separate (ATM 2013). Therefore, these islands are not included as potential borrow sites in this document. The upland sources were eliminated based on concerns related to frequent truck hauls and potential road impact/maintenance issues as well as limited volumetric availability and variability in sand color. However, the Town does value these upland sites as an emergency back-up source of sand. These sources have been used previously after major storms when sand is needed quickly for dune and beach berm repair (Personal communication, Fran Way, ATM, Holden Beach Engineer of Record, March 2015).

5.2 Impact Analysis Methodology

This section evaluates the potential environmental consequences (hereinafter referred to synonymously as effects and impacts) of the six alternatives according to the CEQ regulations for implementing the NEPA (40 CFR 1500 *et. seq.*). The analysis of each alternative considers the direct, indirect, and cumulative effects on environmental resources within the Permit Area

As defined by CEQ regulations, direct impacts are those occurring at the same time and place as the proposed action while indirect impacts are those occurring later in time or at a greater distance from the proposed action. Cumulative impacts are those caused by the effects of the proposed action when added to other separate past, present, and reasonably foreseeable future actions regardless of the agency or person that undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. The projected direct, indirect, and cumulative impacts of the five action alternatives (Alternatives 2, 3, 4, 5, and 6) are evaluated against the projected impacts of the No-Action alternative (Alternative 1) (Table 5.1). The No-Action alternative, as defined in this EIS, represents the continuation of East End Beneficial Use Projects and, thus, would include beach nourishment and associated dredging activities similar to those that are currently being implemented by the Town and the USACE.

Table 5.1. Project alternatives.

Alternative #1	No Action (Status Quo)
Alternative #2	Abandon and Retreat
Alternative #3	Beach Nourishment
Alternative #4	Inlet Management and Beach Nourishment
Alternative #5	Short Terminal Groin and Beach Nourishment
Alternative #6	Intermediate Terminal Groin and Beach Nourishment

5.2.1 Direct and Indirect Impact Analysis

Direct impacts are defined in this EIS as those occurring during the active processes of beach fill placement, dredging, and/or groin construction and within the active project areas associated with these activities. In contrast, indirect impacts are those that are expected to occur after the completion of project activities and/or at a location away from the active project areas. Direct and indirect impacts were projected through quantitative and qualitative methods of analysis. Quantitative methods consisting of a geographic information system (GIS) and numerical modeling analyses were used primarily to determine direct and indirect impacts on the physical environment. Direct impacts on physical habitats were quantified through GIS analysis by superimposing the beach fill, dredging, and groin footprints of disturbance on the baseline (existing condition) map of habitats. Indirect impacts on physical coastal processes, shorelines, and habitats were quantified via numerical modeling analyses. Direct and indirect impacts on biological resources and public interest factors, which in most cases do not lend themselves to numerical measurements, were primarily assessed qualitatively by reviewing scientific literature, communicating with state and federal natural resource agencies via phone calls and email correspondence, and considering the quantitative physical impact projections.

Numerical Modeling

The Coastal Modeling System (CMS) developed by the USACE Coastal Inlets Research Program (CIRP) was used to predict the long-term effects of the alternatives on coastal processes and morphology within the Permit Area. The CMS model simulates flow, sediment transport, morphological changes in response to local forcing conditions (e.g., waves, wind, and tides), and physical environmental modifications associated with beach nourishment, dredging, and other coastal engineering projects. The model simulations constitute the primary basis for evaluating the relative effects of the alternatives on coastal processes, shorelines, and physical habitats. The model-predicted shoreline changes under Alternative 2 (Abandon and Retreat) were used as the standard of comparison or "control" for purposes of evaluating the model-predicted changes under the remaining five alternatives. Whereas the modeling results for Alternatives 1, 3, 4, 5, and 6 reflect the influence of various shoreline management activities (i.e., beach filling, dredging/inlet management, groin construction); the modeling results for Alternative 2 represent the predicted shoreline response to forcing conditions alone (e.g., waves, tides, ocean currents, storms). By comparing the projected morphological changes under the shoreline management alternatives to those of Alternative 2; the effects of beach filling, dredging, and groin construction can be distinguished from the effects of natural coastal processes. Accordingly, the impact analysis sections refer to the model-predicted changes under Alternatives 1, 3, 4, 5, and 6 as “changes relative to Alternative 2” or simply as “relative changes.”

It should be noted that the modeling results for Alternatives 1 (No Action) and 3 (nourishment only) reflect identical beach nourishment regimes. Although Alternative 3 incorporates additional supplemental borrow sites; the beach fill footprint, placement volumes, and nourishment interval would be the same as those associated with Alternative 1. Consequently, the model-predicted shoreline changes under the two alternatives, as shown in Table 5.2 and Figure 5.2, are also the same.

Model-projected changes in bathymetric contours (isobaths) and sediment volumes were used to quantify shoreline and habitat changes under the alternatives. For modeling purposes, the shoreline was defined as the area landward of the 0-m (NAVD) isobath which approximates Mean Sea Level (MSL). The relative effects of the alternatives on shoreline width were quantified by comparing projected changes in the 0-m isobath over the four-year modeling simulations. Physical habitat changes were quantified by superimposing model-projected MHW/MLW isobaths on the baseline habitat map. Compartmentalized sediment volume projections were used to quantify shoreline change and beach fill performance in terms of volumetric sand losses and gains. Although the modeling results are presented as quantitative numerical projections, these estimates must be considered within the context of the model limitations. It is not possible to accurately predict all of the complex environmental variables that influence changes in coastal morphology. In fact, some anthropogenic activities, such as AIWW navigation dredging, were purposely excluded from the modeling runs to minimize the potential for masking of project-induced changes. Consequently, the model-projected changes should not be interpreted as a precise estimate of future conditions in the Permit Area. Rather than trying to incorporate all of the variables, which would severely limit the ability to detect project-induced effects, the model emphasizes a subset of environmental parameters that are deemed most critical to morphological change in barrier island/inlet systems.

5.2.2 Cumulative Impact Analysis

The analysis of cumulative effects considers the impacts of each alternative in combination with the impacts of separate federal and non-federal beach management activities, borrow site operations, and navigation dredging projects that are anticipated to occur in the vicinity of the Permit Area. Therefore, the cumulative impacts were evaluated from additional management activities of Holden Beach and Oak Island, including activities associated with the Brunswick County Beaches (BCB) Coastal Storm Damage Reduction Project (BCB Project), Holden Beach Central Reach Project, the Lockwoods Folly River Habitat Restoration Project, Phase I – Eastern Channel, and AIWW and inlet navigation projects.

Table 5.2. Holden Beach and Oak Island shore protection projects.

Length/Volume/ Interval	Alt 3 East End Holden Beach	Brunswick County Beaches Coastal Storm Damage Reduction			Holden Beach Central Reach	Lockwoods Folly River Habitat Restoration West End Oak Island
		Holden Beach	Oak Island[1]	Oak Island Caswell Beach		
Segment Length (mile)	0.7	4.5	3.8	2.9	4.1	0.83
Initial Construction Volume (mcy) [2]	0.1	4.5	3.0	2.0	1.3	0.23
Renourishment Volume (mcy) [2]	0.1	1.7	1.8	1.8	>5.0	0.18
Renourishment Interval (yrs)	2	5	6	8	7-10	N/A

[1] West end of Oak Island

[2] Volume is shown as million cubic yards (mcy)

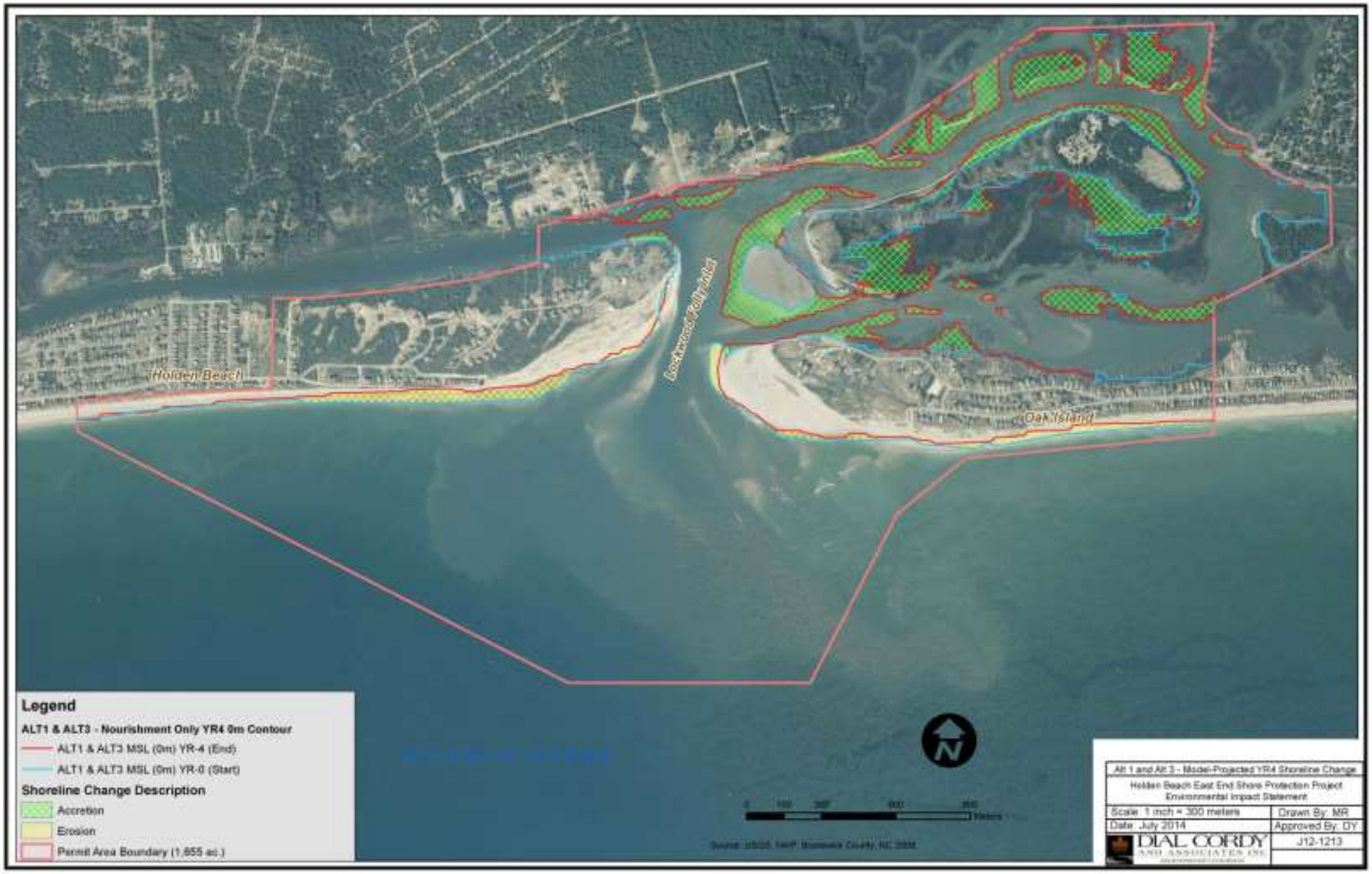

Figure 5.2. Alternative 1 – Model-Projected Year 4 Shoreline Change

The BCB Project encompasses nourishment projects along central Holden Beach (4.5 miles), central Oak Island (3.8 miles) and Caswell Beach on eastern Oak Island (2.9 miles) (Table 5.2). Initial construction of these three BCB segments was preliminarily planned to occur over four consecutive winter seasons beginning in 2020 with subsequent renourishment events following at intervals of approximately five, six, and eight years (Table 5.2). Based on this preliminary BCB sequence, East End Holden Beach nourishment events under the various alternatives could potentially coincide with two of the initial BCB events and one to two renourishment events per cycle. Note that as of March 2015, the BCB project status has been delayed indefinitely and therefore has not been included in the modeling analysis.

As indicated in a February 2015 USACE brief: *Corps' headquarters has determined that (1) no additional Federal expenditures are authorized for substantive GRR completion and (2) 100% non-Federal funds are to be used to complete the study pending execution of an agreement that also includes a non-Federal upfront repayment plan for the sponsors' proportionate share of sunk Federal costs which have been fully Federally funded to date. The Corps is working with the sponsors on a path forward on this project. In the meantime, no direct actions are currently being undertaken on the GRR.*

While the cumulative impact analyses in this DEIS account for the BCB project, initial project construction will not occur in 2020 as indicated in the BCB preliminary DEIS. Furthermore, the current impediments to the BCB project are likely to preclude implementation at any future date (Personal communication, David Hewett, Town of Holden Beach, February 2015).

The maximum combined linear extent of oceanfront beach impact during any given year would be 5.2 miles in the event of simultaneous nourishment of the 0.7-mile East End beach and the longest ~4.5-mile BCB segment (central Holden Beach). The Holden Beach Central Reach Project will include placement of up to 1,310,000 cy of beach-compatible sand along 4.1 miles of shoreline and will utilize an offshore borrow site as the sand source (Table 5.2). Based on historical erosion rates, this project is designed to last up to ten years. State and federal permits have been obtained and the project is currently planned to take place either during winter 2015/2016 or winter 2016/2017 (ATM 2014; Appendix N).

In addition to dredging by the Town at the Central Reach offshore borrow site, other anticipated offshore dredging actions include federal dredging operations at Frying Pan Shoals in conjunction with BCB nourishment projects and dredging by the Town of Bald Head Island at Jay Bird Shoals under their proposed long-term beach management plan. Anticipated separate federal navigation projects include maintenance dredging of the AIWW navigation channel behind Holden Beach and Oak Island, the LFI ebb channel, the Shallotte Inlet ebb channel and the Wilmington Harbor entrance channel. Phase 1 of the Lockwoods Folly River Habitat Restoration Project (Eastern Channel) included the dredging of a new channel within Eastern Channel, placement of compatible dredged material on the beach at the west end of Oak Island (Table 5.2), and placement of non-compatible material in the upland disposal area on Horse Island (DA-284A) (Figure 5.1). This navigation channel/nourishment project was completed during the spring of 2015 by the Town of Oak Island (Photos 5.1 and 5.2).

Photo 5.1. The dredge *Marion* working in Eastern Channel, spring 2015.

Photo 5.2. Sand placement activities on the west end of Oak Island, spring 2015.

The analysis of cumulative effects focuses on the potential for impact “crowding” at temporal and spatial scales. Temporally crowded cumulative effects can occur when the time required for resources to recover from a single impact event is greater than the time between repeated impact events. Temporally crowded effects are primarily associated with frequent repeated impacts on a specific resource in the same area; for example, repeated dredging impacts may occur at a specific borrow site where the interval between dredging events is shorter than the time required for the benthic community to recover. Spatially crowded cumulative effects can occur when the proximity of separate actions is such that their impacts overlap in space. Overlap does not necessarily mean that the physical impacts of the separate actions are contiguous. For instance, beach fill projects on separate barrier islands might affect foraging habitat for the same population of shorebirds.

5.3 Projected Effects of the Alternatives on Shoreline Change

This section describes the projected relative effects of the alternatives on oceanfront and inlet shorelines within the Permit Area. The CMS model was set to simulate sediment transport and morphological change in response to local forcing conditions (e.g., waves, wind, and tides) and the physical environmental modifications associated with the alternatives. The projected effects of the alternatives on shoreline change are based on model-predicted changes in bathymetry and topography. For modeling purposes, the shoreline was defined as the MSL (0-m NAVD88) bathymetric contour and beach width was defined as the cross-shore distance between the MSL contour and the toe of the primary dune. Projected losses and gains of intertidal beach and supratidal (dry) beach and dune habitats are based on model-predicted changes in the MHW and MLW contours. As previously described, the projected shoreline changes under Alternative 2 are used as a standard of comparison for identifying projected changes under Alternatives 1, 3, 4, 5, and 6. Under Alternative 2, the model-simulated shoreline changes represent the projected shoreline response to forcing conditions alone without any influence from beach management activities. The projected relative changes under Alternatives 1, 3, 4, 5, and 6 represent the difference between their projected changes and the projected changes under Alternative 2. For reference, the six alternatives are outlined in Table 5.1 above.

Holden Beach East End Oceanfront Shoreline

Under Alternative 2, the simulated East End ocean shoreline (i.e., MSL contour) is recessive throughout the four-year modeling period; by the end of Year 4, the average width of the East End beach has been reduced by ~80 ft (Figure 5.1). The projected extent of shoreline recession is consistent with the chronically high erosion rates that have been observed along the East End beach over the past several decades. The simulated MHW line follows a similar recessional pattern, migrating landward of the primary dune between Avenue B and the eastern terminus of McCray Street (~1,700 linear ft) by the end of Year 4 (Figure 5.3). The projected change in the MHW line corresponds to a net loss of ~5 ac of supratidal (dry beach/dune) habitat at the end of Year 4 (Table 5.3). The majority of the MLW line (west of Station 30+00) is similarly recessive; however, as a result of shoal attachment along the inlet shoulder, the MLW

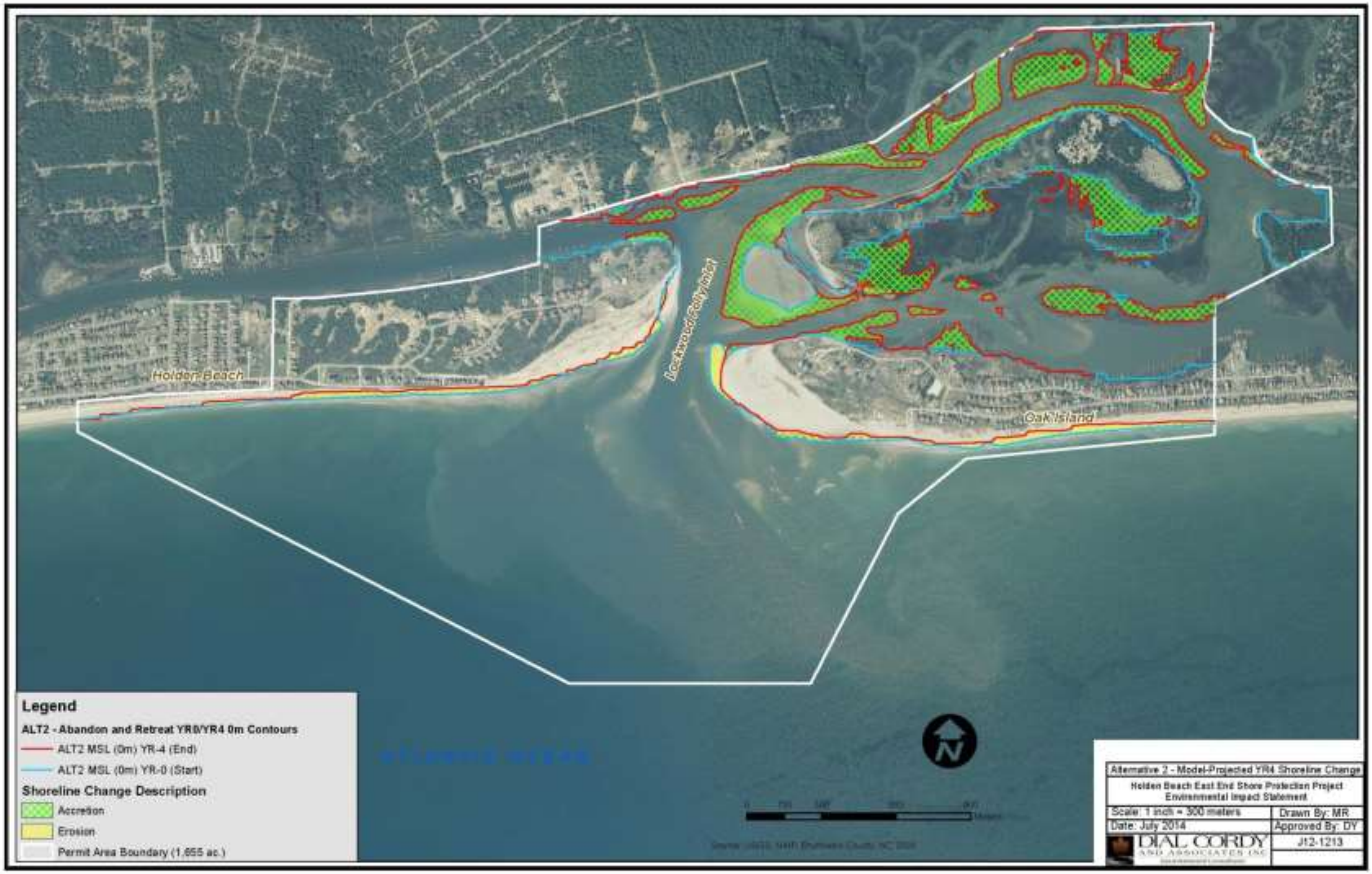

Figure 5.3. Alternative 2 – Model-Projected YR4 Shoreline Change

line to the east of Station 30+00 grows seaward (Figure 5.4). Shoal attachment adds ~3 ac of intertidal beach habitat along the easternmost reach; however, the loss of ~10 ac along the western reach results in a projected net loss of ~7 ac at the end of Year 4 (Table 5.3).

Under Alternatives 1, 3, 4, 5, and 6; the starting (Year 0) shoreline positions correspond to the seaward-extended shoreline positions immediately following beach nourishment (Figures 5.5 - 5.9). As a result of nourishment, the starting Year 0 average beach widths under the five Alternatives are 85 to 93 ft wider than the starting Year 0 average width under Alternative 2 (see Figure 5.10, and Table 5.4). During Year 1, all five with-project alternatives are effective at maintaining the initial post-nourishment relative increases in average beach width. At the end of Year 1, projected relative average beach widths under Alternatives 1, 3, 4, and 5 are minimally reduced to ~78 ft, ~78 ft, ~79 ft, and ~84 ft, respectively; whereas relative average beach width under Alternative 6 increases to ~98 ft. During Year 2, shoreline erosion accelerates rapidly under Alternatives 1, 3, 4, and 5; resulting in substantial reductions in relative average beach width. Under Alternatives 1 and 3, accelerating erosion reduces relative average beach width to ~57 ft at the end of Year 2. Alternatives 4 and 5 are similarly ineffective at maintaining a wider beach, with projected Year 2 ending relative beach widths of ~66 ft and ~64 ft, respectively. In contrast, relatively minor shoreline erosion under Alternative 6 reduces relative average beach width to ~93 ft, thus suggesting no net reduction average beach width through the end of Year 2. Shoreline erosion under Alternatives 1 and 3 continues to accelerate rapidly over the remaining two years of the model simulation, resulting in reduced relative average beach widths of ~19 ft at the end of Year 4. Alternatives 4 and 5 are similarly ineffective at maintaining a wider beach over the remaining two years, with projected Year 4 ending relative average beach widths of ~35 ft and ~36 ft, respectively. Under Alternative 6, shoreline erosion accelerates over the remaining two years of the model simulation, resulting in a reduced relative average beach width of ~63 ft at the end of Year 4.

The simulated MHW line responses under Alternatives 3, 4, 5, and 6 generally mirror the respective MSL shoreline responses. Relative to Alternative 2, all four alternatives maintain a seaward extended MHW line throughout the four-year model simulations. As a result, dry beach and dune habitat losses under the five with-project alternatives are reduced by ~1 to ~4 ac in relation to Alternative 2 (Table 5.3). The projected MLW line responses under Alternatives 3, 5, and 6 are similar in pattern to the projected MLW response under Alternative 2; with shoal attachment resulting in seaward growth of the MLW line along the easternmost ~1,300-ft reach, and MLW recession occurring along the remainder of the East End shoreline to the west. Alternatives 1, 3, 5, and 6 all maintain seaward extended MLW lines in relation to Alternative 2, thereby reducing Year 4 intertidal beach habitat losses by ~4 to ~5 ac (Table 5.3). Under Alternative 4, the MLW line is similarly recessive along the western reach; however, hydrodynamic effects attributable to the relocated outer channel prevent shoal attachment along the easternmost reach, resulting in additional erosion and further recession of the MLW line. As a result, Alternative 4 increases intertidal beach habitat loss by ~2 ac in relation to Alternative 2.

Figure 5.4. Holden Beach – Model-Projected YR4 MHW Lines for all Alternatives

Table 5.3. Year 4 model-projected net habitat change (acres).

Habitat	ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6
Holden Beach Ocean Dry Beach/Dune	-3.1	-5.0	-3.1	-3.4	-1.7	-0.7
Holden Beach Ocean Intertidal Beach	-2.7	-6.9	-2.7	-8.8	-2.1	-3.1
Oak Island Ocean Dry Beach/Dune	-2.5	-2.5	-2.5	-2.5	-2.4	-2.4
Oak Island Ocean Intertidal Beach	-9.6	-9.6	-9.6	-10.4	-8.6	-8.9
Holden Beach Inlet Dry Beach/Dune	-0.5	-0.8	-0.5	-1.8	-0.8	-0.1
Holden Beach Inlet Intertidal Beach	-1.8	-1.6	-1.8	-4.4	0.4	-2.1
Oak Island Inlet Dry Beach/Dune	-0.8	-1.0	-0.8	-1.0	-1.0	-0.9
Oak Island Inlet Intertidal Beach	-6.8	-7.3	-6.8	-6.8	-6.4	-6.9
Inlet Flood Shoal Supratidal	12.4	12.5	12.4	7.3	11.4	11.5
Inlet Flood Shoal Intertidal	0.2	1.5	0.2	7.7	2.6	3.3

Figure 5.5. Oak Island – Model-Projected YR4 MLW Lines for all Alternatives

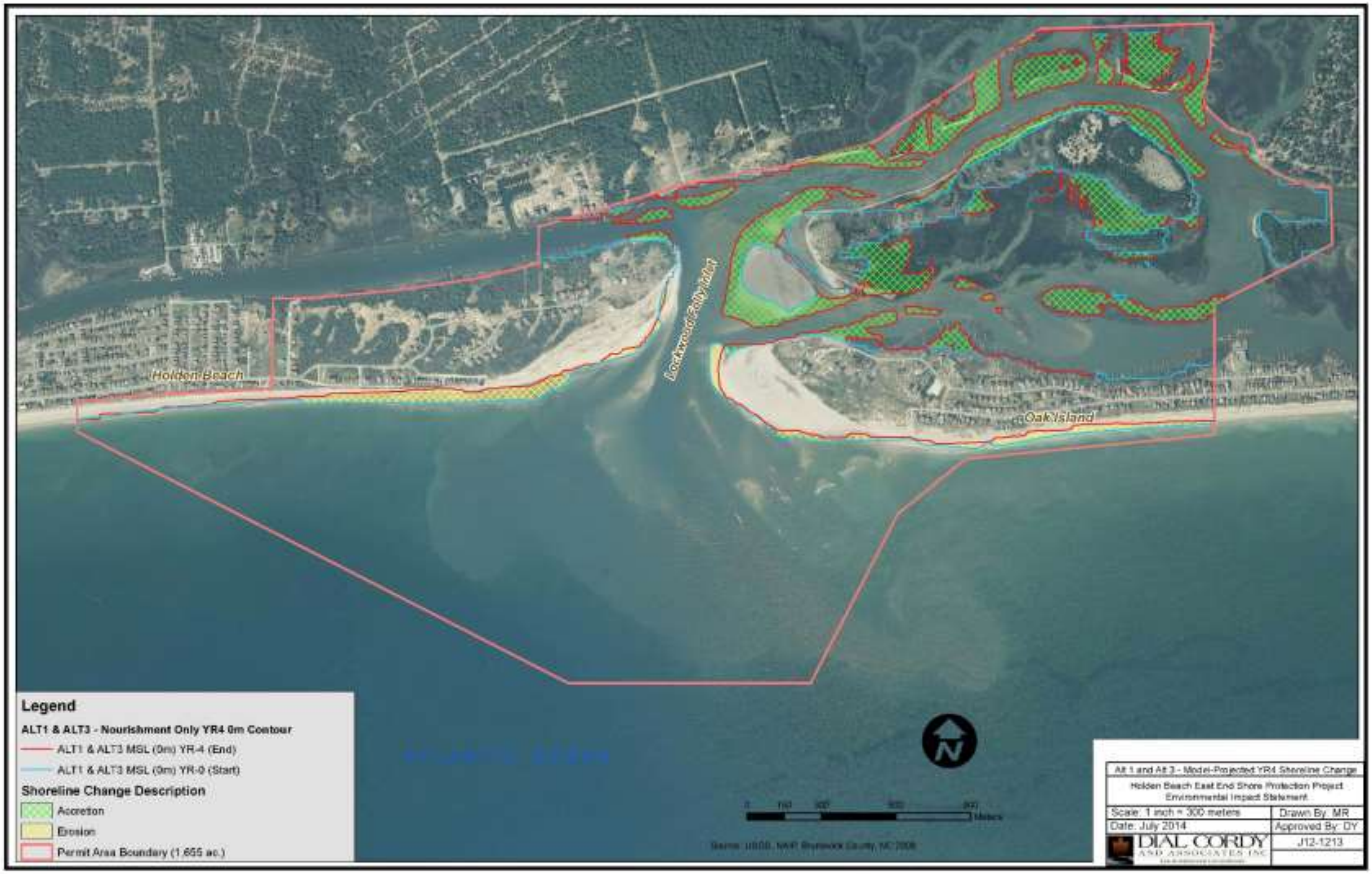

Figure 5.6. Alternative 1 and 3 – Model-Projected YR4 Shoreline Change

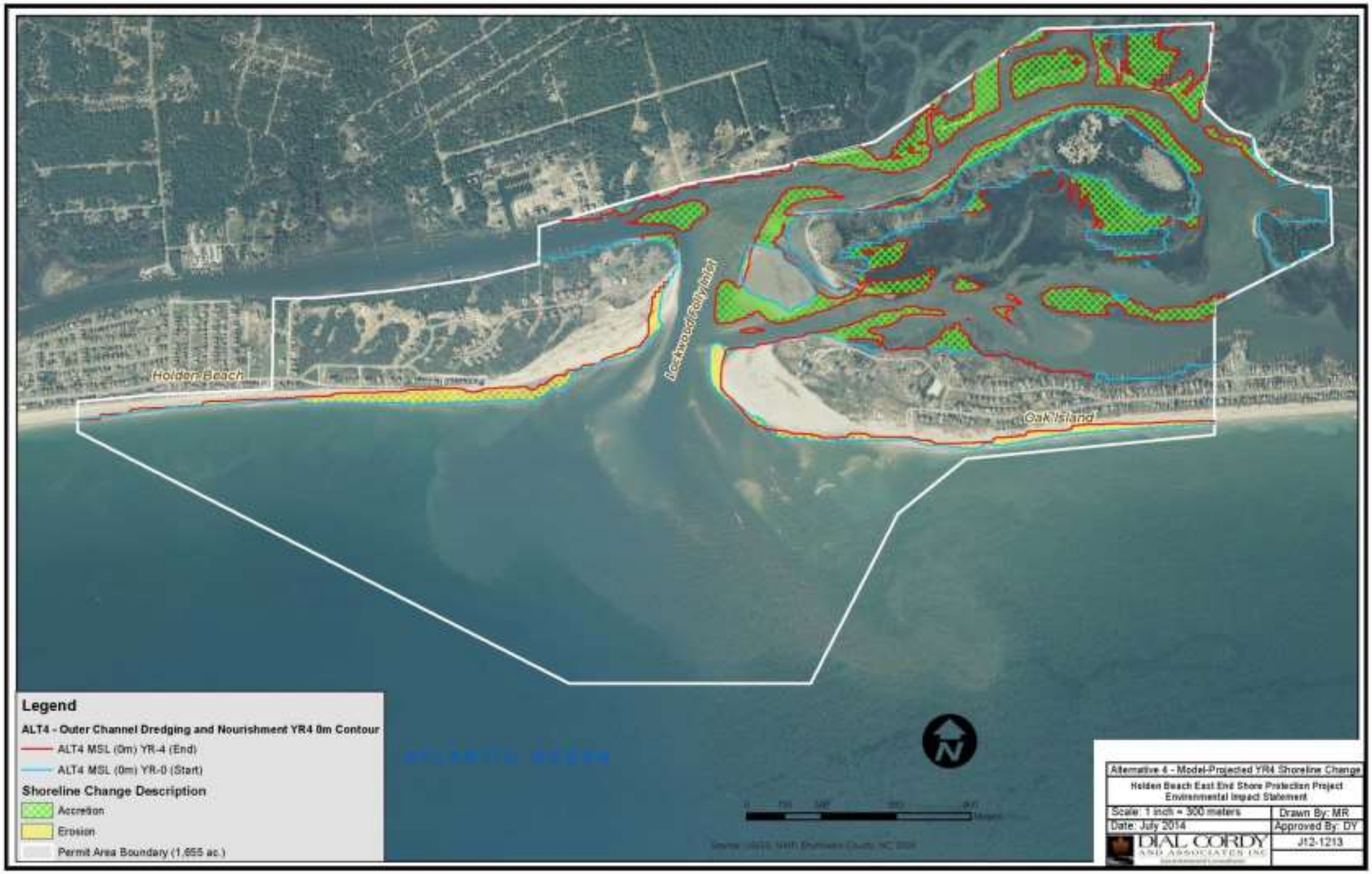

Figure 5.7. Alternative 4 – Model-Projected YR4 Shoreline Change

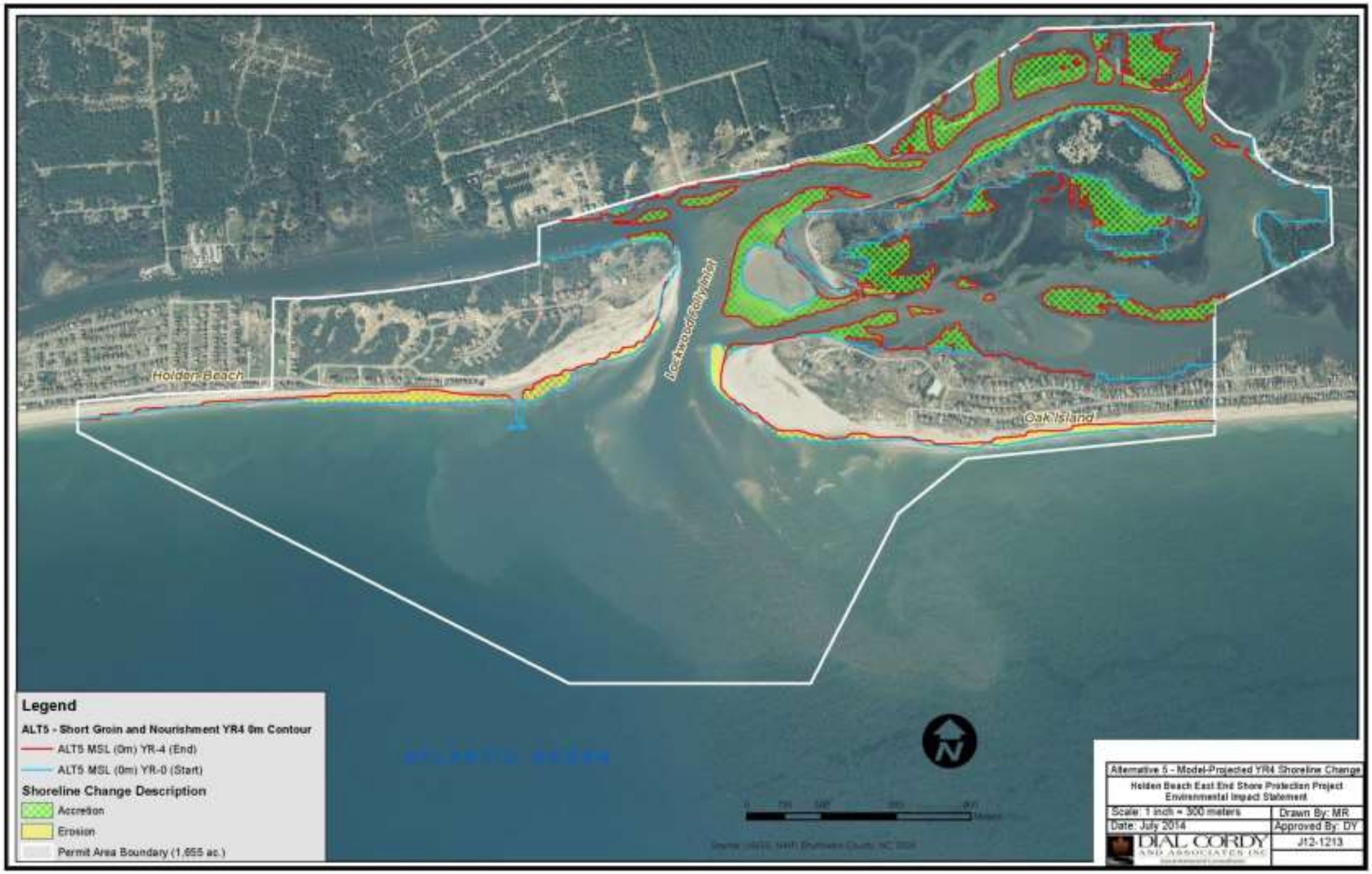

Figure 5.8. Alternative 5 – Model-Projected YR4 Shoreline Change

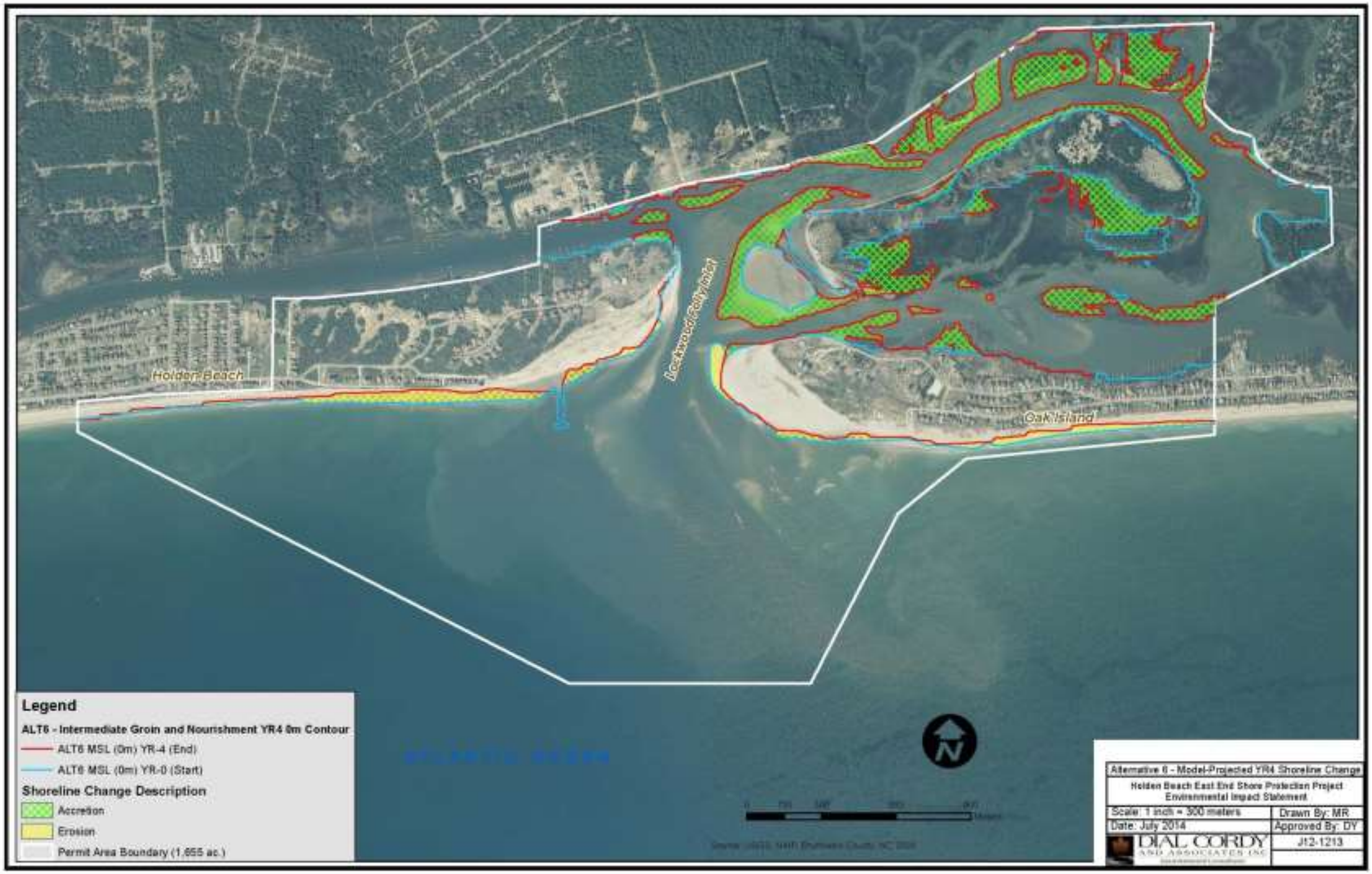

Figure 5.9. Alternative 6 – Model-Projected YR4 Shoreline Change

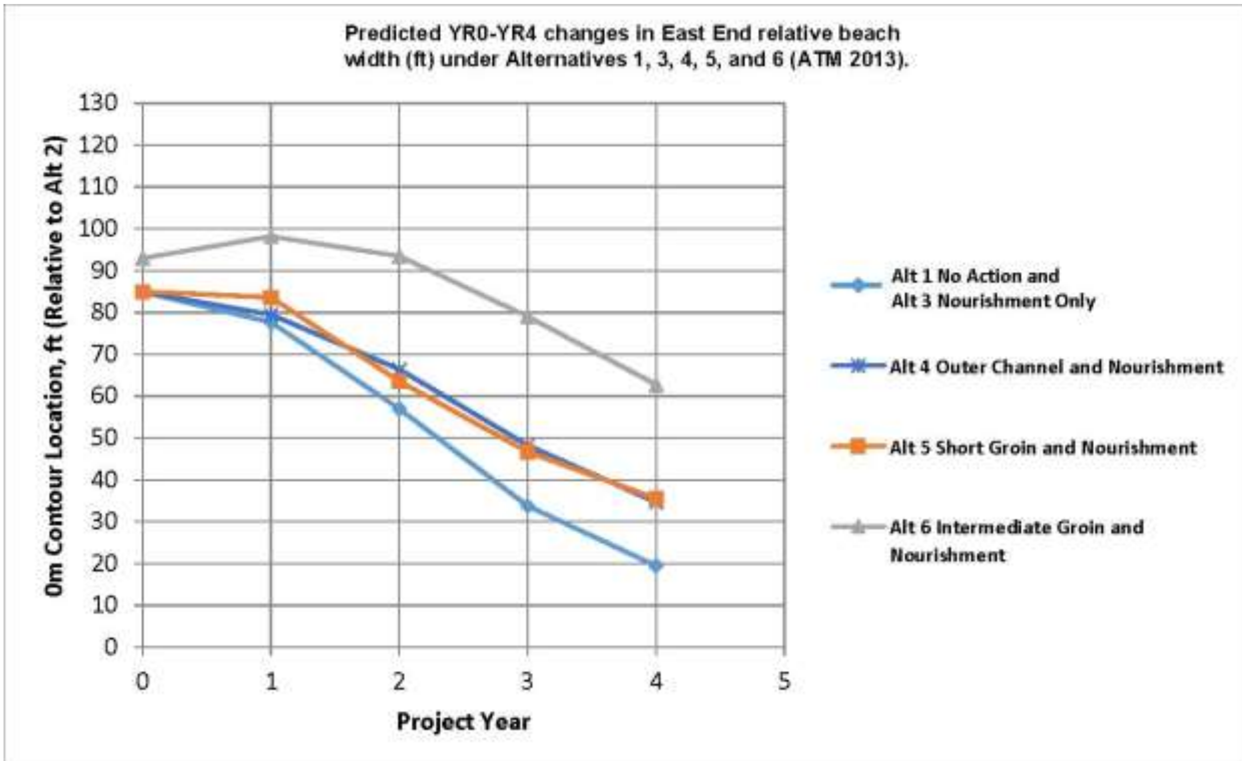

Figure 5.10. Predicted YR0-YR4 Changes in East End Relative Beach Width (ft) Under Alternatives 1, 3, 4, 5, and 6

Table 5.4. Model-projected East End relative beach widths (0 ft NAVD88).

Alternative	Year 0 (Start)	Year 1	Year 2	Year 3	Year 4
Alt 1: No Action	85	78	57	34	19
Alt 3: Nourishment Only	85	78	57	34	19
Alt 4: Nourishment and Inlet Management	85	79	66	48	35
Alt 5: Short Groin and Nourishment	85	84	64	47	36
Alt 6: Intermediate Groin and Nourishment	93	98	93	79	63

As described above, all five with-project alternatives maintain a consistently wider East End beach throughout the four-year modeling simulations in relation to Alternative 2 (Table 5.4, Figure 5.10). General patterns of East End shoreline change are similar under the five with-project alternatives, with most of the erosional losses occurring along the easternmost ~2,000-ft reach where historical erosion rates have been the highest. Among the five with-project alternatives, differences between the projected relative beach widths primarily reflect different sand retaining/trapping efficiencies along the easternmost ~2,000-ft shoreline reach. Under Alternatives 1 and 3 (No Action/nourishment only), beach fill is rapidly eroded from the easternmost reach at a rate consistent with observed losses following previous beneficial use nourishment projects. Alternative 4 (outer channel relocation) maintains a substantially wider beach in relation to Alternatives 1 and 3, thus indicating that outer channel relocation would provide enhanced shore protection benefits relative to No Action or nourishment only. However, outer channel relocation has substantial negative effects on inlet hydrodynamics that increase erosion of the beach below the MSL shoreline contour. Alternative 5 maintains a relative increase in average beach width similar to that of Alternative 4; however, Alternative 5 is more effective at maintaining the MHW and MLW lines and capturing sediment below the MSL shoreline contour. Under Alternative 6, the projected relative average beach width at the end of Year 4 is nearly double that of Alternative 5. The difference between the projected beach widths under Alternatives 5 (short groin) and 6 (intermediate groin) primarily reflect different sand trapping efficiencies along the ~600-ft reach separating the two groin structures. Although the short groin is effective at retaining beach fill and trapping new sand along the adjoining western ~2,900-ft reach, it is considerably less effective at maintaining beach width along the adjoining eastern reach. Under Alternative 6, the intermediate groin has a longer effective sand trapping zone (~3,500 ft) that encompasses an additional ~600 ft of shoreline to the east of the short groin.

Lockwoods Folly Inlet

Under Alternative 2, the simulated responses of the flood shoal and the inlet shorelines of Holden Beach and Oak Island (Figure 5.3) reflect heavily on the absence of navigation dredging in the model simulations. The flood shoal has a natural propensity for westward accretional growth that is normally kept in check by maintenance dredging of the LFI/LFIX navigation channels. However, in the absence of federal channel dredging (due to potential loss of future federal funding), the flood shoal response is one of westward expansion. Westward accretion results in substantial new intertidal shoal habitat formation, while concurrent sediment deposition on the existing flood shoal results in substantial intertidal-to-supratidal shoal habitat conversion. The overall effect of these projected changes is a net increase in intertidal shoal habitat of ~2 ac and a net increase in supratidal shoal habitat of approximately ~13 ac at the end of Year 4 (Table 5.3). The westward-expanding flood shoal pushes the inlet throat ebb channel westward, accelerating erosion along the Holden Beach inlet shoreline. Flood shoal expansion also pushes the mouth of the Eastern Channel slightly southward, redirecting flow towards the western tip of Oak Island.

Concurrently, the southern segment of the inlet throat ebb channel adopts a straighter north-south alignment, resulting in an eastward channel shift towards the Oak Island inlet shoreline. The majority of the Holden Beach inlet shoreline is recessional throughout the model simulation period, resulting in a projected loss of ~5 ac of intertidal inlet beach habitat at the end of Year 4. However, shoal attachment along the inlet shoulder adds ~3 ac of intertidal beach habitat along the southernmost ~700-ft reach of the Holden Beach inlet shoreline, resulting in a projected net loss of ~2 ac (Table 5.3). The Oak Island inlet shoreline is recessional throughout the model simulation period, resulting in a projected loss of ~10 ac of intertidal inlet beach habitat at the end of Year 4. In the case of both the Holden Beach and Oak Island inlet shorelines, model-predicted changes in the MHW lines and corresponding effects on dry inlet beach habitats are negligible under Alternative 2.

Projected flood shoal and inlet shoreline responses under Alternatives 1 and 3 (Figure 5.6) and Alternative 6 (Figure 5.9) are essentially the same as those projected under Alternative 2. Alternative 5 has a minor relative effect on the southernmost ~700-ft reach of the Holden Beach inlet shoreline that is related to the sand trapping effect of the short terminal groin. Under Alternative 5, the pattern of shoal attachment is shifted eastward (Figure 5.8), increasing accretion along the inlet shoreline and reducing the extent of projected intertidal inlet beach habitat loss by ~2 ac in relation to Alternative 2 (Table 5.3). In the case of Alternative 4 (Figure 5.7), the modeling predictions indicate substantial relative effects on inlet hydrodynamics. The projected effects are related to the expanded depth and width of the relocated outer inlet channel which substantially increase the inlet tidal prism. As a result, the inlet throat ebb channel is highly unstable throughout the four-year simulation period. The principal ebb channel response is one of - westward migration and associated increases in erosion along the inlet shoreline of Holden Beach. Westward migration of the ebb channel also affects shoal attachment along the inlet shoulder of Holden Beach. Similar to the other alternatives, the model predicts the formation of an emergent shoal along the inlet shoulder; however, westward migration of the expanded outer channel prevents immediate shoal attachment, as outer channel infilling initially impedes shoreward shoal migration. The channel eventually fills in and the shoal resumes its natural shoreward migration pattern; however, the shoal has not yet attached at the end of the four-year modeling run. The predicted inlet hydrodynamic changes also cause the LFIX ebb channel segment along the northwest corner of the flood shoal to widen, deepen, and dip southward; shifting the pattern of accretion along the flood shoal southward relative to Alternative 2. Westward channel migration under Alternative 4 also increases the extent of erosion along the remainder of the Holden Beach inlet shoreline to the north, further increasing intertidal habitat loss relative to Alternative 2. Overall, the quantity of intertidal inlet beach habitat on Holden Beach under Alternative 4 is reduced by ~3 ac relative to Alternative 2 (Table 5.3).

Oak Island West End Oceanfront Shoreline

Under Alternative 2 (abandon and retreat), the Oak Island west end oceanfront shoreline is recessional throughout the four-year model simulation (Figure 5.3). The MLW line follows a similar recessional pattern, resulting in the loss of ~10 ac of intertidal beach habitat at the end of

Year 4 (Figure 5.11). The model results show a relatively minor and irregular landward shift in the MHW line which results in the loss of ~3 ac of dry beach habitat at the end of Year 4 (Figure 5.12, Table 5.3). Under Alternatives 1, 3, 4, 5, and 6, projected shoreline changes (Figures 5.6 – 5.9) and corresponding habitat effects (Table 5.3) are essentially the same as those projected under Alternative 2; thus indicating that the with-project alternatives would not have any significant project-related effects on the Oak Island west end ocean shoreline. Under Alternative 4, the model predicts a slight increase in erosion along the extreme western reach of the shoreline which is related to the hydrodynamic effects of outer channel relocation. As a result, Alternative 4 increases intertidal beach habitat loss by ~1 ac in relation to Alternative 2 (Table 5.3). Minor reductions in erosion under Alternatives 5 and 6 slightly reduce intertidal beach habitat loss by ~1 ac in relation to Alternative 2.

5.4 Projected Environmental Impacts of the Alternatives

General environmental consequences are summarized for each alternative below. An alternatives matrix is provided to depict these general findings (refer to Appendix O). Note that more detailed information is provided in the following subsections for specific resource categories located within and adjacent to the identified project area. In addition, economic benefits and costs are evaluated in further detail in the below discussion.

5.4.1 Alternative 1: No Action

Under the No-Action alternative, the Town would continue to rely solely on the USACE's beneficial use projects for shore protection of the East End of Holden Beach. For impact analyses, the East End Beneficial Use Projects under Alternative 1 are assumed to continue at an average frequency of every two years. Beach fill placement volumes would vary according to channel shoaling rates and the availability of local funding for inclusion of the 400-ft bend widener. For impact analysis purposes, projects using only material from the main channel would presumably place ~100,000 cy of material on the East End whereas projects using sand from both the main channel and the bend widener would place ~150,000 cy of material. Dredging and beach fill placement methods would be similar to those associated with current operations. Sand would be extracted from the LFIX/bend widener channel by cutterhead pipeline dredges and pumped directly to the east end beach via submerged pipelines. Temporary containment berms would be constructed at the beach discharge points to allow for dewatering and suspended sediment redeposition, and bulldozers operating on the beach would distribute and grade the dewatered fill according to the beach profile design specifications. Front-end loaders would be used to transport and position emergent sections of the discharge pipeline on the beach. As nourishment activities progress, the emergent pipeline would be extended along the beach through the addition of extra sections of pipe.

Figure 5.11. Oak Island – Model-Projected YR4 MHW Lines

Figure 5.12. Oak Island – Model-Projected YR4 MLW Lines

5.4.1.1 Marine Benthic Communities

<u>Soft Bottom</u>

Dredging

Direct Impacts

Under Alternative 1, project-related dredging operations would involve federal maintenance dredging of the main LFIX navigation channel every two years. As described above, it is anticipated that some dredging events would also include the 400-ft-wide bend widener depending on the availability of funding from the Town. Assuming inclusion of the 400-ft-wide bend widener, individual dredging events would directly impact ~20 ac of soft bottom habitat. Sand extraction would remove the majority of the associated soft bottom benthic invertebrate infauna and epifauna, resulting in an initial sharp reduction in community levels of abundance, diversity, and biomass within the dredged channels. Soft bottom habitats in dredged channels experience frequent disturbance from waves and currents; therefore, the associated benthic communities are typically dominated by opportunistic taxa that recover rapidly from high-frequency disturbances (Wilber and Clarke 2007). Stickney (1974) reported minor, short-term impacts on benthic communities in a dredged AIWW channel in GA with full recovery occurring in one to two months. In a subsequent study, Stickney and Perlmutter (1975) reported complete removal of the benthic community in a dredged GA AIWW channel; however, full recovery was observed in only two months. Van Dolah et al. (1979) observed minor, isolated effects on the benthic community in a dredged estuarine channel in SC; recovery occurred within two months. In another SC study of benthic community response in a dredged AIWW channel, recovery occurred within six months (Van Dolah et al. 1984). In both the GA and SC channels, the rapid rates of recovery were attributed in part to recolonization via slumping of adjacent undisturbed sediments into the dredged channel. Van Dolah et al. (1984) also attributed rapid recovery to infilling by sediments that were similar in composition to the extracted sediment and avoidance of spring benthic invertebrate recruitment periods. The LFIX channel is subject to rapid infilling by similar medium sand substrate as evidenced by its repeated use as a source of fill for the east end beach. In addition, the established environmental nourishment window (16 November – 30 April) would necessitate the completion of dredging operations prior to the onset of spring benthic invertebrate recruitment periods. Therefore, it is anticipated that benthic community recovery periods in the LFIX and bend widener channels would be within two to six months based on these previous studies.

Indirect Impacts

In addition to the direct impacts of dredging on benthic communities within the actively dredged channels, dredging operations may also have indirect impacts on these communities from increased sedimentation and deposition of fine sediments that are temporarily suspended during dredging operations and can be dispersed and redeposited outside of the active dredging footprint. These sediments may potentially impact adjacent soft bottom benthic communities through burial and/or adverse effects on the gill-breathing and filter-feeding functions of benthic organisms. The spatial extent of sediment dispersal is influenced by sediment composition, dredging methods, and hydrodynamic conditions (Wilber et al. 2005). Dredging-induced sediment dispersal is primarily associated with the suspension of fine silt/clay particles which have relatively slow settling velocities compared to sand and gravel which make up the coarse-grained sediment fraction and resettle rapidly in the immediate vicinity of the dredge before they can be transported offsite (Schroeder 2009).

Among dredge types, side-cast dredges and mechanical (clamshell/bucket) dredges are generally associated with relatively high rates of sediment suspension and dispersal compared to hydraulic hopper and cutterhead dredges (Clarke and Wilber 2000, LaSalle et al. 1991). Furthermore, hopper dredges are generally associated with higher rates of suspension and dispersal than cutterhead dredges primarily due to the surface discharge associated with overflow hopper dredging. In the case of cutterhead dredging, sediment suspension is generally confined to the near bottom water column in the immediate vicinity of the rotating cutterhead assembly (LaSalle et al. 1991). Field data collected during cutterhead navigation dredging projects has shown average sediment resuspension rates ranging from 0.003 to 0.135 percent of the fine silt/clay fraction and a maximum fine sediment resuspension rate of 0.51 percent (Hayes et al. 2000, Hayes and Wu 2001).

Under Alternative 1, dredging operations in the LFIX/bend widener channel would be conducted by cutterhead pipeline dredges. Sediments associated with this channel are composed of medium sand (mean grain size = 0.41 mm) with a very small (~6 percent) fine sediment fraction. In addition, there can be isolated pockets of clay. This usually only occurs if the dredge contractor unintentionally dredges too deep or outside of the permitted footprint (Personal communication, Fran Way, Holden Beach engineer, March 19, 2015). Therefore, it is anticipated that indirect, dredging-induced sediment dispersal and redeposition effects under Alternative 1 would be localized and minor.

Direct, dredging-induced loss of benthic invertebrates would constitute a temporary reduction in the availability of prey for predatory demersal fishes. Potential indirect prey-loss effects on demersal fishes could include reduced foraging efficiency within the dredging footprint and/or displacement to adjacent undisturbed soft bottom foraging habitats. A slight increase of fine sediments in the water column can reduce the ability of visually oriented demersal fishes to capture benthic prey (Manning et al. 2013). The potential for longer-term indirect prey-loss effects on demersal fishes at the community and/or population level is difficult to assess. However, based on the anticipated rapid rates of benthic community recovery and considering that dredging would impact only 20 ac out of the 900 total ac of soft bottom habitat within the Permit Area, it is anticipated that the indirect effects of prey loss on demersal fishes would be localized and short term.

Cumulative Impacts

The potential for temporally crowded cumulative effects on soft bottom communities under Alternative 1 would depend on the frequency of dredging on soft bottom communities within the same area. Specifically, effects would be considered likely if the intervals between repeated LFIX/bend widener dredging events were insufficient to allow for full recovery of benthic communities. Although the No-Action alternative includes only one LFIX dredging event every two years, interim federal maintenance dredging events would continue the current annual cycle of dredging (exclusive of the 400-ft bend widener). Additional separate actions affecting the LFIX and/or bend widener channels would not be anticipated during the 30-year project period. As described above, benthic communities associated with the dredged channels are expected to recover from dredging events in less than one year, and, therefore, based on the anticipated one-year interval between LFIX dredging events, temporally crowded cumulative impacts would not be expected under Alternative 1. The potential for spatially crowded cumulative impacts under Alternative 1 would depend on the proximity of separate dredging actions to the bend widener and the potential for overlapping effects on soft bottom communities. Dredging of other federal navigation channels, including segments of the AIWW behind Holden Beach and Oak Island and/or the LFI navigation channel, would likely coincide with project-related LFIX/bend widener dredging events. Combined losses of benthic invertebrate prey in the LFIX/bend widener channels and other dredged channels could potentially have cumulative effects on predatory demersal fishes. However, the combined area of temporary habitat/prey loss would constitute a small fraction of the available inlet/estuarine soft bottom habitat in the vicinity of Holden Beach and Oak Island, and any cumulative effects would be limited to the period of benthic community recovery. Therefore, it is anticipated that spatially crowded cumulative effects on soft bottom communities would be localized and short term.

Beach Fill Placement

Direct Impacts

Alternative 1 would continue the ongoing two-year cycle of East End nourishment via beneficial use of material from the LFIX channel and the 400-ft bend widener. Beach fill placement volumes would vary according to sediment volume availability in the LFIX channel and bend widener and the availability of local funding for inclusion of the 400-ft bend widener. It is anticipated that nourishment events using only material from the main LFIX channel would place ~100,000 cy on the East End beach whereas a combined LFIX/bend widener borrow site would provide ~150,000 cy of compatible material for the beach. Alternative 1 does not have a defined beach fill footprint; however, based on similar placement volumes under the action alternatives, a 100,000 cy nourishment event would directly impact ~8 ac of soft bottom habitat on the subtidal shoreface. Beach fill placement would cause mortality of associated benthic invertebrate infauna and epifauna by temporary burial under the deposited sand (Oliver et al. 1977, McCall 1977, Bolam et al. 2006). The addition of fill would extend the MLW seaward, converting some of the impacted subtidal habitat to intertidal beach habitat. Benthic communities associated with the remaining subtidal portion of the beach fill footprint would experience an initial sharp decline in abundance, diversity, and biomass but would be expected to recover relatively rapidly. The delivery of dredged sand to the beach would involve the placement of pipelines on the subtidal seafloor, resulting in additional direct impacts on soft bottom communities; however, it is anticipated that pipeline impacts would be negligible since the impacts would be confined primarily to a narrow strip of substrate underlying the pipelines, and the extent of physical habitat disturbance would be minimal once the pipelines are removed.

Shallow soft bottom habitats along the beach experience frequent wave and current disturbance, and consequently, the associated benthic assemblages are dominated by opportunistic taxa that recover rapidly from high-frequency disturbance (Wilber and Clarke 2007). According to Burlas et al. (2001), the responses of nearshore soft bottom benthic communities to a beach nourishment project in NJ were limited to short-term (≤6.5 months) reductions in abundance, biomass, and taxa richness. Rakocinski et al. (1996) also reported relatively rapid recovery (≤1 year) of nearshore benthic communities following a beach nourishment project in FL. The principal project-related factors that influence recovery rates include the composition of the beach fill sediments relative to those of the native beach and the timing of nourishment projects relative to spring benthic invertebrate larval recruitment periods (Wilber et al. 2009). Reported rates of recovery have been rapid when highly compatible beach fill sediments were used and spring larval recruitment periods were avoided. Conversely, longer recovery periods have been associated with the use of incompatible fill and/or the execution of nourishment projects during larval recruitment periods. The LFIX navigation channel has been a consistent source of compatible beach fill for many years, and the existing environmental nourishment window (16 November - 30 April) would avoid the peak benthic invertebrate recruitment periods in NC [May through September (Hackney et al. 1996, Diaz 1980, Reilly and Bellis 1978)]. Therefore, benthic communities would be expected to recover relatively rapidly from beach nourishment activities.

Indirect Impacts

In addition to the direct burial of benthic organisms in the beach fill footprint, beach fill placement may also indirectly impact soft bottom benthic communities via increased turbidity and siltation (Michel et al. 2013). Increased turbidity from resuspension of fine sediments during deposition and subsequent rehandling may reduce growth and have adverse effects on suspension feeders. Since dispersion and redeposition may occur outside the beach fill footprint, these potential impacts may occur in adjacent soft bottom benthic communities. Siltation arising from settlement of these fine particles may also induce mortality by smothering benthic organisms (Michel et al. 2013). The sediments associated with the LFIX channel are composed of medium sand (mean grain size = 0.41 mm) with a very small (~6 percent) fine sediment fraction; therefore, it is anticipated that sediment dispersal and redeposition would be confined to the immediate vicinity of the beach fill footprint. The direct removal of benthic invertebrates by sand placement would constitute a reduction in potential prey for soft bottom demersal fishes (e.g., flounders, rays, spots, and croakers). Potential indirect effects on demersal fishes may include reduced foraging efficiency within the beach fill footprint and/or displacement to adjacent undisturbed soft bottom foraging habitats. Alternative soft bottom foraging habitats cover vast areas of the nearshore ocean seafloor along Holden Beach and Oak Island relative to the anticipated habitat impact area (~8 ac), and rapid recolonization of the disturbed area by early successional benthic invertebrate taxa would provide substantial food resources within a relatively short period of time. Therefore, it is expected that any effects on demersal fishes would be negligible.

Cumulative Impacts

The potential for temporally crowded cumulative effects on nearshore soft bottom communities would depend on the frequency of repeated beach fill placement activities and their potential impacts on soft bottom communities within and adjacent to the footprint. Specifically, temporally crowded cumulative effects would be considered likely if the intervals between repeated nourishment events were insufficient to allow for full recovery of benthic communities. Based on the studies and project parameters described above, soft bottom communities within the beach fill footprint would be expected to fully recover during the two-year intervals between project-related nourishment events. Separate dredge and fill actions affecting the East End beach fill footprint during the 30-year project are not anticipated; therefore, temporally crowded cumulative effects on nearshore soft bottom communities would not be expected under Alternative 1.

The potential for spatially crowded cumulative impacts under Alternative 1 would depend on the proximity of separate beach fill actions to the east end beach and the potential for overlapping effects on nearshore soft bottom communities. Spatially separate nourishment projects that are expected to occur along Holden Beach and/or Oak Island during the 30-year project period include the Holden Beach Central Reach Project, the federal BCB Project, and the Lockwoods Folly River Habitat Restoration Project, Phase 1 – Eastern Channel. These projects are described in more detail in Section 5.3. This latter project involves dredging of the Eastern Channel and subsequent nourishment of the west end of Oak Island and occurred in the spring of 2015. The Central Reach Project will also be a one-time nourishment event and is currently scheduled for winter 2015/2016 or winter 2016/2017. The BCB project encompasses nourishment projects along central Holden Beach (4.5 miles), central Oak Island (3.8 miles), and eastern Oak Island/Caswell Beach (2.9 miles). Initial construction of the three BCB segments is anticipated to occur over four consecutive winter seasons beginning in 2020 with subsequent renourishment events following at intervals of approximately five, six, and eight years. East End nourishment events could potentially coincide with the Central Reach Project and/or subsequent BCB nourishment projects. Based on this preliminary BCB sequence, East end nourishment events could potentially coincide with two of the initial BCB events and one to two renourishment events per cycle. In the event of concurrent East End Holden Beach - Central Reach/BCB nourishment projects, East End nourishment would increase the total area of soft bottom habitat impact by only ~8 ac. The addition of ~8 ac of impact would not be expected to affect benthic infaunal recovery rates along either reach; therefore, spatially crowded cumulative impacts on soft bottom communities would not be expected under Alternative 1.

Hardbottom

Direct, Indirect and Cumulative Impacts

Exposed hardbottom features are associated with areas of thin sediment cover on the lower shoreface and adjacent inner continental shelf which are located well seaward of the beach fill footprint, dredging area, and pipeline placement areas. Therefore, Alternative 1 is not expected to have any direct, indirect, or cumulative impacts on hardbottom communities.

5.4.1.2 Water Column

Hydrodynamics

Direct, Indirect, and Cumulative Impacts

The LFIX/bend widener dredging regime under Alternative 1 would be similar to the ongoing dredging regime; therefore, no dredging-induced impacts on hydrodynamic conditions would be expected. Alternative 1 would continue the ongoing two-year cycle of East End nourishment. Beneficial Use East End Nourishment Projects have been ongoing for many years and have not resulted in adverse effects on hydrodynamic conditions. Therefore, no adverse effects on hydrodynamics would be expected under Alternative 1. Based on the absence of direct and indirect impacts, cumulative impacts on hydrodynamic conditions would not be expected.

Sediment Suspension and Turbidity

Dredging activities may indirectly impact pelagic organisms via temporary sediment suspension and associated increases in turbidity. Increased sedimentation and turbidity during the dredging process can potentially affect the behavior (e.g., feeding, predator avoidance, habitat selection) and physiological functions (e.g., photosynthesis, gill-breathing, filter-feeding) of pelagic marine organisms. The extent and duration of these impacts are influenced by sediment composition at the borrow site, the type of dredge employed and hydrodynamic conditions at the dredge site (Wilber et al. 2005). Prolonged sediment suspension and extensive turbidity plumes are primarily associated with the suspension of fine silt/clay particles that have relatively slow settling velocities whereas, sands and gravels, which make up the coarse-grained sediment fraction, resettle rapidly in the immediate vicinity of the dredge before they can be transported offsite (Schroeder 2009). In reporting the results of turbidity monitoring during navigation dredging in Delaware Bay, Miller et al. (2002) described the turbidity plume associated with overflow hopper dredging in coarse-grained (97 percent sand) sediments as being confined to the dredged channel footprint with suspended sediment concentrations returning to ambient levels within one hour of the passing of the dredge. Miller et al. (2002) also noted that observed turbidity levels remained within the range of pre-project ambient turbidities throughout the period of dredging in coarse-grained sediments. Among dredge types, side-cast dredges and mechanical (clamshell/bucket) dredges are generally associated with relatively high rates of sediment suspension and dispersal compared to hydraulic, hopper and cutterhead dredges (Clarke and Wilber 2000, LaSalle et al. 1991). In comparison to cutterhead dredges, hopper dredges are generally associated with higher rates of suspension and dispersal primarily due to the surface discharge associated with overflow dredging. With cutterhead dredging, sediment suspension is generally confined to the near bottom water column in the immediate vicinity of the rotating cutterhead assembly (LaSalle et al. 1991). Based on sediment resuspension data collected during multiple cutterhead navigation dredging projects, Hayes et al. (2000) and Hayes and Wu (2001) reported average sediment resuspension rates ranging from 0.003 to 0.135 percent of the fine silt/clay fraction. Dredging operations under Alternative 1 would be carried out by cutterhead dredges, and sediments associated with LFIX channel and bend widener are composed of medium sand (mean grain size = 0.41 mm) with a very small (~6 percent) fine sediment fraction. Therefore, it is anticipated that any effects of dredging-induced sediment suspension in the water column under Alternative 1 would be localized and short term.

Sediment suspension and turbidity effects would be limited to periods of active dredging; therefore, temporally crowded cumulative impacts would not be expected. Sediment suspension and turbidity effects would be localized to the immediate vicinity of the active dredging area and, therefore, overlapping spatially crowded cumulative impacts are not expected.

Beach Fill Placement

Direct and Indirect Impacts

Fine sediment suspension and increased turbidity would also occur during beach fill placement operations in the nearshore ocean zone. However, similar to the extraction process, the small fine sediment fraction suggests that sediment suspension effects related to beach fill placement under Alternative 1 would be localized and short term.

Cumulative Impacts

Sediment suspension and turbidity effects would be limited to periods of active beach nourishment and, therefore, temporally crowded cumulative impacts would not be expected. Sediment suspension and turbidity effects would be localized to the immediate vicinity of the beach fill placement areas. Therefore, overlapping spatially crowded cumulative impacts would not be expected.

<u>Entrainment</u>

Direct and Indirect Impacts

Cutterhead dredges have the potential to entrain fishes and invertebrates during all life cycle phases including adults, juveniles, larvae, and eggs. Among adult and juvenile fishes, demersal species that inhabit the near bottom water column environment are most likely to be entrained (Reine and Clarke 1998); however, studies have also reported the entrainment of small numbers of pelagic fishes (McGraw and Armstrong 1990). Entrainment studies indicate that dredging elicits an avoidance response by demersal and pelagic species and that most juvenile and adult fishes are successful at avoiding entrainment (Larson and Moehl 1990, McGraw and Armstrong 1990). Larson and Moehl (1990) also found that adult and juvenile anadromous fishes were less likely to be entrained in large open water bodies as opposed to constricted waterways. Based on the available information on entrainment rates, larger demersal and pelagic juvenile and adult finfishes are likely to avoid dredging areas during operations (Michel et al. 2013). Therefore, it is expected that entrainment-related effects on adult and juvenile fishes would be minor.

Many of the common marine fishes and invertebrates in NC are estuarine-dependent species that spawn offshore as adults and reside in estuarine nursery areas during juvenile development. The recruitment of ocean-spawned planktonic larvae to estuarine nursery areas is dependent on passive ocean-to-sound transport through tidal inlets. Recruitment studies indicate that larvae accumulate along the beaches in the nearshore ocean zone where they are carried by alongshore currents to laterally adjacent tidal inlets (Churchill et al. 1999). The results of a long-term sampling program at Beaufort Inlet, NC, indicate that inlet larval densities are highest from late May to early June and lowest in November (Hettler and Chester 1990). The results of larval entrainment modeling studies conducted at Beaufort Inlet indicate that dredge entrainment rates are very low regardless of inlet larval concentrations and the distribution of larvae within the water column (Settle 2002). Even under worst case conditions when the dredge is assumed to be operating 24 hours/day and all larvae are assumed to be concentrated in the bottom of the navigation channel, the projected entrainment rate barely exceeds 0.1 percent of the daily (24-hour) larval flux through the inlet. Based on the maximum intake rate of the largest hydraulic dredge that could potentially be employed, the maximum volume of water taken in and discharged during a 24-hr dredging period would constitute 0.004 percent of the daily spring tidal flow and 0.006 percent of the daily neap tidal flow through the inlet (Table 5.5). In addition, the existing environmental nourishment window (16 November - 30 April) would avoid the peak inlet larval ingress periods. Based on all of these considerations, it is anticipated that the effects of larval entrainment on estuarine-dependent fish and invertebrate populations under Alternative 1 would be negligible. It is anticipated that the direct and indirect impacts of entrainment on pelagic communities would be minor, localized, and short term. Therefore, cumulative impacts related to entrainment would not be expected under Alternative 1.

Underwater Noise

Increased anthropogenic noise from the dredging activities may impact fishes in the water column. The effects of dredging sounds on fishes have not been fully assessed, and there are currently no specific criteria for evaluating the potential impacts of continuous dredging

Table 5.5. **Maximum percentage of daily (24-hr) inlet flow volume entrained during dredging.**

Tide Condition	Tidal Prism[1] (Ft^3)	Daily (24-hr) Flow[1] (Tidal Prism x 2)	Daily Dredge Intake Rate (CFS x 1 day)	Percent of Daily Flow Entrained[2] (Dredge Intake/Daily Flow)
Spring	791,830,000	1,583,660,000	6,123,570	0.004
Neap	533,590,000	1,067,180,000	6,123,570	0.006

[1]Source: ATM 2013.

noise on marine fishes. Limited empirical evidence suggests that increased sound levels have the potential to induce behavioral (e.g., site avoidance) and physiological (e.g.,temporary or permanent loss of hearing) changes in fishes (Popper and Hastings 2009). Dredging noise may also mask biologically important signals, thereby interfering with fish communication and predator/prey interactions [Normandeau Associates, Inc. (NAI) 2012]. Although the potential effects of dredging noise on fishes are not fully known, dredges generally produce low levels of sound energy that are of short duration, thus indicating that effects on fish are likely to be temporary and localized (Michel et al. 2013). According to a study by Clarke et al. (2002), cutterhead dredges produce peak sound levels in the range of 100 to 110 dB re 1μPa rms with rapid attenuation occurring at short distances from the dredge and sound levels becoming essentially inaudible at a distance of approximately 500 m. Dredging is known to elicit an avoidance response by marine fishes (Larson and Moehl 1990, McGraw and Armstrong 1990); and therefore, considering that cutterhead dredges are anchored during active dredging, it is likely that most fish would move away from the dredge long before they are exposed to potentially injurious noise levels. Based on currently available information, it is expected that any non-injurious effects on fishes would be temporary and localized. In the absence of significant direct and indirect impacts, noise-related cumulative impacts would not be anticipated.

5.4.1.3 Oceanfront Beach and Dune Communities

Intertidal Beach

Direct Impacts

Alternative 1 would continue the ongoing two-year cycle of East End nourishment via beneficial use of material from the LFIX channel and 400-ft bend widener. Beach fill placement volumes would vary according to sediment volume availability in the LFIX and bend widener channels and the availability of local funding for inclusion of the 400-ft bend widener. It is anticipated that nourishment events using only material from the main LFIX channel would place ~100,000 cy on the East End beach, whereas combined LFIX/bend widener nourishment events would place ~150,000 cy. Alternative 1 does not have a defined beach fill footprint; however, based on similar placement volumes under the action alternatives, a 100,000 cy nourishment event would directly impact ~13 ac of intertidal beach habitat. Beach fill placement would eliminate the majority of the intertidal benthic invertebrate infauna through direct burial; and construction of the berm would shift the intertidal zone seaward, where the process of benthic infaunal recovery would begin upon the cessation of beach placement operations. The direct impacts of beach construction activities would include the disturbance and displacement of shorebirds from intertidal beach foraging habitats in the vicinity of the active construction zone. Although the duration of disturbance along any given segment of the nourishment beach would be short term, the indirect effects of benthic infaunal prey removal (described below) would likely preclude the immediate return of shorebirds.

The principal project-related factors that influence benthic community recovery rates are the compatibility of the beach fill sediments with those of the native beach and the timing of nourishment projects relative to spring benthic invertebrate larval recruitment periods (Wilber et al. 2009). Most benthic recovery studies have reported rapid recovery within seven months of the initial impact when highly compatible beach fill sediments were used and larval recruitment periods were avoided (Jutte et al. 1999a, Burlas et al. 2001, Van Dolah et al. 1994, Van Dolah et al. 1992, Gorzelany and Nelson 1987, Salomon and Naughton 1984, Parr et al. 1978, Hayden and Dolan 1974). Conversely, longer recovery periods of up to 15 months (Rakocinski et al. 1996) have generally been associated with the use of incompatible beach fill sediments containing excessively large quantities of fine silt and clay material. In an effort to minimize the biological impacts of beach nourishment projects, NC has enacted regulatory technical standards for the compatibility of beach fill sediments with those of the native beach (15A NCAC 07H.0312). Approvals of state CAMA permits for nourishment projects are contingent on the results of quantitative comparative analyses demonstrating sediment compatibility between proposed borrow areas and corresponding beach fill sites. The LFIX channel and bend widener have been a consistent source of compatible beach fill for many years, and the existing environmental nourishment window (16 November - 30 April) would necessitate avoidance of spring benthic invertebrate recruitment periods. Therefore, benthic communities would be expected to recover relatively rapidly from beach nourishment events under Alternative 1.

Indirect Impacts

Direct losses of intertidal benthic infauna within the beach fill footprint would constitute a temporary reduction in the availability of potential prey for shorebirds and predatory surf zone fishes. A two-year investigation of the effects of beach nourishment on shorebird and waterbird communities at Holden Beach and Oak Island detected no significant effects on shorebird or waterbird abundances (Grippo et al. 2007). However, the authors noted the possibility that abundances on nourished beaches could have been maintained by a continuous flux of arriving and departing migratory birds as opposed to extended residency by the same individuals. In terms of behavioral effects, Grippo et al. (2007) detected a significant reduction in waterbird feeding activity on nourished beaches; however, the feeding activities of shorebirds that are heavily dependent on intertidal beach foraging habitats (e.g., willet and sanderling) were not affected. Peterson et al. (2006) reported a 70 to 90 percent decline in shorebird feeding activity on a nourished beach at Bogue Banks. The decline in shorebird activity was attributed primarily to depressed infaunal communities; however, the use of incompatible fill containing large quantities of shell hash may have contributed to the decline by impeding shorebird foraging. Following the winter nourishment event, feeding activity remained severely depressed through July, but increased substantially between July and September and returned to normal between September and November. According to Wilber et al. (2003), the effects of a beach nourishment project in NJ on surf zone fishes were limited to short-term, localized decreases (bluefish) and increases (northern kingfish) in abundance. Analyses of the stomach contents of kingfishes and silversides showed no evidence of reduced foraging efficiency or dietary changes along nourished beaches. Under Alternative 1, potential indirect prey-loss effects on shorebirds and surf zone fishes could include a temporary reduction in foraging efficiency along the East End beach and/or temporary displacement to adjacent undisturbed intertidal foraging habitats. However, based on the anticipated rapid rates of benthic community recovery, the minimal intertidal habitat impacts, and the availability of adjacent undisturbed intertidal foraging habitat, it is anticipated that indirect impacts on shorebirds and surf zone fishes would be localized and short term under Alternative 1.

Cumulative Impacts

The potential for temporally-crowded cumulative effects on intertidal beach communities would depend on the frequency of repeated beach fill placement impacts within the beach fill footprint. Specifically, temporally-crowded cumulative effects would be considered likely if the intervals between repeated nourishment events were insufficient to allow for full recovery of benthic infaunal communities. As indicated above, intertidal beach communities within the beach fill footprint would be expected to fully recover during the two-year intervals between project-related nourishment events. Separate dredge and fill actions affecting the East End beach fill footprint during the 30-year project would not be anticipated; therefore, temporally-crowded cumulative effects on intertidal beach communities would not be expected under Alternative 1.

The potential for spatially-crowded cumulative impacts under Alternative 1 would depend on the proximity of separate beach fill actions to the East End beach and the potential for overlapping effects on intertidal beach communities. Spatially-separate nourishment projects that would be expected to occur along Holden Beach and/or Oak Island during the 30-year project period would include the planned 2014/2015 Holden Beach Central Reach nourishment project as well as maintenance of the Lockwoods Folly River Habitat Restoration Project, Phase I – Eastern Channel. There is no known schedule of maintenance for the Eastern Channel as it was permitted as a one-time project. The 2014/2015 Central Reach project would be a one-time nourishment event, and the initial East End nourishment event would not be expected to occur until at least 2015/2016. Therefore, no overlapping effects with the Central Reach project would be expected. Simultaneous nourishment of both reaches would reduce the pool of potential infaunal invertebrate recruits for recolonization of the East End beach; thus potentially extending the infaunal community recovery period. However, full recovery would still be expected during the two-year intervals between East End nourishment events; therefore, spatially-crowded cumulative impacts on intertidal benthic infaunal communities would not be expected under Alternative 1. Simultaneous losses of intertidal benthic infauna along both reaches may have minor adverse effects on surf zone fishes and shorebirds; however, such effects would be confined to the benthic community recovery period and would not carry over to subsequent nourishment events. Therefore, any spatially-crowded cumulative impacts on surf zone fishes and shorebirds under Alternative 1 would be short term and localized.

Dry Beach and Dune

Direct Impacts

Beach fill placement would be limited to areas seaward of the primary dune toe, thus avoiding direct impacts on dunes and associated dune grass communities. The placement of beach fill on the upper dry beach would impact ghost crabs and other burrowing invertebrate macrofauna through direct burial. The reported effects of beach nourishment and beach scraping on ghost crabs range from no significant response (Bergquist et al. 2008) to significant long-term effects lasting >1 year (Dixon 2007). The results of ghost crab recovery studies indicate that influential project-related factors are similar to those associated with intertidal benthic infaunal recovery rates; including sediment compatibility, the timing of operations relative to recruitment periods, and the frequency of repeated impacts. Bergquist et al. (2008) attributed the absence of any clear response to a nourishment project at Folly Beach, SC, to the use of highly compatible beach fill; however, Lindquist and Manning (2001) and Peterson et al. (2000) attributed significant reductions in ghost crab abundances lasting six to eight months to changes in sediment composition on newly constructed dune faces at Bogue Banks. In contrast to the minimal effects of (winter) nourishment reported by Bergquist et al. (2008), a separate investigation of a summer nourishment project at Folly Beach reported significant long-term (>1 year) effects on local population structure, including the loss of entire cohorts (Dixon 2007). Lindquist and Manning (2001) detected no response to an initial beach nourishment project at Topsail Beach; however, repeated annual nourishment projects resulted in significant reductions in ghost crab abundances. Based on the results of these studies, it is anticipated that the use of compatible sediments in accordance with the state technical standards for beach fill and avoidance of recruitment periods in accordance with the established environmental nourishment window (16 November - 30 April) would minimize the potential for significant long-term effects on ghost crabs and other beach-dwelling invertebrate macrofauna. The established nourishment window would necessitate avoidance of sea turtle and shorebird/waterbird nesting seasons; therefore, no direct impacts on nesting activity or success would be expected. Construction activities would result in short-term displacement of shorebirds and waterbirds from upper beach loafing and/or roosting habitats; however, the spatial extent of displacement at any given time would amount to a relatively small segment of the beach in the immediate vicinity of the active construction zone.

Indirect Impacts

Beach nourishment has the potential for both beneficial and detrimental indirect effects on dry beach communities. In the case of severely eroded beaches, the restoration of a wider and higher dry beach can improve the quality of potential nesting habitats for sea turtles (Davis et al.

1999, Byrd 2004) and potential loafing, roosting, and nesting habitats for shorebirds and waterbirds (Melvin et al. 1991). Conversely, nourishment can modify the physical characteristics of dry beach and dune habitats in ways that reduce habitat quality. Potential detrimental effects on the quality of dry beach and dune habitats are primarily related to changes in sediment composition and the modification of other physical substrate characteristics and/or changes in beach profile morphology. As indicated by ongoing federal disposal actions, the LFIX channel and bend widener have been a consistent source of compatible east end beach fill for many years. Much of the LFIX source material is derived from the adjacent beaches of Holden Beach and Oak Island. Prior to the use of any sand source by the Town, minimum state sediment compatibility standards must be met. Available sediment data from the borrow sites indicate the presence of beach-compatible sand in sufficient volumes for nourishment. Each of the sites consists of sediments characterized by a high percentage of sand by percent weight and low percentage of fines (see Appendix F).

The use of heavy machinery to redistribute and establish the design beach profile can result in compaction of the newly deposited beach sediments, which in turn can impede sea turtle nest excavation. Sediment compaction and changes in sediment composition can also affect the suitability of the nest incubation environment and the ability of hatchlings to emerge from the nest (Nelson and Dickerson 1988, Crain et al. 1995). The initial post-construction dry beach (aka berm) profile is generally flatter than the natural beach profile, and consequently, is subject to a period of adjustment during which sediments are sorted and redistributed by wave and wind driven transport processes. This adjustment process often results in the formation of escarpments that can prevent sea turtles from accessing upper dry beach nesting habitats. The potential effects of beach nourishment and other project-related activities on sea turtles and sea turtle nesting habitat are evaluated in detail along with other threatened and endangered species in Section 5.4.1.6.

Changes in sediment composition can also potentially affect the suitability of dry beach habitats for nesting shorebirds (Melvin et al. 1991). However, in the case of the developed East End oceanfront beach, nourishment is unlikely to have any beneficial or detrimental impact on the suitability of potential dry beach shorebird/waterbird nesting habitats. Although shorebird/waterbird nesting attempts along the oceanfront beach cannot be entirely ruled out, traditional oceanfront dry beach and dune breeding sites on NC's stabilized developed barrier islands have essentially been abandoned in favor of more isolated inlet spit/shoal habitats and estuarine spoil islands. The anticipated effects of nourishment on East End oceanfront beach habitats would be negligible in comparison to the overriding long-term exclusionary effects of development, stabilization, and chronic human disturbance. Therefore, Alternative 1 would not be expected to have any indirect effects on the suitability of oceanfront beach shorebird/waterbird nesting habitats. The maintenance of a wider oceanfront dry beach under Alternative 1 would be expected to improve the quality of potential shorebird/waterbird loafing and roosting habitats.

Cumulative Impacts

The potential for temporally-crowded cumulative effects on dry beach and dune communities would depend on the frequency of repeated beach fill placement impacts within the beach fill footprint. Specifically, temporally-crowded cumulative effects would be considered likely if the intervals between repeated nourishment events were insufficient to allow for full recovery of macrofaunal invertebrate communities and physical habitat characteristics. As indicated above, dry beach macrofaunal invertebrate communities within the beach fill footprint would be expected to fully recover from beach fill placement impacts during the two-year intervals between project-related nourishment events. Separate dredge and fill actions affecting the East End beach fill footprint during the 30-year project would not be anticipated; therefore, temporally-crowded cumulative effects on dry beach communities would not be expected under Alternative 1. The potential for spatially-crowded cumulative impacts under Alternative 1 would depend on the proximity of separate beach fill projects to the East End beach and the potential for overlapping effects on dry beach and dune communities. The maximum combined linear extent of oceanfront beach impact during any given year would be 5.2 miles in the event of simultaneous nourishment of the ~0.7-mile East End beach and the longest ~4.5-mile Central Reach Project on Holden Beach. Simultaneous nourishment of both reaches would reduce the pool of potential macrofaunal invertebrate recruits for recolonization of the East End beach, thus potentially extending the macrofaunal community recovery period. However, full recovery would still be expected during the two-year intervals between East End nourishment events; therefore, spatially-crowded cumulative impacts on dry beach communities would not be expected under Alternative 1.

5.4.1.4 Inlet Resources

<u>Intertidal Flats and Shoals</u>

Direct Impacts

Although small short-lived emergent shoals occasionally form along the margins of the ebb channel at the mouth of the inlet throat, the interior Flood Shoal is the only persistent intertidal flat/shoal feature associated with the LFI/LFIX complex. Nourishment-related dredging operations would be confined to the existing federally authorized LFIX and bend widener navigation channels; therefore, direct dredging-induced impacts on intertidal flats and shoals would not be expected under Alternative 1. The eastern extent of beach fill placement may approach the inlet shoulder where small shoals originating along the western margin of the ebb channel have attached in the past; however, chronic erosion generally precludes the formation of any persistent intertidal flat or shoal-like features along the Holden Beach inlet shoulder. Therefore, direct nourishment-related impacts on intertidal flats and shoals would not be expected under Alternative 1.

Indirect Impacts

The LFIX and bend widener dredging regimes under Alternative 1 would be similar to current operations; therefore, indirect dredging-induced hydrodynamic effects on flats and shoals would not be expected. Net sediment transport along the East End beach is eastward towards the inlet, and the inlet itself is flood-dominant in terms of sediment transport. Consequently, sand extracted from the LFIX/bend widener channels for East End nourishment purposes would be retained within the inlet system. Therefore, indirect impacts on the Flood Shoal via modification of the inlet sediment budget would not be expected under Alternative 1.

Cumulative Impacts

In the absence of anticipated direct and indirect effects, cumulative impacts on intertidal flats and shoals within the Permit Area would not be expected under Alternative 1.

<u>Inlet Dry Beach and Dune</u>

Direct Impacts

Due to the chronically eroded nature of the East End shoreline, the demarcation between the oceanfront beach and the inlet beach is poorly defined on Holden Beach. The eastern extent of beach fill placement may encompass short reaches of the transitional southeast-facing oceanfront/inlet shoreline. Beach fill placement would be limited to areas seaward of the dune toe, thus avoiding direct impacts on dunes and associated dune grass communities. Beach fill placement would result in minor direct impacts on inlet dry beach communities.

Indirect Impacts

The potential indirect impacts of beach fill placement on inlet dry beach communities would be similar to those described above for the oceanfront beach. Based on the limited spatial extent of beach fill placement along the southeast-facing shoreline, it is anticipated that associated indirect effects would not add measurably to those already described for the oceanfront beach.

Cumulative Impacts

The potential cumulative impacts of beach fill placement on inlet dry beach communities would be similar to those described above for the oceanfront beach. Based on the limited extent of direct and indirect impacts, it is anticipated that any associated cumulative impacts would not add measurably to those already described for the oceanfront beach.

5.4.1.5 Estuarine Resources

Shellfish

Direct, Indirect, and Cumulative Impacts

Dredging operations would be confined to the existing LFIX and bend widener navigation channels; therefore, Alternative 1 would not be expected to have any direct impact on shellfish beds. The LFIX and bend widener dredging regimes under Alternative 1 would be similar to current operations; therefore, indirect dredging-induced hydrodynamic effects on shellfish beds would not be expected. As described in Section 5.4.1.2, it is anticipated that dredging-induced sediment suspension and dispersal would be short term and highly localized, thus indicating that the potential for redeposition effects on shellfish beds would also be minimal. In the absence of anticipated direct and indirect effects, cumulative impacts on shellfish beds would not be expected under Alternative 1.

SAV

Direct, Indirect, and Cumulative Impacts

Distribution maps developed by the SAV Cooperative Habitat Mapping Program depict a few small SAV patches along the Eastern Channel between Oak Island and Sheep Island; however, according to the NCDMF, SAV does not occur in the Eastern Channel (Personal communication, NCDMF, Anne Deaton, 22 May 2014). The absence of SAV in the Eastern Channel was confirmed via ground-truthing by Dial Cordy and Associates Inc. in September 2014. Dredging operations would be confined to the existing LFIX and bend widener navigation channels; therefore, Alternative 1 would not be expected to have any direct impact on SAV. As stated above, indirect dredging-induced hydrodynamic and redeposition effects would not be expected under Alternative 1. In the absence of anticipated direct and indirect effects, cumulative impacts on SAV would not be expected under Alternative 1.

Tidal Marshes

Direct, Indirect, and Cumulative Impacts

Dredging operations would be confined to the existing LFIX and bend widener navigation channels; therefore, Alternative 1 would not be expected to have any direct impact on tidal marshes. As stated above, indirect dredging-induced hydrodynamic effects would not be expected under Alternative 1. In the absence of anticipated direct and indirect effects, cumulative impacts on tidal marshes would not be expected under Alternative 1.

5.4.1.6 Threatened and Endangered Species

North Atlantic Right Whale and Humpback Whale

Direct, Indirect, and Cumulative Impacts

Under Alternative 1 dredging operations in the LFIX and bend widener channels would coincide with North Atlantic right whale and humpback whale migration periods along the NC coast. The potential impacts of dredging on large whales include vessel collisions and acoustic disturbance. Although right and humpback whales routinely swim close to shore during winter migration periods along the NC coast, dredging activities under Alternative 1 would be confined to the inshore LFIX and bend widener channels, thus precluding any risk of vessel collisions. NMFS currently uses generic noise exposure thresholds to define two levels of acoustic “take” under the MMPA. Actions that may expose marine mammals to root mean square sound pressure levels ≥180 dB re 1μPa rms constitute Level A harassment with the potential to cause injury, and actions that may expose marine mammals to impulse noise levels ≥140 dB re 1μPa rms or continuous noise levels ≥120 dB re 1μPa constitute Level B harassment with the potential to cause behavioral disruption. As described by Clarke et al. (2002), cutterhead dredges produce peak sound levels in the range of 100 to 110 dB re 1μPa rms. Sound levels are rapidly reduced at short distances from the dredge and are essentially inaudible at a distance of ~500 m. Therefore, dredging operations under Alternative 1 would not be expected to produce noise levels at or above the thresholds described above for injurious or behavioral effects on marine mammals. Furthermore, the LFIX and bend widener channels are located ~700 m inland of the International Regulations for Preventing Collisions at Sea (COLREGS) line across the mouth of the inlet throat, thus indicating that any dredging noise that does reach the open ocean would be inaudible. Therefore, dredging noise would not be expected to have any direct or indirect effect on right or humpback whales. The essential features of proposed critical habitat for the right whale within the Permit Area are those associated with calving habitat; including sea surface temperature, water depth, and sea state (roughness). Dredging and beach fill placement operations under Alternative 1 would not affect any of these essential features, nor would they preclude right whales from accessing or using the proposed critical habitat areas. Therefore, no adverse effects on critical habitat would be expected under Alternative 1. In the absence of anticipated direct and indirect effects, cumulative impacts on right and humpback whales or proposed right whale critical habitat would not be expected under Alternative 1.

West Indian Manatee

Direct, Indirect and Cumulative Impacts

The principal project-related threat to manatees would be the potential for vessel collisions related to dredging operations in the LFIX and bend widener channels. Cutterhead dredges operate from anchored barges; therefore, any potential risk of collisions would be limited to relatively brief periods of barge repositioning. Furthermore, the established environmental nourishment window (16 November - 30 April) would limit operations to the colder months when manatees are unlikely to be present in NC waters. Of the 53 live manatee sightings that were reported in NC between 1994 and 2011, nearly all (94 percent) occurred between June and October when water temperatures were above 20°C (Cummings et al. 2011). Nonetheless, conservation measures would include implementation of *Guidelines for Avoiding Impacts to the West Indian Manatee: Precautionary Measures for Construction Activities In North Carolina Waters* (USFWS 2003). Based on the minimal collision risk associated with cutterhead dredges, the timing of project activities, and adherence to USFWS manatee guidelines; no direct, indirect, or cumulative impacts on manatees would be expected under Alternative 1.

<u>Piping Plover</u>

Direct Impacts

Sand flat and emergent shoal habitats associated with the Oak Island sand spit and the flood shoal are designated critical habitat for the Atlantic Coast wintering population of piping plovers; however, these areas are located on the opposite (eastern) side of the LFI channel at a minimum distance of ~0.5 mile from the eastern terminus of the beach fill placement area on Holden Beach. Wintering plovers are very rarely seen on developed oceanfront beaches in NC; consequently, such beaches are not considered to be suitable wintering habitat (Cameron 2009). Therefore, East End beach fill placement operations under Alternative 1 would not be expected to have any direct impacts on wintering plovers. Similarly, piping plover breeding sites on NC's developed barrier islands are restricted to inlet habitats associated with the accreting ends of the islands (USFWS 2009); therefore, direct beach fill placement impacts on breeding and nesting activity would not be expected. Dredging activities would be confined to the existing federally authorized LFIX and bend widener navigation channels; therefore, no direct dredging-related impacts on piping plovers or critical habitat would be expected under Alternative 1.

Indirect Impacts

Although the restoration of a wider beach can theoretically improve the quality of oceanfront beach habitats for piping plovers, the anticipated beneficial effects of nourishment on the East End beach under Alternative 1 would not be expected to reverse the long-term exclusionary effects of development, stabilization, human disturbance, and chronic high rates of background erosion. Therefore, Alternative 1 would not be expected to have any indirect beneficial or detrimental effects on the suitability of East End beach habitats for piping plovers. The LFIX and bend widener dredging regimes under Alternative 1 would be similar to current operations; therefore, indirect dredging-induced impacts on inlet habitats would not be expected.

Cumulative Impacts

In the absence of anticipated direct and indirect effects, cumulative impacts on piping plovers would not be expected under Alternative 1.

Red Knot

The red knot is a non-breeding, migratory species in NC; therefore, Alternative 1 would not have any direct effect on breeding activity or reproductive success. On September 30, 2013, the USFWS proposed listing the rufa red knot (or red knot) as threatened throughout its range. Migrating red knots forage along sandy beaches in NC during spring (mid-April - May) and fall (July - mid-October) migrations. Red knots appear to be most abundant in May during spring migration (Personal communication, S. Schweitzer, NCWRC, 17 October 2014). Adherence to the proposed environmental window (15 November – 30 April) would avoid migratory periods when red knots are most likely to occur within the Permit Area, thus limiting the potential for direct impacts on red knots. Direct losses of intertidal benthic infauna within the beach fill footprint would constitute a temporary reduction in the availability of potential prey for red knots. Potential indirect prey-loss effects on red knots could include a temporary reduction in foraging efficiency along the East End beach and/or temporary displacement to adjacent undisturbed intertidal foraging habitats. Conversely, nourishment would increase the quantity of available intertidal foraging habitat along the East End beach, potentially resulting in beneficial indirect effects on red knots. Based on the anticipated rapid rates of benthic community recovery, the limited spatial extent of intertidal habitat impacts, the availability of adjacent undisturbed foraging habitat, and the potential for beneficial effects through foraging habitat expansion; it is anticipated that any adverse indirect impacts on red knots would be localized and short term. In the absence of significant direct and indirect effects, cumulative impacts on red knots would not be expected under Alternative 1. There is no designation of critical habitat for red knot.

Wood Stork

Alternative 1 would not be expected to have any effect on nesting sites or estuarine foraging habitats. Therefore, no direct, indirect, or cumulative impacts on wood storks would be expected under Alternative 1.

Sea Turtles

Direct Impacts

The established environmental nourishment window (16 November - 30 April) would preclude the occurrence of East End nourishment activities during the 1 May - 15 November sea turtle nesting and hatching season; therefore, direct beach fill placement impacts on sea turtles would not be expected under Alternative 1. Cutterhead pipeline dredges, the type of dredge typically used for navigation maintenance in the AIWW crossing, are not historically known to take sea turtles, and the established nourishment window would limit dredging to periods when most sea turtles are confined to warmer offshore waters. Therefore, direct dredging impacts on sea turtles would not be expected under Alternative 1.

Indirect Impacts

Beach nourishment has the potential for both beneficial and detrimental indirect effects on sea turtle nesting habitat. In the case of severely eroded beaches, such as the East End beach, the restoration of a wider and higher dry beach can improve the quality of potential nesting habitats for sea turtles (Davis et al. 1999, Byrd 2004). Conversely, nourishment can modify the physical characteristics of dry beach habitats in ways that reduce habitat quality. Potential detrimental effects on the quality of potential sea turtle nesting habitats are primarily related to the modification of beach profile morphology and/or changes in sediment composition and other physical substrate properties. The initial post-construction dry beach (aka berm) profile is generally flatter than the natural beach profile; consequently, it is subject to a period of adjustment during which sediments are sorted and redistributed by wave and wind driven transport processes. This adjustment process often results in the formation of escarpments that can prevent sea turtles from accessing upper dry beach nesting habitats. The use of heavy machinery to redistribute and establish the design beach profile can result in compaction of the newly deposited beach sediments, which in turn can impede sea turtle nest excavation. Sediment compaction and changes in sediment composition can also affect the suitability of the nest incubation environment and the ability of hatchlings to emerge from the nest (Nelson and Dickerson 1988, Crain et al. 1995). Embryonic development and hatching success are influenced by temperature, gas exchange, and moisture content within the nest environment (Carthy et al. 2003). Changes in substrate characteristics such as grain size, density, compaction, organic content, and color may alter the nest environment; leading to adverse effects on embryonic development and hatching success (Nelson and Dickerson 1988, Nelson 1991, Ackerman et al. 1991, Crain et al. 1995, Ehrhart 1995, and Ackerman 1996). Nourished beaches often retain more water than natural beaches, thus impeding gas exchange within the nest (Mrosovsky 1995, Ackerman 1996); and uncharacteristically dark sediments absorb more solar radiation, thus potentially resulting in warmer nest temperatures (Hays et al. 2001). Dark sediments that increase nest temperatures may prevent successful embryonic development (Matsuzawa et al. 2002) or increase the incidence of late-stage embryonic mortality by reducing incubation periods (Ernest 2001). Nest temperature also influences sex determination in hatchlings, with warmer temperatures producing more females and cooler temperatures producing more males (Wibbels 2003), thus indicating that the use of uncharacteristically dark beach fill sediments could potentially alter hatchling sex ratios.

Holloman and Godfrey (2008) studied the effects of multiple beach nourishment events on sea turtle nesting and hatching success on Bogue Banks. This five year study (2002-2007) included monitoring of nesting activity, hatching success, substrate compaction, and nest temperature. No significant beach nourishment effects on nesting success (i.e., nest/false crawl ratios) were detected, and there was no indication that nourishment adversely affected egg development or hatching success, with the exception of one nest that apparently failed due to poor gas exchange. Nourishment had no significant effect on compaction; however, nests in nourished areas were on average 1.9°C warmer than nests laid at the same time on undisturbed beaches. Although sex ratios were not determined, Holloman and Godfrey concluded that the increase in nest temperature on nourished beaches probably increased the number of females produced.

Studies documenting declines in nesting success on nourished beaches have generally reported a return to normal nesting activity by the second or third post-nourishment nesting season (Crain et al. 1995, Steinitz et al. 1998, Ernest and Martin 1999, Herren 1999, Rumbold et al. 2001, Byrd 2004, and Brock et al. 2009). These studies attributed the observed declines in nesting primarily to substrate compaction, escarpment formation, and/or modification of the natural beach profile. In contrast, studies have also reported immediate increases in nesting success following nourishment projects on chronically eroded beaches (Davis et al. 1999 and Byrd 2004). Studies of hatching success on nourished beaches have reported positive effects (Broadwell 1991, Ehrhart and Holloway-Adkins 2000, and Ehrhart and Roberts 2001), negative effects (Ehrhart 1995, Ecological Associates Inc. 1999), and no effect (Raymond 1984, Nelson et al. 1987, Broadwell 1991, Ryder 1993, Steinitz et. al. 1998, Herren 1999, and Brock et al. 2009). The variation in responses has been attributed to differences in the physical attributes of individual projects, the extent of erosion on the pre-nourishment beach, and construction techniques (Brock et al. 2009).

It is anticipated that the use of compatible sediments in accordance with the state technical standards for beach fill would minimize the potential for long-term effects on sea turtle nesting habitat. Conservation measures would include escarpment and sediment compaction monitoring with appropriate remediation as needed (see further discussion of Conservation Measures in Section 6). Therefore, it is anticipated that physical habitat recovery would occur relatively rapidly, thus minimizing the duration of any adverse indirect habitat-modification effects on sea turtles. Nourishment would improve the quality of potential East End nesting habitat through the maintenance a wider dry beach. In the absence of nourishment, the potential for sea turtle nesting along the chronically eroded East End beach would be very low; therefore, it is anticipated that Alternative 1 would have a net beneficial indirect impact on the quality of East End nesting habitat.

Cumulative Impacts

Beach fill placement and associated dredging activities under Alternative 1 would not be expected to have any direct impacts on sea turtles, and it is anticipated that Alternative 1 would have a net beneficial indirect impact on habitat quality. Therefore, adverse cumulative impacts on sea turtles would not be expected under Alternative 1.

<u>Atlantic and Shortnose Sturgeons</u>

Direct, Indirect, and Cumulative Impacts

Dredging operations can potentially impact Atlantic and shortnose sturgeons directly through entrainment in the dredge intake pipe and/or indirectly through sediment suspension and soft bottom habitat modification. Between 1990 and 2007, federal navigation dredging operations along the Atlantic Coast resulted in the take of 11 Atlantic sturgeons and 11 shortnose sturgeons (USACE 2008). All of the shortnose sturgeon takes occurred along the North Atlantic Coast in the Delaware and Kennebec Rivers, whereas all but one of the Atlantic sturgeon takes occurred along the South Atlantic Coast. Shortnose sturgeons were taken by hopper, cutterhead, and clamshell dredges; whereas Atlantic sturgeons were taken by hopper and clamshell dredges. Atlantic sturgeon takes at Wilmington Harbor included one by a hopper dredge and one by a clamshell dredge. The shortnose sturgeon is typically found in the upper portions of rivers above the freshwater-saltwater interface; therefore, its presence in the LFIX and bend widener channels during dredging operations would not be expected. Based on its low probability of occurrence and the absence of reported dredge interactions along the South Atlantic Coast, direct and indirect impacts on shortnose sturgeon would not be expected under Alternative 1. As indicated above, cutterhead dredges are not historically known to take Atlantic sturgeon; therefore, direct dredging-induced impacts on Atlantic sturgeon would not be expected. Dredging operations would be confined to the existing federally authorized LFIX and bend widener navigation channels; therefore, indirect impacts related to foraging habitat modification would not be expected under Alternative 1. In the absence of anticipated direct and indirect effects, cumulative impacts on shortnose and Atlantic sturgeons would not be expected under Alternative 1.

Seabeach Amaranth

Direct, Indirect, and Cumulative Impacts

The USACE has conducted comprehensive annual surveys for seabeach amaranth on Holden Beach since 1992. Small numbers of plants were recorded on the East End beach during each of the annual surveys conducted from 1992 through 2006; however, seabeach amaranth was not found on the East End during surveys conducted from 2007 – 2011. Beach nourishment has the potential for both beneficial and detrimental indirect effects on seabeach amaranth. In the case of severely eroded beaches, the restoration of a wider vegetation-free dry beach can improve the quality of potential habitat; whereas projects conducted during the growing season can have adverse effects through the burial of living plants (USFWS 2005). Seabeach amaranth is an annual, meaning that the presence of plants in any given year is dependent on seed production and dispersal during previous years. Seeds that are redistributed by sand placement and grading operations may be deposited in unsuitable habitats; whereas seeds that are banked in borrow site sediments may be transferred to suitable beach habitats. Little is known of the relationship between nourishment, seed burial, and germination; however, increases in seabeach amaranth numbers have been observed following nourishment projects on Bogue Banks, possibly due to the creation of new habitat and/or the redistribution of seeds along with the beach fill (Personal communication, D. Suitor, USFWS Raleigh Ecological Services Field Office, 2011). Although the full effects of beach nourishment are not known, the USFWS generally believes that nourishment projects completed during the winter are not detrimental to seabeach amaranth (USFWS 2005). Under Alternative 1, the established environmental nourishment window (16 November - 30 April) would avoid the majority of the seabeach amaranth growing season; however, nourishment towards the end of the window in April could result in the burial of some early seedlings. Nourishment would be expected to improve habitat quality by increasing the width of the dry beach. The absence of plants along the East End in recent years is likely the result of long-term chronic erosion, thus indicating that future occurrences may be unlikely without nourishment. Therefore, it is anticipated that the net effect of East End nourishment on seabeach amaranth would be beneficial.

5.4.1.7 Cultural Resources

Direct, Indirect, and Cumulative Impacts

The remains of four Civil War vessels at LFI are listed in the National Register of Historic Places (NRHP) under the Cape Fear Civil War Shipwreck District. The U.S.S. *Iron Age* and two sidewheel steamer blockade-runners (*Elizabeth* and *Bendigo*) are located in a line across the mouth of the inlet, and a third sidewheel blockade-runner (Ranger) is located ~1 mile west of the inlet (Tidewater Atlantic Research 2011). All of the Civil War shipwrecks are located seaward of the COLREGS line that extends across the mouth of the inlet throat; whereas the LFIX and bend widener channels are associated with the AIWW on the soundside of the inlet. Alternative 1 would involve the continuation of current dredging practices within the existing federally authorized LFIX/bend widener navigation channels; and therefore, no direct, indirect, or cumulative impacts on cultural resources would be expected.

5.4.1.8 Public Interest Factors

<u>Public Safety</u>

Direct, Indirect, and Cumulative Impacts

Beach Construction

Beach construction would involve the use of bulldozers and possibly backhoes to redistribute beach fill as it is discharged onto the nourishment beach. In order to take advantage of the limited nourishment window and maximize the efficient use of manpower and machinery, beach nourishment operations would be conducted around-the-clock. As with any construction project involving the use of heavy machinery, beach construction would present a minor short-term risk to public safety. However, adherence to the established environmental nourishment window (16 November - 30 April) would limit beach construction to the colder months when recreational use is at its lowest point, thus limiting public exposure to construction activities. In order to maintain separation between the public and potentially hazardous operations, the active construction area, consisting of a ~500-ft zone on either side of the beach fill discharge point, would be fenced. During nighttime operations, appropriate lighting would be provided in accordance with USACE and OSHA safety regulations. The USACE Safety and Health Requirements Manual (EM 385-1-1) specifies a minimum luminance of three lumens per square foot for outdoor construction zones. Regulations also require front and back lighting on all transport vehicles and bulldozers during nighttime operations. Considering these safety measures, as well as the anticipated low level of recreational activity during the period of construction and the short-term duration of potential effects; it is anticipated that any direct, indirect, and cumulative impacts on public safety under Alternative 1 would be negligible.

Dredging

As indicated above, the limited nourishment window and the high costs associated with dredging would necessitate around-the-clock operations in the LFIX/bend widener channels. Dredges and associated pump and pipeline systems would present a minor short-term collision risk to recreational boaters. However, adherence to the established environmental nourishment window (16 November – 30 April) would limit operations to the colder months when recreational boating activity is at its lowest point, thus limiting the potential for interactions between dredges and recreational vessels. During nighttime operations, appropriate on-board lighting would be provided in accordance with USACE and OSHA safety regulations. The USACE Safety and Health Requirements Manual (EM 385-1-1) specifies a minimum luminance of 30 lumens per square foot on dredges. Dredges would be subject to vessel inspections and other federal safety regulations that are enforced by the USCG. As necessary to ensure the safety of recreational boating activities, the USCG would establish temporary safety zones around dredging operations. Considering these safety measures, as well as the anticipated low level of recreational boating activity during the period of construction and the short-term duration of potential effects, it is anticipated that any direct, indirect, and cumulative impacts on public safety under Alternative 1 would be negligible.

Aesthetics and Recreation

Direct, Indirect, and Cumulative Impacts

During beach nourishment events, the presence of pipelines and construction equipment on the beach, as well as the associated emissions of noise and light, would temporarily diminish the aesthetic quality of the East End beach. Temporary construction safety zones would restrict public beach access within a ~500-ft zone on either side of the beach fill discharge point, thus potentially impacting recreational activities such as beach-combing, fishing, and surfing. Similarly, the presence of dredges and support vessels/barges within the LFIX/bend widener channels would temporarily degrade scenic vistas and could slow recreational boating traffic. Public exposure to aesthetic and recreational impacts would be limited, as the proposed environmental nourishment window (16 November – 30 April) would limit beach fill and dredging operations to the colder months when recreational beach use is at its lowest point. Conversely, beach nourishment projects under Alternative 1 would maintain a wider beach, thus resulting in long-term beneficial effects on recreation and aesthetic quality. Furthermore, the additional storm protection provided by nourishment would reduce the need for emergency measures (sandbags, beach/dune scraping) that would be detrimental to recreation and the aesthetic quality of the beach. Considering the short-term nature of the adverse impacts and the low level of public exposure to these impacts, the long-term beneficial effects would be expected to outweigh any adverse effects, thus resulting in a net beneficial effect on aesthetics and recreation. Therefore, adverse direct, indirect, or cumulative impacts on aesthetics and recreation would not be expected under Alternative 1.

Navigation

Direct, Indirect, and Cumulative Impacts

Alternative 1 would involve the continuation of current dredging operations within the existing federally authorized LFIX and bend widener channels. Therefore, no direct, indirect, or cumulative impacts on navigation would be expected under Alternative 1.

Infrastructure

Although not specifically modeled, Alternative 1 would involve nourishment intervals and beach fill placement volumes that are essentially the same as those associated with Alternative 3. Thus, Alternative 1 would be expected to have similar effects on infrastructure. Under Alternative 3, the CMS model-projected response of the developed East End oceanfront beach is one of recession throughout the four-year simulation period. By the end of Year 4, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~1,200 linear ft) has migrated landward of the existing primary dune, resulting in impacts to 19 oceanfront properties and ~250 ft of roads and associated linear utilities (see Section 5.4.3.8).

Economics

Under Alternative 1, construction and maintenance costs would include those associated with periodic beach nourishment, including the costs of beach fill, mobilization/demobilization, monitoring, surveying and permitting. Additional costs would be associated with risk to properties and infrastructure, loss of recreational opportunities, loss of habitat, and environmental impacts associated with periodic nourishment and borrow site dredging activities. Over a 30-year planning horizon, assuming nourishment of the East End Beach with approximately 100,000 cy of sand every two years, and an annual four percent increase in fill costs, Alternative 1 is expected to involve total construction costs of approximately $46.21 million. In present value terms, construction costs range from $18.45 million (6% discount rate) to approximately $30.34 million (2.5% discount rate).

The erosional impacts of the alternatives on properties and infrastructure were projected based on model-predicted shoreline changes. Specifically, properties and infrastructure that fall within 25 ft of the model-projected MHW at the end of the four-year simulation were considered to be impacted. Costs associated with these impacts were based on the assessed tax value of properties and the estimated cost of infrastructure replacement (see Appendix M). As described above, Alternative 1 would be expected to impact 19 properties (13 improved) and ~250 linear ft of roads and associated water, sewer, and power lines. The total assessed value of all properties projected to be newly impacted under Alternative 1 is roughly $3.01 million. The 250 linear ft of anticipated infrastructure replacement cost is valued at approximately $191,000, with a present value ranging from approximately $151,000 (6% discount rate) to $173,000 (2.5% discount rate). Under Alternative 1, use and non-use values associated with recreation, aesthetics, and the natural environment (Table 5.6) are generally expected to be enhanced relative to Alternative 2 and diminished relative to Alternatives 3, 4, 5, and 6. Public recreational values would be affected to the extent that the activities associated with nourishment physically impede and diminish the aesthetic appeal of the East End beach. These effects may result in economic losses associated with diminished use and non-use values and may have adverse effects on ecosystem service values in terms of provisioning and regulating services provided by the affected species and habitats. The principle benefit of Alternative 1 would be maintenance of the current stock and flow of market and non-market goods and services.

Table 5.6. Alternative 1 scope of costs and benefits.

Costs (Relative to Status Quo)	
Construction and Maintenance	$46.21 M
Construction and Maintenance (Present Value)	$18.45 M – $30.34 M
Parcels affected	19
Assessed Tax Value of Affected Parcels	$3.01 M
Infrastructure Replacement Costs	$190,699
Infrastructure Replacement Costs (Present Value)	$151,052 - $172,764
Reduction in tax base	High
Transition costs	High
Diminished recreation value	High
Diminished aesthetic value	Intermediate
Environmental Damage	
Public non-use value losses (nature)	Low
Public non-use value losses (Holden Beach)	High
Benefits (Relative to Status Quo)	
Reduction in future nourishment expense	Intermediate
Enhanced property value	None
Enhanced Recreation value	Low
Environmental Improvement	
Public non-use value (nature)	Intermediate
Public non-use value (Holden Beach)	Low

5.4.2 Alternative 2: Abandon and Retreat

Under Alternative 2, the Town would not pursue a long-term management plan, and there would not be any federally-implemented or federally-permitted actions undertaken to mitigate erosion along the East End beach. The USACE would not conduct any East End beneficial use projects; and the Town would not conduct any actions that require a federal dredge and fill permit; including beach nourishment, beach scraping, dune restoration, temporary sandbag placement, and inlet dredging. Instead, the town would develop and implement a 30-year managed retreat plan; under which structures that are threatened with erosional damage would be either relocated to unimproved interior lots or demolished.

5.4.2.1 Marine Benthic Communities

<u>Soft Bottom Communities</u>

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would be limited to shore-based demolition and relocation activities; and therefore, no project-related direct, indirect, or cumulative impacts on soft bottom communities would be expected. Federal maintenance dredging of the main LFIX navigation channel would continue under a regime similar to that of the No Action alternative; however, in the absence of beneficial use projects, the 400-ft bend widener would not be dredged under Alternative 2. Therefore, relative to the No Action alternative; dredging-induced direct, indirect, and cumulative impacts on soft bottom benthic invertebrate communities and predatory demersal fishes would be slightly reduced under Alternative 2.

<u>Hardbottom Communities</u>

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would be limited to shore-based demolition and relocation activities; and therefore, no direct, indirect, or cumulative impacts on hardbottom communities would be expected.

5.4.2.2 Water Column

<u>Hydrodynamics</u>

Direct and Indirect Impacts

Actions taken under Alternative 2 would be limited to shore-based demolition and relocation activities; and therefore, no project-related direct or indirect impacts on hydrodynamics would be expected. Hydrodynamic changes under Alternative 2 were modeled to establish a baseline for analyzing the relative impacts of the remaining action alternatives (Alternatives 3 – 6). In the absence of project-related effects, the model-projected hydrodynamic changes under Alternative 2 primarily reflect the influence of natural coastal processes. As is the case for all of the alternatives, the modeling results for Alternative 2 do not account for federal navigation dredging.

Modeling was conducted on the outer channel and resulted in insignificant effects on the shoreline and sediment transport processes (Personal communication, F. Way, ATM, Engineer on record, July 2015). Shoaling and/or migration of the LFI channel occurred within a few months in the modeling (agreement with analysis of past USACE surveys). The LFI channel is narrow and shallow and follows deep water, thereby it wouldn't be expected to remain navigable. Additionally, the side-cast dredgers work the outer channel and their movement of material is negligible from a sediment transport perspective. Federal channel dredging has been absent for up to a year in recent history. For example, in 2012 the inlet buoys were pulled for 36 weeks due to lack of federal dredging (the channel remained navigable for 3 - 4 months prior to the last LFI dredging event, therefore 36 weeks + ~3.5 months = a year). Similar long-term events have also occurred where the Coast Guard has needed to pull the buoys from the inlet. Due to the lack of consistent federal funding and the fact that several model runs of different channel alignments showed no significant effect on the shoreline and sediment transport processes, the four-year Alternative 2 model run did not include the LFI maintenance dredging. Additionally, all long-term four-year modeled runs were run under similar conditions in order to compare "apples to apples." Stopping the different model runs to "dredge" a 150-ft wide channel following deep water every 3 months would be impractical to implement for every single run, especially considering that sidecasting this small channel was modeled for several 1-yr simulations and shown to be insignificant on shoreline and sediment transport processes.

In the absence of maintenance dredging, sediment deposition in the Permit Area AIWW/LFIX navigation channels rapidly reduces their water volume capacity, thereby restricting tidal flow and reducing the inlet tidal prism (the “tidal prism” refers to the combined total volume of water that flows in and out of the inlet during a single ebb/flood tidal cycle). Model-simulated tidal prism volumes across transects located in the inlet throat, Eastern Channel, AIWW East channel, and AIWW West channel are steadily reduced over the course of the four-year model simulation period (Table 5.7). By the end of Year 4, the projected volumes are reduced 20 to 90 percent relative to the starting Year-0 condition. The reduction of tidal flow is most extreme in the AIWW West channel, where the extent of model-projected shoaling at the end of Year 4 is such that flow is essentially completely restricted at low tide. As flow is reduced through the navigation channels, extensive shoaling occurs in the adjacent estuarine waters bordering the AIWW West channel and the Eastern Channel. By the end of Year 4, shoaling across the mouth of the Lockwoods Folly River has reached the extent that tidal flow between the river and the AIWW is almost completely restricted at low tide. Most of the outer LFI navigation channel has filled in by the end of Year 4, and the inlet throat ebb channel has shifted westward in response to westward expansion of the Flood Shoal. The Flood Shoal has a natural propensity for westward expansion; a characteristic that is normally kept in check by maintenance dredging

Table 5.7. Alternative 2 model-simulated tidal prism volumes (100 mcf).

Year	Inlet		AIWW West		AIWW East		Eastern Channel	
	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb
Spring Tide								
0	4.24	3.68	0.52	0.13	2.19	2.14	0.54	0.69
1	4.02	3.74	0.33	0.27	2.07	1.96	0.55	0.64
2	3.68	3.69	0.22	0.22	1.95	1.83	0.56	0.65
3	3.28	3.05	0.16	0.15	1.84	1.74	0.52	0.49
4	2.79	2.88	0.12	0.14	1.75	1.64	0.31	0.46
Neap Tide								
0	2.90	2.43	0.40	0.16	1.57	1.47	0.34	0.38
1	2.73	2.33	0.25	0.20	1.47	1.34	0.36	0.34
2	2.39	2.19	0.11	0.10	1.37	1.23	0.35	0.35
3	2.07	1.83	0.07	0.08	1.36	1.21	0.25	0.24
4	1.71	1.62	0.04	0.04	1.18	1.06	0.18	0.22

of the LFIX and LFI navigation channels. However, in the absence of navigation dredging, the Flood Shoal reverts to its natural accretional pattern.

Cumulative Impacts

Although not accounted for in the modeling analyses, federal maintenance dredging of the Permit Area navigation channels would be expected to continue under a regime similar to that of current operations, thus slowing the projected Flood Shoal/ebb channel response described above. However, the federally authorized LFI navigation project stipulates that dredging must follow the path of the deep-water ebb channel as it exists at the time of maintenance events. Unimpeded erosion of the East End shoreline would lead to an accelerated rate of westward channel migration during the interim periods between maintenance events, thus potentially resulting in a gradual incremental westward shift in the channel position towards Holden Beach. Therefore, it is anticipated that hydrodynamic conditions could eventually approximate those projected by the model.

<u>Sediment Suspension, Underwater Noise, and Entrainment</u>

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would not include dredging or any other in-water activities; and therefore, no direct, indirect, or cumulative impacts related to sediment suspension, underwater noise, or entrainment would be expected.

5.4.2.3 Oceanfront Beach and Dune Communities

Intertidal Beach Communities

Direct Impacts

Under Alternative 2, the demolition and relocation of structures would potentially include operations by heavy machinery on the beach; potentially resulting in minor direct impacts on intertidal beach communities through mechanical substrate disturbance. However, demolition and relocation projects would occur individually; and therefore, the extent of direct impacts at any given time would be negligible.

Indirect Impacts

Under Alternative 2, the CMS model-projected oceanfront shoreline responses along the east end of Holden Beach and the west end of Oak Island primarily reflect the influence of natural background processes of erosion and accretion. On Holden Beach, the projected shoreline and intertidal beach habitat changes along the easternmost ~1,000-ft section of the oceanfront beach are dominated by shoal attachment along the inlet shoulder. As a result of shoal attachment, the eastern 1,000-ft reach is net accretional at the end of four-year model simulation period, resulting in a net gain of ~2 ac of intertidal beach habitat (Figure 5.13). The remainder of the East End oceanfront shoreline to the west (~5,500-ft) is erosional throughout the model simulation period, resulting in a net loss of ~14 ac of intertidal beach habitat at the end of Year 4. Additionally, ~5 ac of intertidal beach habitat are added to the western reach through erosional dry beach-to-intertidal beach habitat conversion. Thus, the overall projected intertidal beach habitat change on Holden Beach is a net loss of ~7 ac at the end of Year 4. On Oak Island, the entire Permit Area west-end oceanfront beach is erosional throughout the model simulation period, resulting in a net loss of ~10 ac of intertidal beach habitat at the end of Year 4. Although not specifically modeled, beach nourishment operations under the No Action alternative would be similar to those associated with Alternative 3, which results in a model-projected loss of ~3 ac of East End intertidal beach habitat at the end of Year 4. Thus, the modeling results suggest that the extent of East End intertidal beach habitat loss under Alternative 2 (~7 ac) would exceed that of the No Action alternative by ~4 ac.

Cumulative Impacts

In the absence of beach management, cumulative effects on the East End beach would be driven by natural erosional processes and sea level rise. As the receding shoreline begins to threaten oceanfront structures, it is assumed that the response of most property owners would include the placement of sandbags. The placement of sandbags would temporarily impede shoreline recession; however, continued shoreface erosion would cause the intertidal beach to gradually steepen and narrow. This process would be expected to accelerate as sea level continues to rise, leading to the failure of existing oceanfront sandbags and the stepwise placement of new sandbags along landward properties. Under a scenario of continued

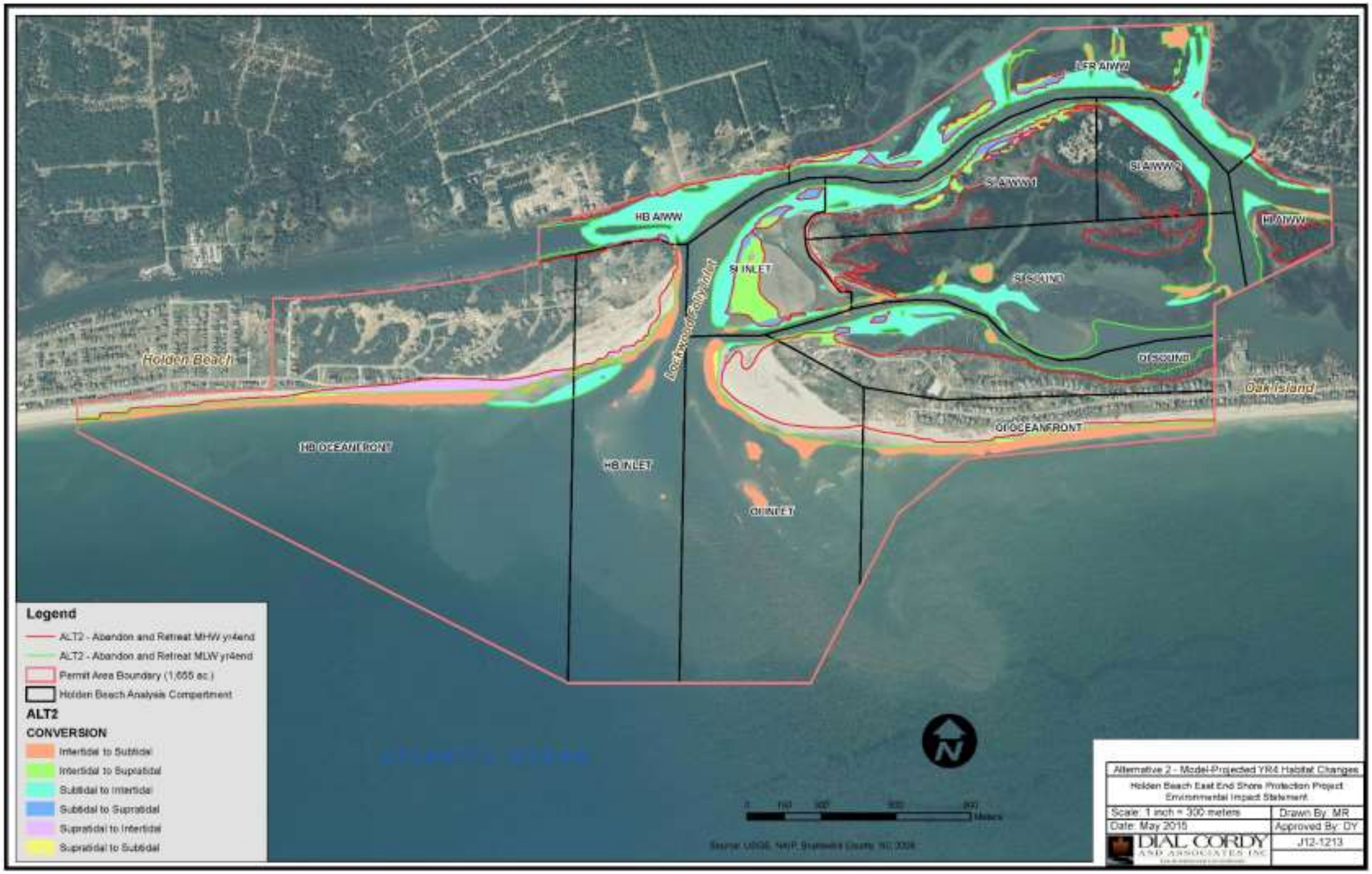

Figure 5.13. Alternative 2 – Model-Projected YR4 Habitat Changes

shoreface erosion without island migration, it is expected that most of the intertidal beach would eventually be converted to subtidal soft bottom habitat. Thus, Alternative 2 would be expected to have adverse cumulative effects on intertidal beach communities via habitat loss.

Dry Beach and Dune Communities

Direct Impacts

As indicated above, the demolition and/or relocation of structures would potentially include operations by heavy machinery on the beach; potentially resulting in minor direct impacts on dry beach and dune communities. Construction contracts would specify avoidance of dunes and dune vegetation to the maximum extent practicable, and any unavoidable or accidental damage to dunes or dune vegetation would require restabilization via replanting with native dune vegetation. Demolition and relocation projects would occur individually; resulting in minor localized disturbance to unvegetated beach sediments that would not be expected to have significant adverse erosional effects. Therefore, it is anticipated that the extent of direct impacts would be negligible.

Indirect Impacts

Under Alternative 2, the CMS modeling results indicate erosional losses of ~5 ac of dry beach and dune habitat along the easternmost ~4,000-ft reach of the Holden Beach oceanfront shoreline (Figure 5.13). To the west along the remaining ~2,500-ft of the East End beach, there is no change in the MHW line position, and thus no projected loss or gain of dry beach habitat. In the case of Oak Island, the modeling results show a relatively minor and irregular landward shift in the MHW line, resulting in erosional losses of ~3 ac of dry beach habitat at the end of Year 4. Although not specifically modeled, beach nourishment operations under the No Action alternative would be similar to those associated with Alternative 3, which results in a model-projected loss of ~3 ac of East End dry beach and dune habitat at the end of Year 4. Thus, the modeling results suggest that the extent of East End dry beach and dune habitat loss under Alternative 2 (~5 ac) would exceed that of the No Action alternative by ~2 ac.

Cumulative Impacts

Potential cumulative effects on dry beach and dune communities would be similar to those described above for the intertidal beach. Under a scenario of continued shoreface erosion with island migration, it is expected that most of the dry beach and dune system would eventually be converted to subtidal soft bottom habitat. Thus, Alternative 2 would be expected to have adverse cumulative effects on dry beach and dune communities via habitat loss.

5.4.2.4 Inlet Complex

<u>Intertidal Flats and Shoals</u>

Direct Impacts

Under Alternative 2, demolition and/or relocation activities would be shore-based and limited to the oceanfront beach. Therefore, direct impacts on intertidal flats and shoals would not be expected under Alternative 2.

Indirect Impacts

Although small, short-lived, emergent shoals occasionally form along the margins of the ebb channel near the mouth of the inlet throat, the interior Flood Shoal is the only persistent intertidal flat/shoal feature associated with the LFI/LFIX complex. The CMS model-projected Flood Shoal response under Alternative 2 is characterized by westward accretional growth, resulting in the creation of ~11 ac of new intertidal shoal habitat (Figure 5.13). In addition, large volumes of sediment are deposited on the existing intertidal flood shoal, resulting in ~9 ac of intertidal-to-supratidal shoal habitat conversion. Thus, the modeling results suggest a net increase in intertidal flood shoal habitat of ~2 ac at the end of Year 4. The flood shoal has a natural propensity for westward expansion; a characteristic that is normally kept in check by maintenance dredging of the LFIX and LFI navigation channels. However, due to the exclusion of navigation dredging in the model simulations, the flood shoal reverts to its natural westward accretional pattern.

The majority of the Holden Beach inlet shoreline is erosional throughout the model simulation period, resulting in a loss of ~7 ac of intertidal inlet beach habitat at the end of Year 4; however, shoal attachment along the inlet shoulder adds ~3 ac of intertidal inlet beach habitat along the southernmost ~700-ft inlet shoreline reach (Figure 5.13). The entirety of the Oak Island inlet shoreline is erosional throughout the model simulation period, resulting in a projected loss of ~7 ac of intertidal inlet beach habitat at the end of Year 4. Much of the projected intertidal inlet beach habitat loss on Holden Beach and Oak Island is related to the exclusion of navigation dredging in the model simulations and the resulting process of westward flood shoal expansion and related effects on the alignment of the inlet throat ebb tidal channel. The westward-expanding flood shoal pushes the inlet throat ebb channel westward, accelerating erosion and habitat loss on Holden Beach. Flood shoal expansion also pushes the mouth of the Eastern Channel slightly southward, redirecting flow towards the western tip of Oak Island; while at the same time the southern segment of the inlet throat ebb channel adopts a straighter north-south alignment, resulting in an eastward channel shift towards the Oak Island inlet shoreline.

Cumulative Impacts

Long-term unmitigated erosion of the East End shoreline in combination with sea level rise could affect inlet hydrodynamics and ebb channel migration. Changes in ebb channel alignment could in turn alter patterns of erosion, accretion, and shoaling within the inlet; thereby leading to the reconfiguration of intertidal habitats. However, continued federal navigation dredging of the inlet ebb channel would limit the potential for rapid ebb channel changes, and it is assumed that the inlet would eventually return to a state of equilibrium. Thus, cumulative effects on intertidal flats and shoals would not be expected under Alternative 2.

<u>Inlet Dry Beach and Dune Communities</u>

Direct Impacts

Under Alternative 2, demolition and relocation activities would be limited to the oceanfront beach; therefore, direct impacts on inlet dry beach and dune communities would not be expected. Construction contracts would specify avoidance of dunes and dune vegetation to the maximum extent practicable, and any unavoidable or accidental damage to dunes or dune vegetation would require restabilization via replanting with native dune vegetation. Demolition and relocation projects would occur individually; resulting in minor localized disturbance to unvegetated beach sediments that would not be expected to have significant adverse erosional effects.

Indirect Impacts

The modeling results show little change in the MHW line positions associated with the Holden Beach and Oak Island inlet shorelines. In the case of both Holden Beach and Oak Island, relatively minor recession of the MHW line results in a loss of ~1 ac of dry inlet beach habitat at the end of the four-year model simulation period (Figure 5.13). As described above, sediment deposition on the existing intertidal flood shoal results in ~9 ac of intertidal-to-supratidal shoal habitat conversion. An additional ~4 ac of supratidal shoal habitat is added to the flood shoal through the process of westward accretion described above, resulting in an overall projected supratidal shoal habitat increase of ~13 ac at the end of Year 4.

Cumulative Impacts

Potential cumulative effects on inlet dry beach and dune communities would be similar to those described above for the intertidal flats and shoals. Unmitigated East End erosion and sea level rise could affect inlet hydrodynamics, thereby leading to the reconfiguration of inlet dry beach and dune habitats. However, continued federal navigation dredging of the inlet ebb channel would limit the potential for rapid ebb channel changes, and it is assumed that the inlet would eventually return to a state of equilibrium. Thus, cumulative effects on inlet dry beach and dune communities would not be expected under Alternative 2.

5.4.2.5 Estuarine Resources

Shellfish

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would not include dredging or any other in-water activities; and therefore, would not be expected to have any direct, indirect, or cumulative impacts on shellfish.

SAV

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would not include dredging or any other in-water activities, and therefore, would not be expected to have any direct, indirect, or cumulative impacts on SAV.

Tidal Marsh Communities

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would not include dredging or any other in-water activities, and therefore, would not be expected to have any direct, indirect, or cumulative impacts on tidal marshes.

5.4.2.6 Threatened and Endangered Species

North Atlantic Right Whale and Humpback Whale

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would not include dredging or any other activity that would generate underwater noise or vessel traffic; and therefore, Alternative 2 would not have any direct, indirect, or cumulative impacts on right or humpback whales or proposed right whale critical habitat.

West Indian Manatee

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would not include dredging or any other activity that would generate vessel traffic or affect potential manatee foraging habitats; therefore, Alternative 2 would not have any direct, indirect, or cumulative impacts on the West Indian manatee.

Piping Plover

Direct, Indirect, and Cumulative Impacts

Under Alternative 2, demolition and relocation activities could include operations by heavy machinery on the East End oceanfront beach; temporarily displacing shorebirds and potentially resulting in minor short-term habitat disturbance. However, wintering piping plovers are very rarely seen on developed oceanfront beaches in NC (Cameron 2009). Similarly, piping plover breeding sites on NC's developed barrier islands are restricted to inlet habitats associated with the accreting ends of the islands (USFWS 2009). Sand flat and emergent shoal habitats associated with the Oak Island sand spit and the flood shoal are designated critical habitat for the Atlantic Coast wintering population of piping plovers; however, these areas are located on the opposite (eastern) side of the LFI channel at a minimum distance of ~0.5 mile from the eastern terminus of the Holden Beach oceanfront shoreline. Therefore, East End relocation and demolition activities under Alternative 2 would not be expected to have any direct, indirect, or cumulative impacts on piping plovers or potential habitat. In the absence of efforts to mitigate East End erosion, unimpeded shoreline recession would be expected to initially reduce the quality and quantity of potential piping plover habitats associated with the Holden Beach inlet shoreline. If all residential structures were removed from the East End of the island, and if ocean-to-sound overwash (barrier island migration or rollover) was allowed to occur unimpeded, the quality and quantity of potential piping plover habitat could eventually improve. However, this scenario would be considered unlikely during the foreseeable future, as the extent of erosion would not be sufficient to warrant the removal of all houses on the East End. The CMS modeling analysis is limited to a four-year period; and furthermore, the model simulations do not account for federal navigation dredging. Thus, the ability to evaluate potential long-term cumulative effects that might result from unmitigated East End erosion is limited. However, continued federal navigation dredging of the inlet ebb channel would limit the potential for rapid ebb channel changes, and it is assumed that the inlet would eventually return to a state of equilibrium. Thus, cumulative effects on piping plovers would not be expected under Alternative 2.

Red Knot

Under Alternative 2, demolition and relocation activities could result in short-term displacement of red knots from East End intertidal beach foraging habitats. Unmitigated erosion under Alternative 2 may affect red knots indirectly via a reduction in available beach foraging and roosting habitats. The CMS modeling results show a reduction in intertidal beach habitat of ~7 ac and a reduction in dry beach habitat of ~5 ac along the East End shoreline at the end of Year 4. As described in Section 5.4.2.3, under a long-term scenario of continued shoreface erosion without island migration, it is expected that most of the intertidal and dry beach habitats along the East End would eventually be converted to subtidal soft bottom habitat. Thus, adverse cumulative effects would be expected via loss of potential foraging and roosting habitat.

Wood Stork

Alternative 2 would not be expected to have any effect on nesting sites or estuarine foraging habitats. Therefore, no direct, indirect, or cumulative impacts on wood storks would be expected under Alternative 2.

Sea Turtles

Direct, Indirect, and Cumulative Impacts

The CMS modeling results show a reduction in dry beach habitat of ~5 ac along the East End shoreline at the end of Year 4. The reduction in dry beach habitat, as a result of natural island roll over, would be expected to have adverse indirect effects on sea turtles via a reduction in available nesting habitat. The USFWS is proposing to designate portions of North Carolina beaches as critical habitat for the Northwest Atlantic population of loggerhead sea turtles. Based on our current knowledge of the physical or biological features and habitat characteristics required to sustain the species' life-history processes, the USFWS has proposed that the terrestrial primary constituent elements specific to the Northwest Atlantic Ocean DPS of the loggerhead sea turtle are: (1) Primary Constituent Element 1- Suitable nesting beach habitat that has (a) relatively unimpeded nearshore access from the ocean to the beach for nesting females and from the beach to the ocean for both post-nesting females and hatchlings and (b) is located above MHW to avoid being inundated frequently by high tides. (2) Primary Constituent Element 2- Sand that (a) allows for suitable nest construction, (b) is suitable for facilitating gas diffusion conducive to embryo development, and (c) is able to develop and maintain temperatures and a moisture content conducive to embryo development. (3) Primary Constituent Element 3- Suitable nesting beach habitat with sufficient darkness to ensure nesting turtles are not deterred from emerging onto the beach and hatchlings and post-nesting females orient to the sea.

As described in Section 5.4.2.3, under a long-term scenario of continued shoreface erosion without island migration, it is expected that most of the East End dry beach would eventually be converted to subtidal soft bottom habitat. Thus, adverse cumulative effects would be expected via loss of potential nesting habitat.

Atlantic and Shortnose Sturgeons

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would not include dredging or any other activity that would present a risk of direct physical injury to sturgeon or affect potential benthic foraging habitats; and therefore, no direct, indirect, or cumulative impacts on Atlantic or shortnose sturgeons would be expected.

Seabeach Amaranth

Direct, Indirect, and Cumulative Impacts

Under Alternative 2, the potential direct, indirect, and cumulative impacts on seabeach amaranth would be similar to those described above for the red knot and sea turtles. Short- and long-term reductions in available dry beach habitat along the East End would be expected to have adverse indirect and cumulative effects on seabeach amaranth.

5.4.2.7 Cultural Resources

Direct, Indirect, and Cumulative Impacts

Actions taken under Alternative 2 would not include dredging or any other activity that would potentially affect underwater archaeological resources; therefore, no direct, indirect, or cumulative impacts on cultural resources would be expected.

5.4.2.8 Public Interest Factors

Public Safety

Direct, Indirect, and Cumulative Impacts

The managed retreat plan would establish an erosional threshold that would trigger preemptive relocations or demolitions of threatened structures prior to the point of imminent structural failure. As with any construction activity involving the use of heavy machinery, operations would present a minor short-term risk to public safety. However, operations would be confined to the winter months to the extent possible, thus limiting public exposure to construction activities. Therefore, no direct, indirect, or cumulative impacts on public safety would be expected under Alternative 2.

Aesthetics and Recreation

Direct, Indirect, and Cumulative Impacts

During relocation and demolition activities, the presence of construction equipment and demolition debris on or adjacent to the beach, as well as the associated emissions of noise, would temporarily diminish the aesthetic quality of the East End beach. However, operations would be confined to the winter months to the extent possible, thus limiting the extent of public exposure to adverse effects. Furthermore, demolition and relocation projects would occur individually; therefore, the extent and duration of direct impacts at any given time would be negligible. Unimpeded erosion would result in a narrow chronically-eroded East End beach, thus diminishing the aesthetic quality of the beach and reducing recreational opportunities. As the receding shoreline begins to threaten oceanfront structures, it is assumed that the response of most property owners would include the placement of individual sandbags. The placement of sandbags would temporarily impede shoreline recession; however, continued shoreface erosion would cause the intertidal beach to gradually steepen and narrow. Under a scenario of continued shoreface erosion without island migration, it is expected that most of the beach would eventually be converted to subtidal bottom. Thus, Alternative 2 would be expected to have adverse cumulative effects on aesthetics and recreation via the placement of sandbags and loss of the recreational beach.

Navigation

Direct, Indirect, and Cumulative Impacts

Federal maintenance dredging of the Permit Area navigation channels would be expected to continue under a regime similar to that of current operations (does not include bend widener). Therefore, no direct, indirect, or cumulative impacts on navigation would be expected under Alternative 2.

Infrastructure

Direct, Indirect, and Cumulative Impacts

Under Alternative 2, the CMS model-projected response of the developed East End oceanfront beach is one of recession throughout the four-year simulation period. By the end of Year 4, the MHW line between Avenue B and the eastern terminus of McCray Street (~1,700 linear ft) has migrated landward of the existing primary dune, resulting in impacts to 28 oceanfront properties and ~800 ft of roads and associated linear utilities (Figure 5.14).

Economics

The costs associated with Alternative 2 would pertain to loss of property and infrastructure, risk to property owners, and the costs associated with the relocation/demolition of homes and infrastructure. Additional costs would be associated with loss of recreational opportunities, loss of habitat and effects on species. Potential erosional impacts to properties and infrastructure were projected based on the model-predicted shoreline changes. Specifically, properties and infrastructure that fall within 25 ft of the model-projected MHW at the end of the four-year simulation were considered to be impacted. Costs associated with these impacts were based on the assessed tax value of properties and the estimated cost of infrastructure replacement (see Appendix M). Under Alternative 2, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~1,700 linear ft) has migrated landward of the primary dune at the end of Year 4, resulting in impacts to 28 properties (19 improved) and ~800 linear ft of roads and associated water, sewer, and power lines (Figure 5.14). The total assessed value of all properties protected under Alternative 2 is roughly $5.2 million. The 800 linear feet of anticipated infrastructure replacement cost is valued at approximately $617,782, with a present value ranging from approximately $489,341 (6% discount rate) to $559,680 (2.5% discount

Figure 5.14. Alternative 2 – Projected Properties at Risk and Infrastructure Impacts at YR4 End

rate). As the market capitalizes the expectation of continued shoreline erosion into the value of at-risk properties, market values may be driven toward zero (Landry 2011). Inland relocation of structures may offset some of these losses, but would involve nontrivial transition costs. A portion of the lost market value may transfer to properties located farther inland; however, a strategy of retreat is likely to convey an expectation of risk to newly beachfront properties, thereby offsetting most of the gains in amenity value. While proximity benefits associated with recreation and aesthetics will likely accrue to some property owners in the near term, it is unlikely that such values would be permanently capitalized into market values due to long term uncertainty and risk of future losses.

As a result of extensive shoreline erosion and associated losses of recreational beach area and natural habitats under Alternative 2, use and non-use values associated with recreation, aesthetics, and the natural environment are expected to be diminished relative to all other alternatives (Table 5.8). In addition, nontrivial losses of aesthetic appeal due to noise, equipment, and congestion would occur during the transition process, which would be expected to persist for the duration of the landward shift of the shoreline. Conversely, as noted by Judge et al. (1995), some individuals have a preference for non-intervention approaches that allow unimpeded erosion to take place. These individuals may derive real economic value from the existence of unfettered coastal ecosystems and natural processes. The timing, nature, and extent of these potential future benefits are difficult to characterize; however, in a sample of NC beachgoers, a majority favored beach nourishment as a means of maintaining beach width while 18 percent felt that beach width should not be altered by people (Whitehead et al. 2008).

5.4.3 Alternative 3: Beach Nourishment

Under Alternative 3, the East End beach would be nourished with ~100,000 – 150,000 cy of sand every two years. The conceptual beach profile at the completion of nourishment events would consist of a +9 ft NAVD high dune with a 50-ft-wide crest, a +7 ft NAVD high, 200-ft-wide berm, and a 90- to 170-ft-wide transition with a slope of ~15 percent. The corresponding borrow site dredging regime would involve the extraction of ~120,000 – 180,000 cy of sand from the LFIX and 400-ft bend widener navigation channels every two years. In the event of a shortfall in available sand volume in the LFIX/bend widener channels, supplemental beach fill would be acquired firstly from the inland segment of the LFI navigation channel and secondarily from the Central Reach offshore borrow site. Sand extraction from the LFIX, bend widener, and inland LFI channels would be conducted by cutterhead pipeline dredges; whereas operations at the Central Reach offshore borrow site would involve the use of a trailing suction hopper dredge.

5.4.3.1 Marine Benthic Resources

<u>Soft Bottom Communities</u>

Dredging Impacts

Direct Impacts

The anticipated borrow site dredging regime under Alternative 3 would involve the extraction of ~120,000 – 180,000 cy of sand from the LFIX and bend widener channels every two years. The direct impacts of dredging on soft bottom benthic communities in the LFIX and bend widener

Table 5.8. Alternative 2 scope of costs and benefits.

Costs (Relative to Status Quo)	
Construction and Maintenance	$0
Construction and Maintenance (Present Value)	$0
Parcels affected	28
Assessed Tax Value of Affected Parcels	5.18 M
Infrastructure Replacement Costs	$617,782
Infrastructure Replacement Costs (Present Value)	$489,341 - $559,680
Reduction in tax base	Highest
Transition costs	Highest
Diminished recreation value	Highest
Diminished aesthetic value	High
Environmental Damage	
Public non-use value losses (nature)	Low
Public non-use value losses (Holden Beach)	Highest
Benefits (Relative to Status Quo)	
Reduction in future nourishment expense	N/A
Enhanced property value	None
Enhanced Recreation value	Lowest
Environmental Improvement	
Public non-use value (nature)	Highest
Public non-use value (Holden Beach)	None

channels would be similar to those described under the No Action alternative. However, the bend widener would be dredged more frequently under Alternative 3, thus increasing the frequency of repeated dredging impacts on the associated benthic communities relative to the No Action alternative. LFIX/bend widener dredging events under Alternative 3 could include the adjoining inland LFI navigation channel as a supplemental sand source, resulting in additional direct impacts on soft bottom communities. In the case of the inland LFI channel, the overall frequency of project-related and interim federal navigation dredging under Alternative 3 would be similar to that of current operations; therefore, direct impacts on the associated benthic communities would not increase relative to the No Action alternative.

Supplemental dredging at the Central Reach offshore borrow site would only be expected in the case of a shortfall in the combined available sand volume in the LFIX, bend widener, and inland LFI channels. Therefore, it is anticipated that the frequency and extent of dredging operations at the Central Reach borrow site over the course of the 30-year project would be very limited. Dredging operations at the Central Reach borrow site would involve thin layer (~3.5 ft) sediment removal by a hopper dredge. At a dredge cut depth of 3.5 ft, extraction of ~120,000 – 180,000 cy of sand would directly impact ~30 ac of soft bottom habitat. Dredging would remove most of the associated benthic invertebrate infauna and epifauna; resulting in an initial sharp reduction in community levels of abundance, diversity, and biomass within the active dredging footprint. Offshore soft bottom benthic communities are also generally dominated by opportunistic taxa that recover relatively rapidly from disturbance (Posey and Alphin 2002). However, in comparison to shallow nearshore and inshore soft bottom habitats, which are subject to frequent natural disturbance, offshore soft bottom habitats occur at much greater depths and are generally more stable. Consequently, offshore benthic assemblages generally include additional longer-lived invertebrate taxa that require longer recovery periods to reach pre-impact biomass levels. Reported rates of recovery at offshore borrow sites range from a few months to three years (Wilber and Clarke 2007). Generally, reports of relatively long recovery periods (>1 year) have been associated with fine silt/clay sediment deposition in relatively deep borrow pits; whereas relatively short recovery periods (<1 year) have generally been associated with shallow borrow pits that were rapidly infilled by sandy sediments of similar composition to the extracted material (Burlas et al. 2001). Posey and Alphin (2002) attributed relatively rapid (<9 months) recovery at ocean borrow sites along Kure Beach to rapid infilling of relatively shallow dredge cuts and avoidance of spring benthic invertebrate larval recruitment periods. Jutte et al. (1999b) attributed rapid benthic community recovery (6-9 months) in relatively shallow (~3 ft) hopper dredge furrows to the retention of benthic invertebrates on undisturbed intervening ridges, which provided an immediate source of potential recruits that likely contributed to rapid recolonization. In the case of potential hopper dredging at the Central Reach offshore borrow site, the relatively shallow (~3.5 ft) cut depths would be expected to facilitate rapid infilling of the furrows by compatible sandy sediments. Furthermore, the proposed hopper dredging environmental window (16 November - 31 March) would necessitate avoidance of spring benthic invertebrate larval recruitment periods, thus increasing the chances of relatively rapid recolonization via larval recruitment. Therefore, it is expected that offshore benthic communities would recover relatively rapidly from dredging.

Indirect Impacts

Under Alternative 3, the indirect impacts of dredging operations in the LFIX, bend widener, and inland LFI channels would be similar to those described under the No Action alternative. However, each of the additional bend widener dredging events under Alternative 3 would result in an additional period of suppressed benthic infaunal prey densities; thus increasing the overall temporal extent of indirect prey-loss effects on demersal fishes. In the event of supplemental dredging at the Central Reach offshore borrow site, indirect impacts on soft bottom communities would be similar to those associated with dredging in the inshore channels; including potential indirect effects related to the redeposition of suspended sediments and losses of benthic infaunal prey. Prolonged sediment suspension and widespread dispersal are associated with fine silt/clay particles that have relatively slow settling velocities; whereas sands and gravels that make up the coarse-grained sediment fraction resettle rapidly in the immediate vicinity of the dredge before they can be transported offsite (Schroeder 2009). Sediments associated with the Central Reach borrow site are composed of medium sand (mean grain size = 0.35 mm) with a very small (~5 percent) fine sediment fraction, thus indicating that the effects of dredging-induced sediment suspension and redeposition would be localized and relatively minor.

Dredging operations at the Central Reach borrow site would employ hopper dredges, which have relatively high sediment suspension rates, primarily due to the discharge of sediments at the surface during overflow dredging (LaSalle et al. 1991). However, even during overflow hopper dredging, sediment suspension is localized and short term when the dredged material is composed of clean sand with a small fine sediment fraction. A turbidity monitoring study by Miller et al. (2002) found that the turbidity plume associated with overflow hopper dredging in coarse-grained sediments (97 percent sand) was confined to the dredged navigation channel. Furthermore, suspended sediment concentrations in the channel returned to ambient levels within one hour of the passing of the dredge, and the range of observed turbidity levels during the project fell within the range of pre-project ambient turbidities. Based on the composition of sediments at the Central Reach borrow site and the reported characteristics of sediment suspension during overflow hopper dredging, it is anticipated that the indirect effects of dredging-induced sediment suspension and redeposition on soft bottom communities would be localized and minor. Potential indirect prey-loss effects on demersal fishes at the Central Reach borrow site would be similar to those associated with dredging in the LFIX, bend widener, and inland LFI channels. Based on the relatively small dredging footprint (~30 ac), the limited overall extent of anticipated dredging over the 30-year project life, and the expansive distribution of ocean soft bottom habitats along Holden Beach and Oak Island; it is anticipated that any indirect impacts on demersal fishes would be localized and minor.

Cumulative Impacts

Under Alternative 3, the potential for temporally-crowded cumulative effects would be related to the frequency of repeated dredging impacts on soft bottom communities within the project-related dredging areas. Specifically, temporally-crowded cumulative effects would be considered likely if the intervals between repeated dredging events at a specific borrow site were insufficient in length to allow for full recovery of benthic communities. In the case of the LFIX and inland LFI channels, the overall frequency of project-related and interim federal navigation dredging would be similar to that of current operations; therefore, temporally-crowded cumulative impacts would be similar to those described under the No Action alternative. Project-related bend widener dredging events under Alternative 3 would occur every two years, whereas benthic communities in dredged channels typically recover in a matter of months. Separate dredge and fill actions affecting benthic communities at the bend widener would not be expected during the 30-year project; therefore, temporally-crowded cumulative effects would not be expected under Alternative 3. The frequency and extent of dredging operations at the Central Reach offshore borrow site over the course of the 30-year project would be very limited; furthermore, the relatively thin compatible sand layer would not be expected to support multiple extractions from the same dredging footprint. Separate actions affecting benthic communities at the Central Reach borrow site would not be expected during the 30-year project; therefore, temporally-crowded cumulative effects would not be expected under Alternative 3.

Spatially-crowded cumulative effects would be related to the overall combined effect of multiple individual dredging-induced soft bottom community impacts in spatially-separate dredging areas; including the project-related borrow areas and dredging areas associated with separate actions. Dredging operations in separate federal navigation channels, including segments of the AIWW behind Holden Beach and Oak Island and the outer LFI navigation channel, could occur in close temporal proximity to project-related and interim federal dredging activities in the LFIX/bend widener and inland LFI channels. Concurrent reductions in benthic invertebrate densities within the LFIX/bend widener, inland LFI, and separate federal channels could potentially result in spatially-crowded cumulative effects on predatory demersal fishes. However, considering the anticipated rapid rates (≤6 months) of benthic community recovery, it is expected that spatially-crowded cumulative effects on demersal fishes at the community and/or population level would be localized and short term. In the event of supplemental dredging at the Central Reach offshore borrow site, potential separate actions affecting spatially-separate areas of soft bottom habitat would include dredging associated with the 2016/2017 Central Reach nourishment project, the Lockwoods Folly River Habitat Restoration Project, Phase I – Eastern Channel and dredging by the Town of Bald Head Island at Jay Bird Shoals under their proposed long-term beach management plan. Dredging associated with the Central Reach nourishment project would likely occur at least one year prior to the initiation of project-related dredging activities under Alternative 3, thus indicating that impacted soft bottom communities would be substantially recovered at the time of any project-related impacts at the Central Reach borrow site. In the event of concurrent East End/Bald Head Island dredging projects, the relatively small area (~30 ac) of East End project-related dredging impact and the distance (~15 miles) between the Central Reach borrow site and Frying Pan Shoals/Jay Bird Shoals suggest that any spatially-crowded cumulative effects would be negligible.

Beach Nourishment

Direct, Indirect, and Cumulative Impacts

Under Alternative 3, the direct, indirect, and cumulative impacts of beach fill placement on soft bottom communities would be similar to those described under the No Action alternative.

Hardbottom Communities

Direct, Indirect, and Cumulative Impacts

State coastal management regulations prohibit borrow sites within 500 m of hardbottom areas (15A NCAC 07H.0208). The 500-m rule is designed to prevent both direct physical impacts from dredging, as well as indirect impacts related to the dispersal and redeposition of suspended sediments. Exposed hardbottom features are associated with areas of thin sediment cover on the lower shoreface and adjacent inner continental shelf, which are located well seaward of the beach fill footprint and the LFIX/LFI navigation channels. In the case of the Central Reach offshore borrow site, compliance with the 500-m rule was confirmed through remote sensing surveys conducted in 2011 (Tidewater Atlantic Research 2011). The Central Reach borrow site was subsequently approved and permitted for the Holden Beach Central Reach nourishment project (Appendix N). Potential sand delivery pipeline routes for East End projects have yet to be identified; however, approvals of proposed East End projects would be contingent on pre-project surveys demonstrating avoidance of hardbottom features. Based on the demonstrated absence of hardbottom features within 500 m of the Central Reach offshore borrow site; and the commitment to avoid hardbottom sites during pipeline placement; Alternative 3 would not be expected to have any direct, indirect, or cumulative impacts on hardbottom communities.

5.4.3.2 Water Column

Hydrodynamics

Direct and Indirect Impacts

Under Alternative 3, the potential direct and indirect impacts of dredging operations in the LFIX/bend widener and LFI channels on hydrodynamics would be similar to those described under the No Action alternative. The CMS modeling results suggest that bend widener dredging tends to shift the corresponding LFI ebb channel segment slightly eastward to a more centralized position between Holden Beach and the flood shoal, thus reducing erosion along the northern inlet shoreline of Holden Beach. The projected shift is temporary, with the channel returning to its westward position against the inlet shoreline as rapid shoaling fills in the bend widener. Under Alternative 3, the bend widener would be dredged more frequently; thus generally maintaining a more eastward alignment and reducing the average rate of erosion over the course of the 30-year project relative to the No Action alternative. Ocean depths at the Central Reach offshore borrow site range from ~30 to 35 ft MSL; and therefore, in the case of supplemental dredging, the relatively shallow (~3.5 ft) furrows created by hopper dredging would not be expected to have any effect on wave conditions or wave-driven currents.

The CMS model-projected inlet and estuarine hydrodynamic responses to beach nourishment under Alternative 3 are essentially the same as the projected future without project responses under Alternative 2. Simulated tidal prism volumes and current velocities across transects located in the inlet throat, Eastern Channel, and AIWW east/west channels are consistently within +/-5 percent of the corresponding Alternative 2 values throughout the four-year model simulation period (Table 5.9). The common pattern of hydrodynamic response under the two alternatives is generally one of steadily decreasing tidal prism volumes and current velocities across all four of the inlet/estuarine transects. Corresponding model-projected changes in channel morphology under Alternative 3 are similarly nearly identical to those associated with Alternative 2. The similarity of the responses suggests that the model-projected hydrological and morphological responses under Alternative 3 are primarily the result of natural background coastal processes; thus indicating that beach nourishment would have little effect on hydrodynamics.

Table 5.9. Alternative 3 - relative tidal prism volumes (percentage of corresponding Alternative 2 volumes).

Year	Inlet		AIWW West		AIWW East		Eastern Channel	
	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb
Spring Tide								
0	100%	100%	99%	97%	100%	100%	100%	100%
1	97%	97%	96%	96%	100%	100%	100%	100%
2	97%	96%	96%	79%	100%	100%	99%	100%
3	100%	98%	94%	98%	101%	97%	97%	100%
4	107%	100%	88%	100%	98%	99%	153%	103%
Neap Tide								
0	100%	100%	100%	98%	100%	100%	100%	100%
1	96%	97%	92%	89%	100%	100%	100%	100%
2	97%	92%	94%	97%	100%	101%	99%	75%
3	98%	99%	90%	67%	97%	101%	97%	101%
4	104%	101%	117%	105%	99%	102%	124%	104%

Cumulative Impacts

Under Alternative 3, the CMS modeling results indicate that direct and indirect impacts on hydrodynamic conditions would be limited to short-term, localized effects on the ebb channel in the immediate vicinity of the bend widener. Furthermore, federal navigation dredging practices within the Permit Area and adjacent federal channels would be expected to continue under the current dredging regime. Therefore, cumulative hydrodynamic impacts would not be expected Under Alternative 3.

<u>Sediment Suspension and Turbidity</u>

Direct, Indirect, and Cumulative Impacts

Dredging

Under Alternative 3 the direct, indirect, and cumulative impacts of dredging operations in the LFIX/bend widener and inland LFI channels would be comparable to those described under the No Action alternative. In the event of supplemental dredging at the Central Reach offshore borrow site, the impacts of dredging-induced sediment suspension would be of a similar nature to the impacts of dredging in the inshore channels. Sediments associated with the Central Reach borrow site are similarly composed of medium sand (mean grain size = 0.35 mm) with a very small (~5 percent) fine sediment fraction. Prolonged sediment suspension and extensive turbidity plumes are primarily associated with the suspension of fine silt/clay particles that have relatively slow settling velocities; whereas sands and gravels that make up the coarse-grained sediment fraction resettle rapidly in the immediate vicinity of the dredge before they can be transported offsite (Schroeder 2009). In contrast to the use of cutterhead dredges in the inshore channels, operations at the Central Reach borrow site would employ hopper dredges. Hopper dredges are generally associated with higher rates of sediment suspension, primarily due to the discharge of sediments at the surface during overflow dredging (LaSalle et al. 1991). However, even in the case of overflow hopper dredging, sediment suspension is characteristically localized and short term when the dredged material is composed of clean sand with a small fine sediment fraction. According to Miller et al. (2002), the turbidity plume associated with overflow hopper dredging in coarse-grained (97 percent sand) sediments was confined to the dredged navigation channel. Suspended sediment concentrations in the channel returned to ambient levels within one hour of the passing of the dredge, and the observed range of turbidity levels during dredging operations remained within the range of pre-project ambient turbidities. Therefore, it is anticipated that the extent and duration of dredging-induced sediment suspension at the Central Reach borrow site would be localized and short term; thus indicating that direct and indirect impacts on water quality and pelagic communities would be relatively minor. Based on the short-term, localized nature of the direct and indirect impacts, cumulative impacts would not be expected under Alternative 3.

Beach Fill Placement

Under Alternative 3, beach fill placement operations and the associated direct, indirect, and cumulative effects of sediment suspension on water quality and pelagic communities would be similar to those described under the No Action alternative.

Underwater Noise

Direct and Indirect Impacts

Under Alternative 3, the direct and indirect impacts of underwater dredging noise associated with operations in the LFIX, bend widener, and inland LFI channels would be the same as those described under the No Action alternative. Dredging operations at the Central Reach offshore borrow site would employ hopper dredges. Clarke et al. (2002) reported hopper dredge noise levels ranging from 120 to 140 dB re 1μPa rms at a distance of 40 m during navigation dredging in Mobile Bay, AL. The NMFS (2010b) has cited the study by Clarke et al. (2002) as an appropriate basis for evaluating hopper dredge noise at sand borrow sites, as it involved similar substrate (i.e., sand) and metrics that are consistent (i.e., SPL rms values) with established NMFS marine mammal and sea turtle noise impact thresholds. The NMFS currently uses generic noise exposure thresholds to define two levels of acoustic "take" under the MMPA. Actions that may expose marine mammals to SPL rms noise levels ≥180 dB re 1μPa rms constitute Level A harassment with the potential to cause injury, and actions that may expose marine mammals to impulse noise levels ≥140 dB re 1μPa rms or continuous noise levels ≥120 dB re 1μPa constitute Level B harassment with the potential to cause behavioral disruption. The NMFS has used similar criteria to assess the impacts of dredging noise on sea turtles, specifically ≥180 dB re 1μPa rms for injurious effects, and based on a study by McCauley (2000), ≥166 dB re 1μPa rms for behavioral disruption (NMFS 2010b). Using the Clarke et al. (2002) study as the basis for its noise impact analysis, the NMFS determined that marine mammals within a 794-m radius of the dredge at an offshore borrow site in VA could be exposed to noise levels at or above the Level B harassment threshold for continuous noise (i.e., ≥120 dB re 1μPa rms). In addition, the highest predicted noise level was 164 dB re 1μPa rms at a distance of one meter from the dredge. Current noise exposure thresholds for fishes are limited to interim criteria developed by the Fisheries Hydroacoustic Working Group (FHWG) for impulsive pile-driving noise; consequently, there are no specific criteria for evaluating the potential impacts of continuous dredging noise on marine fishes.

Based on the studies conducted by Clarke et al. (2002) and the NMFS (2010b), hopper dredging at the Central Reach offshore borrow site would not be expected to produce noise levels ≥180 dB re 1μPa rms (i.e., Level A harassment); therefore, dredging would not be expected to result in direct injury to marine mammals or sea turtles. Marine mammals could be exposed to noise levels ≥120 dB re 1μPa rms (Level B Harassment) within an approximate 800-m radius of the hopper dredge. Marine mammals that may be present in the vicinity of the Central Reach borrow site during dredging operations would include Atlantic spotted and bottlenose dolphins, humpback whales, and North Atlantic right whales. The rapid swimming capabilities of dolphins would most likely limit their exposure to noise levels ≥120 dB to very brief periods. The potential effects of dredging noise on the behavior of large whales are not fully known; however, it is assumed that hopper dredging noise could elicit short-term avoidance responses such as diving or an increase in swimming speed. Since large whales are transient within the study area and are not actively engaged in critical feeding or mating behaviors, no significant adverse behavioral effects would be expected. A detailed evaluation of the potential impacts to humpback and right whales under Alternative 3 is included with the assessment of impacts to other federally listed threatened and endangered species in Section 5.4.3.6.

Dredging noise levels would not be expected to reach 166 db re 1μPa rms; therefore, based on the noise thresholds described above, adverse behavioral effects on sea turtles would not be expected. Although the potential for dredging noise to cause injury to fishes is not known, dredging is known to elicit an avoidance response by marine fishes (Larson and Moehl 1990, McGraw and Armstrong 1990). Therefore, it is likely that most fish would move away from the slow-moving (~3 knots) dredge long before they are exposed to potentially injurious noise levels.

Cumulative Impacts

The anticipated effects of underwater dredging noise on marine organisms would be non-injurious, localized, and short term. Therefore, noise-related cumulative impacts would not be expected under Alternative 3.

Entrainment

Direct and Indirect Impacts

Hopper and cutterhead dredges have the potential to entrain fishes and invertebrates during all life cycle phases; including adults, juveniles, larvae, and eggs. Among adult and juvenile fishes, demersal species that inhabit the near-bottom water column environment are most likely to be entrained (Reine and Clarke 1998); however, studies have also reported the entrainment of pelagic fishes in small numbers (McGraw and Armstrong 1990). Entrainment studies indicate that dredging elicits an avoidance response by demersal and pelagic species and that most juvenile and adult fishes are successful at avoiding entrainment (Larson and Moehl 1990, McGraw and Armstrong 1990). Larson and Moehl (1990) also found that adult and juvenile anadromous fishes were less likely to be entrained in large open water bodies as opposed to constricted waterways. Based on the results of these studies, it is assumed that most juvenile and adult finfish would avoid the active dredging zone in response to elevated levels of noise and turbidity, thus avoiding entrainment in the dredge intake pipe. Hopper dredges also have the potential to entrain sea turtles; consequently, the NMFS requires the use of turtle deflecting (rigid deflector) dragheads on hopper dredges. Navigation channel and sand borrow site dredging projects are also generally restricted to the colder months when most sea turtles have moved to warmer offshore waters. A detailed evaluation of the potential dredging-related impacts to sea turtles under Alternative 3 is included in Section 5.5.3.5.

Many of the common marine fishes and invertebrates in NC are estuarine-dependent species that spawn offshore as adults and reside in estuarine nursery areas during juvenile development. The recruitment of ocean-spawned planktonic larvae to estuarine nursery areas is dependent on passive ocean-to-sound transport through tidal inlets. Recruitment studies indicate that larvae accumulate along the beaches in the nearshore ocean zone where they are carried by alongshore currents to laterally adjacent tidal inlets (Churchill et al. 1999). The results of a long-term sampling program at Beaufort Inlet indicate that inlet larval densities are highest from late May to early June and lowest in November (Hettler and Chester 1990). Under Alternative 3, dredging operations at the LFIX/LFI and/or offshore borrow sites would be completed within the proposed dredging window (16 November - 30 April), thus avoiding peak periods of larval ingress through LFI. As described under Alternative 1 (see Section 5.4.1.2), the anticipated maximum volume of water entrained per 24-hr period would equate to 0.0008 percent of the daily (24-hour) spring tidal flow and 0.0012 percent of the daily (24-hour) neap tidal flow through LFI. The results of larval entrainment modeling based on simulated dredging at Beaufort Inlet indicate that entrainment rates are very low regardless of inlet larval concentrations and the distribution of larvae within the water column (Settle 2002). Even under worst case conditions when the dredge is assumed to be operating 24 hours/day and all larvae are assumed to be concentrated in the bottom of the navigation channel, the projected entrainment rate barely exceeds 0.1 percent of the daily (24-hour) larval flux through the inlet. Considering the relatively small volume of water that would be entrained, the low model-projected rates of larval entrainment, and the timing of dredging operations relative to peak larval ingress periods; it is anticipated that the effect of larval entrainment on estuarine-dependent fish and invertebrate populations under Alternative 3 would be negligible.

Cumulative Impacts

It is anticipated that entrainment-related impacts on marine organisms at the community and/or population level would be negligible. Therefore, cumulative impacts related to entrainment would not be expected under Alternative 3.

5.4.3.3 Oceanfront Beach and Dune Communities

<u>Intertidal Beach Communities</u>

Direct Impacts

Under Alternative 3, individual beach fill placement events would directly impact ~13 ac of intertidal oceanfront beach habitat. Direct impacts on physical habitat characteristics and the associated benthic invertebrate infaunal communities would be similar to those described under the No Action alternative.

Indirect Impacts

Initial Beach Fill Placement Effects

Under Alternative 3, indirect impacts associated with the initial placement of beach fill; including temporary sediment suspension and benthic infaunal prey-loss effects; would be similar to those described under the No Action alternative.

Long-Term Model-Projected Effects

Under Alternative 3, the CMS model-projected shoreline and intertidal habitat changes along the Oak Island west-end oceanfront beach (Figure 5.15) are the same as the projected future without project changes under Alternative 2 (Figure 5.13). Under both alternatives, shoreline erosion over the course of the four-year model simulation period results in projected intertidal beach habitat losses of ~10 ac (Table 5.3). The similarity of the responses indicates that the projected shoreline changes and intertidal beach habitat losses under Alternative 3 are primarily the result of natural background coastal processes; thus suggesting that Alternative 3 would not affect intertidal beach habitat on Oak Island. The projected response of the East End oceanfront shoreline on Holden Beach under Alternative 3 is similar in pattern to the projected response under Alternative 2; however, under Alternative 3, the performance of the beach fill is reflected in a wider East End beach. On average, the nourished East End beach at the end of Year 4 is ~19 ft wider than the corresponding East End beach under Alternative 2 (Table 5.4). The corresponding effect on the quantity of intertidal beach under Alternative 3 is an increase of ~4 ac relative to Alternative 2 (Table 5.3).

Cumulative Impacts

Under Alternative 3, potential cumulative impacts on intertidal beach habitats and communities would be similar to those described under the No Action alternative.

<u>Dry Beach and Dune Communities</u>

Direct Impacts

Under Alternative 3, individual beach fill placement events would directly impact ~4 ac of dry oceanfront beach habitat. Direct impacts on physical habitat characteristics and associated dry beach communities would be the same as those described under the No Action alternative. Unlike the No Action alternative, beach nourishment under Alternative 3 would include the reconstruction of eroded dunes. Reconstruction could directly impact up to an additional ~6 ac of dune habitat. The existing dune system consists of a narrow (~75-ft-wide), artificially-constructed, continuous berm. Thus, impacts related to morphological alteration and/or loss of habitat heterogeneity would not be expected. Dune reconstruction would result in temporary losses of dune vegetation and ghost crabs through direct burial and/or mechanical disturbance. Reconstructed dunes would be immediately replanted with native species that are characteristic

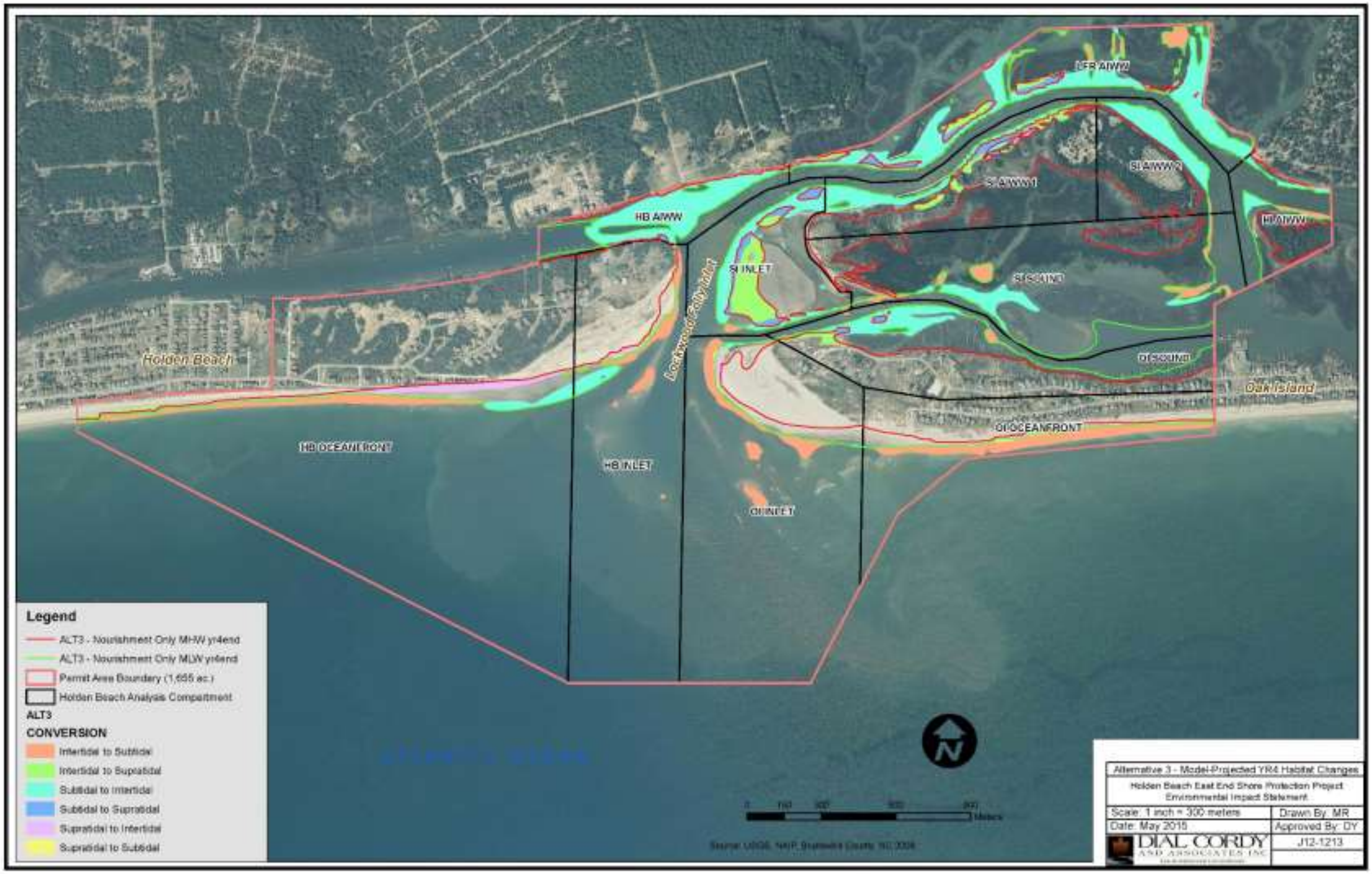

Figure 5.15. Alternative 3 – Model-Projected YR4 Habitat Changes

of natural dune plant communities, thereby facilitating habitat recovery. As in the case of impacts to the dry beach, avoidance of infaunal recruitment periods and the use of compatible sediments would be expected to facilitate relatively rapid recovery of dune communities.

Indirect Impacts

Initial Beach Fill Placement Effects

Under Alternative 3, the potential indirect effects of physical habitat modification, including changes in beach profile morphology and sediment composition, would be similar to those described under the No Action alternative.

Long-Term Model-Projected Effects

As described above, the CMS model-projected responses of the Oak Island west end oceanfront shoreline under Alternatives 3 and 2 are the same. Corresponding dry beach/dune habitat changes on Oak Island under Alternatives 3 (Figure 5.15) and 2 (Figure 5.13) are also the same, with both alternatives resulting in projected losses of ~3 ac (Table 5.3). In the case of Holden Beach, the projected relative increase in beach width under Alternative 3 corresponds to an increase in dry beach/dune habitat of ~2 ac relative to Alternative 2. Thus, the modeling results suggest that Alternative 3 would not affect dry beach/dune habitat on Oak Island, whereas the projected effect of Alternative 3 on Holden Beach is a relative increase of ~2 ac.

Cumulative Impacts

Under Alternative 3, cumulative impacts on dry beach and dune communities would be similar to those described under the No Action alternative.

5.4.3.4 Inlet Complex

<u>Intertidal Flats and Shoals</u>

Direct Impacts

Although small short-lived emergent shoals occasionally form along the margins of the ebb channel at the mouth of the inlet throat, the interior flood shoal is the only persistent intertidal flat/shoal feature associated with the LFI/LFIX complex. Nourishment-related dredging operations would be confined to the existing federally authorized LFIX/bend widener and LFI navigation channels; therefore, direct dredging impacts on intertidal flats and shoals would not be expected under Alternative 3. The eastern extent of beach fill placement may approach the inlet shoulder where small shoals originating along the western margin of the ebb channel have attached in the past; however, chronic erosion generally precludes the formation of any persistent intertidal flat or shoal-like features along the Holden Beach inlet shoulder. Therefore, direct beach fill placement impacts on intertidal flats and shoals would not be expected under Alternative 3.

Indirect Impacts

Under Alternative 3, the LFIX/bend widener and LFI dredging regimes would be similar to current operations; therefore, indirect dredging-induced hydrodynamic effects on flats and shoals would not be expected. Net sediment transport along the East End beach is eastward towards the inlet, and the inlet itself is flood-dominant in terms of sediment transport. Consequently, sand extracted from the LFIX/bend widener channels for East End nourishment purposes would be retained within the inlet system. Therefore, indirect impacts on the flood shoal via modification of the inlet sediment budget would not be expected under Alternative 3.

The CMS model-projected inlet response under Alternative 3 (Figure 5.15) is essentially the same as the projected future without project response under Alternative 2 (Figure 5.13). The only difference between the projected responses is a minor reduction in accretion along the western margin of the flood shoal under Alternative 3, which reduces new intertidal habitat creation by ~1 ac relative to Alternative 2 (Table 5.3). The similarity in responses indicates that the projected inlet changes under Alternative 3 are primarily the result of natural background coastal processes; thus suggesting that Alternative 3 would have little effect on intertidal inlet habitats.

Cumulative Impacts

In the absence of anticipated direct and indirect effects, cumulative impacts on intertidal flats and shoals would not be expected under Alternative 3.

<u>Inlet Dry Beach and Dune Communities</u>

Direct Impacts

Due to the chronically eroded nature of the East End shoreline, the demarcation between the oceanfront beach and the inlet shoreline is poorly defined on Holden Beach. The eastern extent of beach fill placement may encompass short reaches of the transitional southeast-facing oceanfront/inlet shoreline. Under Alternative 3, beach fill placement would result in minor direct impacts on inlet dry beach and dune communities. Direct effects on physical habitat characteristics and dry inlet beach and dune communities would be similar in nature to those described for the oceanfront beach.

Indirect

The potential indirect impacts of beach fill placement on inlet dry beach and dune communities would be similar in nature to those described for the oceanfront beach. Based on the limited spatial extent of beach fill placement along the southeast-facing shoreline, it is anticipated that associated indirect effects would not add measurably to those already described for the oceanfront beach.

As described above, the CMS model-projected inlet response under Alternative 3 (Figure 5.15) is essentially the same as the projected future without project response under Alternative 2 (Figure 5.13). Corresponding inlet dry beach/dune and supratidal shoal habitat changes are also essentially the same, with similar projected gains occurring under Alternatives 3 and 2 (Table 5.3). The similarity of the responses indicates that the projected inlet changes under Alternative 3 are primarily the result of natural background coastal processes; thus suggesting that Alternative 3 would have little effect on inlet dry beach and dune habitats.

Cumulative Impacts

The potential cumulative impacts of beach fill placement on transitional dry beach and dune communities would be similar to those described for the oceanfront beach. Based on the limited extent of direct and indirect impacts, it is anticipated that any associated cumulative impacts would not add measurably to those already described for the oceanfront beach.

5.4.3.5 Estuarine Resources

<u>Shellfish</u>

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 3 on shellfish beds would be the same as those described under the No Action alternative.

<u>SAV</u>

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 3 on SAV would be the same as those described under the No Action alternative.

<u>Tidal Marsh Communities</u>

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 3 on tidal marshes would be the same as those described under the No Action alternative.

5.4.3.6 Threatened and Endangered Species

North Atlantic Right Whale and Humpback Whale

Direct, Indirect, and Cumulative Impacts

Sand extraction dredging operations would potentially coincide with North Atlantic right whale and humpback whale migration periods along the NC coast. Right and humpback whales routinely swim close to shore during winter migration periods along the NC coast; therefore, both species could be present in offshore waters of the Permit Area during potential East End borrow site dredging operations. Dredging can potentially impact large whales through acoustic disturbance and vessel collisions. NMFS currently uses generic noise exposure thresholds to define two levels of acoustic “take” under the MMPA. Actions that may expose marine mammals to root mean square sound pressure levels ≥180 dB re 1μPa rms constitute Level A harassment with the potential to cause injury, and actions that may expose marine mammals to impulse noise levels ≥140 dB re 1μPa rms or continuous noise levels ≥120 dB re 1μPa constitute Level B harassment with the potential to cause behavioral disruption.

Under Alternative 3; the potential direct, indirect, and cumulative impacts of cutterhead dredging operations in the LFIX/bend widener and inland LFI channels would be the same as those described under the No Action alternative. Dredging activities under Alternative 3 could also include limited supplemental hopper dredging at the Central Reach borrow site. Clarke et al. (2002) reported hopper dredge noise levels ranging from 120 to 140 dB re 1μPa rms at a distance of 40 m during navigation dredging in Mobile Bay, AL. The NMFS has used the data collected by Clarke et al. (2002) as the basis for evaluating hopper dredging noise impacts at ocean sand borrow sites, citing the similarity in substrate (i.e., sand) and the use of metrics that are consistent (i.e., SPL rms values) with established marine mammal noise impact thresholds (NMFS 2010b). Based on the results of a noise impact analysis for dredging at an offshore sand borrow site in VA, the NMFS determined that marine mammals within a 794-m radius of the dredge could be exposed to noise levels at or above the Level B harassment threshold for continuous noise (i.e., ≥120 dB re 1μPa rms). The highest predicted sound level was 164 dB re 1μPa rms at a distance of one meter from the dredge, thus indicating that marine mammals would not be exposed to injurious noise levels. Based on these studies, hopper dredging at the Central Reach offshore borrow site would not be expected to produce noise levels ≥180 dB re 1μPa rms (i.e., Level A harassment); and therefore, dredging would not be expected to result in direct injury to right or humpback whales. Right and humpback whales could be exposed to noise levels ≥120 dB re 1μPa rms (Level B Harassment) within an approximate 800-m radius of the hopper dredge. The potential behavioral effects of dredging noise on large whales are not fully known; however, it is assumed that hopper dredging noise could elicit short-term avoidance responses such as diving or an increase in swimming speed. Since large whales are transient within the study area and are not actively engaged in critical feeding or mating behaviors, it is anticipated that behavioral effects would be minor. Considering that the anticipated effects of underwater dredging noise on right and humpback whales would be limited to localized, short-term, behavioral responses; cumulative noise-related impacts would not be expected under Alternative 3.

Instances of lethal whale-dredge interactions (i.e., vessel collisions) have not been documented; however, a non-lethal interaction was reported in 2005 when a hopper dredge collided with an apparent North Atlantic right whale along the GA coast near the Brunswick Harbor entrance channel (NMFS 2012a). The risk of collisions between dredges and large whales during sand extraction at the Central Reach borrow site would be low, as hopper dredges travel at slow speeds (~3 knots) during the active dredging process. The maximum unloaded transit speed of a hopper dredge is ~17 knots; and therefore, the risk of collisions would increase during transit between the borrow site and nearshore pump-out stations. Offshore borrow site dredging contracts would incorporate standard conservation measures to minimize the risk of marine mammal collisions; including speed limits (≤10 knots), 24-hour presence (during active dredging and transit) of protected species observers with at-sea large whale identification experience, and compliance with federal regulations [50 CFR 224.103(c)] prohibiting the approach of any vessel within 500 yards of a right whale. It is anticipated that supplemental dredging at the Central Reach borrow site would be minimal; and considering the relatively small East End beach fill volume requirements, the number of transits between the borrow site and pump-out stations would be low. Considering the anticipated limited extent of offshore dredging, it is expected that the proposed conservation measures would reduce the risk of collisions to negligible levels.

The essential features of proposed critical habitat for the right whale within the Permit Area are those associated with calving habitat; including sea surface temperature, water depth, and sea state (roughness). Dredging and beach fill placement operations under Alternative 3 would not affect any of these essential features; and furthermore, based on the proposed conservation measures described above, supplemental dredging at the Central Reach offshore borrow site would not preclude right whales from accessing or using the proposed critical habitat areas. Therefore, no adverse effects on proposed critical habitat would be expected under Alternative 3.

West Indian Manatee

Direct, Indirect, and Cumulative Impacts

Under Alternative 3, direct; indirect; and cumulative impacts on the West Indian manatee would be the same as those described under the No Action alternative.

Piping Plover

Direct, Indirect, and Cumulative Impacts

Under Alternative 3, direct; indirect; and cumulative impacts on piping plovers would be similar to those described under the No Action alternative.

Red Knot

Under Alternative 3, direct; indirect; and cumulative impacts on the red knot would be similar to those described under the No Action alternative.

Wood Stork

Under Alternative 3, direct; indirect; and cumulative impacts on the wood stork would be similar to those described under the No Action alternative.

Sea Turtles

Direct, Indirect, and Cumulative Impacts

Beach Nourishment

Under Alternative 3, the direct; indirect; and cumulative impacts of beach fill placement on sea turtles would be similar to those described under the No Action alternative.

Dredging

Under Alternative 3; the direct, indirect, and cumulative impacts of cutterhead dredging operations in the LFIX/bend widener and inland LFI channels would be the same as those described under the No Action alternative. Supplemental dredging operations at the Central Reach offshore borrow site would employ hopper dredges. Sea turtles are vulnerable to direct injury by hopper dredges as a result of being entrained in the dredge intake pipe during the sediment extraction process. Consequently, the NMFS requires the use of turtle deflecting (rigid deflector) dragheads on hopper dredges, and hopper dredging projects are generally restricted to the colder months when most sea turtles have moved to warmer offshore waters. Sea turtle entrainment rates are dramatically reduced when rigid deflector dragheads are used and deployed correctly (Dickerson et al. 2004). The rigid deflector draghead creates a V-shaped sand ridge in front of the draghead as it is drawn along the seafloor, thus providing for the deflection of sea turtles while avoiding direct contact with draghead. The distribution of sea turtles along the NC coast is characterized by a seasonal pattern of inshore migration during the spring and offshore migration during the fall. Aerial surveys indicate that inshore and nearshore sea turtle occurrences are strongly correlated with sea surface temperatures ≥11°C (Goodman et al. 2007, Epperly et al. 1995c). The temporal distribution of sea turtle observations reported by Goodman et al. (2007) included a range of 16 April to 20 November for inshore waters and a range of 23 April to 27 November for nearshore ocean waters.

Supplemental dredging at the Central Reach offshore borrow site would only be expected in the case of a shortfall in the combined available sand volume in the LFIX, bend widener, and inland LFI channels. Therefore, it is anticipated that the frequency and extent of dredging operations at the Central Reach borrow site over the course of the 30-year project would be very limited.

Rigid deflector dragheads would be required on all hopper dredges, thus reducing the potential for sea turtle entrainment. The proposed environmental hopper dredging window (16 November to 31 March) would limit dredging to periods when most sea turtles have moved to warmer offshore waters, thus further reducing the potential for sea turtle entrainment. Based on the use of rigid deflector dragheads, the proposed environmental hopper dredging window, and the anticipated limited extent of offshore dredging; it is anticipated that the risk of sea turtle entrainment under Alternative 3 would be very low.

Atlantic and Shortnose Sturgeons

Under Alternative 3; the direct, indirect, and cumulative impacts of cutterhead dredging operations in the LFIX/bend widener and inland LFI channels on Atlantic and shortnose sturgeon would be similar to those described under the No Action alternative. The frequency of bend widener dredging events under Alternative 3 would relatively be the same as the No Action alternative, thus maintaining the frequency (approximately a two-year cycle) of repeated impacts on benthic foraging habitats and the overall temporal extent of potential indirect benthic infaunal prey-loss effects.

Supplemental dredging operations at the Central Reach offshore borrow site would employ hopper dredges. Hopper dredging can potentially impact sturgeons directly through entrainment in the dredge intake pipe and/or indirectly through impacts to soft bottom benthic foraging habitats. Between 1990 and 2007, 11 shortnose sturgeons and 11 Atlantic sturgeons were taken during federal dredging operations along the Atlantic Coast (USACE 2008). All shortnose sturgeon takes occurred along the North Atlantic Coast, whereas all but one of the Atlantic sturgeon takes occurred along the South Atlantic Coast. Shortnose sturgeons were taken by hopper, cutterhead, and clamshell dredges; whereas Atlantic sturgeons were taken by hopper and clamshell dredges. Atlantic sturgeon takes at Wilmington Harbor during this period included one during hopper dredging and one during clamshell dredging. The shortnose sturgeon is typically found in the upper portions of rivers above the freshwater-saltwater interface; and therefore, its presence in the vicinity of the Central Reach offshore borrow site during dredging operations would not be expected. Therefore, based on its low probability of occurrence in the Permit Area and the absence of reported dredge interactions along the South Atlantic Coast, direct, indirect, and cumulative impacts on the shortnose sturgeon would not be expected under Alternative 3. Atlantic sturgeons could potentially be present in the vicinity of the Central Reach offshore borrow site during dredging operations. The use of rigid deflector dragheads on hopper dredges would be expected to reduce the risk of Atlantic sturgeon entrainment. It is anticipated that the frequency and extent of dredging operations at the Central Reach borrow site over the course of the 30-year project would be very limited; and based on the relatively small East End beach fill volume requirements (~100,000 – 150,000 cy), the extent and duration of individual dredging events would also be limited. Therefore, it is anticipated that the risk of entrainment to Atlantic sturgeon would be very low under Alternative 3.

Seabeach Amaranth

Direct, indirect, and cumulative impacts on seabeach amaranth under Alternative 3 would be similar to those described under the No Action alternative.

5.4.3.7 Cultural Resources

Direct, Indirect, and Cumulative Impacts

The remains of four Civil War vessels at LFI are listed in the NRHP under the Cape Fear Civil War Shipwreck District. The U.S.S. *Iron Age* and two sidewheel steamer blockade-runners (*Elizabeth* and *Bendigo*) are located in a line across the mouth of the inlet, and a third sidewheel blockade-runner (*Ranger*) is located ~1 mile west of the inlet (Tidewater Atlantic Research 2011). All of the Civil War shipwrecks are located seaward of the COLREGS line, whereas the LFIX/bend widener and inland LFI channels are located landward of the COLREGS line. Therefore, direct and indirect impacts on NRHP-listed vessels would not be expected under Alternative 3. LFIX/bend widener and inland LFI channel dredging would be confined to the existing federally authorized navigation channels; and therefore, impacts on undocumented shipwrecks would not be expected. In the case of the Central Reach offshore borrow site, a remote sensing survey for potential cultural resources was conducted as part of the environmental review process for the Holden Beach Central Reach nourishment project (Tidewater Atlantic Research 2011). The results of the remote sensing survey identified a single magnetic anomaly and no acoustic targets. Data analysis indicated that the magnetic anomaly was a single isolated object most likely consisting of modern debris. Therefore, potential supplemental dredging operations at the Central Reach borrow site would not be expected to have any direct or indirect impacts on cultural resources. Based on the absence of anticipated direct and indirect impacts, cumulative effects on cultural resources would not be expected under Alternative 3.

5.4.3.8 Public Interest Factors

Public Safety

Direct, Indirect, and Cumulative Impacts

Beach Construction

Beach construction would involve the use of bulldozers and possibly backhoes to redistribute beach fill as it is discharged onto the nourishment beach. In order to take advantage of the limited environmental dredging window and maximize the efficient use of expensive construction equipment, beach nourishment operations would be conducted around-the-clock. As with any construction project involving the use of heavy machinery, beach construction would present a minor, short-term risk to public safety. In order to maintain separation between the public and potentially hazardous operations; the active construction area, consisting of a ~500-ft zone on either side of the beach fill discharge point, would be fenced. During nighttime operations, appropriate lighting would be provided in accordance with the USACE and OSHA safety regulations. The USACE Safety and Health Requirements Manual (EM 385-1-1) specifies a minimum luminance of three lumens per square foot for outdoor construction zones. Regulations also require front and back lighting on all transport vehicles and bulldozers during nighttime operations. Adherence to the proposed environmental dredging window (16 November - 30 April) would restrict beach construction activities to the colder months when recreational use is at its lowest point, thus limiting public exposure to potential construction-related risks. Considering the safety measures that would be implemented and the anticipated low level of recreational activity during the period of construction; no direct, indirect, or cumulative impacts to public safety would be expected under Alternative 3.

Dredging

Dredging operations within the LFIX/LFI channels would employ a cutterhead pipeline dredge, whereas operations at the offshore borrow site would most likely employ a hopper dredge. As indicated above, the limited dredging window and the high costs associated with dredging would necessitate around-the-clock operations. Dredges and associated pump and pipeline systems would present a minor short-term collision risk to recreational boaters. Adherence to the proposed environmental dredging window (16 November - 30 April) would limit operations to the colder months when recreational boating activity is at its lowest point, thus limiting the potential for dredge/recreational vessel interactions. During nighttime operations, appropriate on-board lighting would be provided in accordance with the USACE and OSHA safety regulations. The USACE Safety and Health Requirements Manual (EM 385-1-1) specifies a minimum luminance of 30 lumens per square foot on dredges. Dredges would be subject to vessel inspections and other federal safety regulations that are enforced by the USCG. As deemed necessary to ensure the safety of recreational boating activities, the USCG would establish temporary safety zones around dredging operations. Considering these safety measures and the anticipated low level of recreational boating activity during the period of construction; no direct, indirect, or cumulative impacts to public safety would be expected under Alternative 3.

<u>Aesthetics and Recreation</u>

Direct, Indirect, and Cumulative Impacts

During beach nourishment events, the presence of pipelines and construction equipment on the beach and associated noise emissions and artificial nighttime lighting would temporarily diminish the aesthetic quality of the East End beach. Temporary construction safety zones would restrict public beach access within a ~500-ft zone on either side of the beach fill discharge point, thus potentially impacting recreational activities such as beach-combing, fishing, and surfing. Similarly, the presence of dredges and support vessels/barges within the LFIX/LFI borrow site channels would temporarily degrade scenic vistas and could slow recreational boating traffic. Public exposure to aesthetic and recreational impacts would be limited, as the proposed environmental dredging window (16 November - 30 April) would limit beach fill and dredging operations to the colder months when recreational beach use is at its lowest point. Beach nourishment projects under Alternative 3 would maintain a wider beach, thus resulting in long-term beneficial effects on recreation and the aesthetic quality of the beach. Furthermore, the additional storm protection provided by nourishment would reduce the need for emergency measures (sandbags, beach/dune scraping) that would be detrimental to recreation and the aesthetic quality of the beach. Considering the low level of public exposure and the short-term nature of the adverse impacts, it is anticipated that the long-term beneficial effects of a wider beach would result in net beneficial effects on aesthetics and recreation.

Navigation

Direct, Indirect, and Cumulative Impacts

Under Alternative 3, the direct, indirect, and cumulative impacts of dredging operations in the LFIX/bend widener and inland LFI channels on navigation would be the same as those described under the No Action alternative. The Central Reach offshore borrow site is not located in the vicinity of any navigation channels; and therefore, supplemental dredging at the Central Reach borrow site would not be expected to have any direct, indirect, or cumulative impacts on navigation.

Infrastructure

Under Alternative 3, the CMS model-projected response of the developed East End oceanfront beach is one of recession throughout the four-year simulation period. By the end of Year 4, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~1,200 linear ft) has migrated landward of the existing primary dune, resulting in impacts to 19 oceanfront properties and ~250 ft of roads and associated linear utilities (Figure 5.16). In comparison, the projected future without project East End beach response under Alternative 2 follows a similar erosional pattern; however, the landward extent of shoreline recession at the end of Year 4 exceeds that of Alternative 3 by an average ~19 ft. Under Alternative 2, the MHW line between Avenue B and the eastern terminus of McCray Street (~1,700 linear ft) has migrated landward of the primary dune by the end of Year 4, resulting in impacts to 28 oceanfront properties and ~800 ft of roads and linear utilities (Figure 5.14). Thus, the modeling results suggest a relative reduction in property, road, and utility impacts under Alternative 3.

Economics

Under Alternative 3, construction and maintenance costs would include those associated with periodic beach nourishment; including the costs of beach fill, mobilization/demobilization, monitoring, surveying and permitting. Additional costs would be associated with risk to properties and infrastructure, loss of recreational opportunities, loss of habitat, and environmental impacts associated with periodic nourishment and borrow site dredging activities. Over a 30-year planning horizon, assuming nourishment of the East End Beach with

Figure 5.16. Alternative 3 – Projected Properties at Risk and Infrastructure Impacts at YR4 End

approximately 150,000 CY of sand every two years, and an annual four percent increase in fill costs, Alternative 3 is expected to involve total construction costs of approximately $55.50 million. In present value terms, construction costs range from $21.97 million (6% discount rate) to approximately $36.32 million (2.5% discount rate). Potential erosional impacts to properties and infrastructure were projected based on the model-predicted shoreline changes. Specifically, properties and infrastructure that fall within 25 ft of the model-projected MHW at the end of the four-year simulation were considered to be impacted. Costs associated with these impacts were based on the assessed tax value of properties and the estimated cost of infrastructure replacement. Under Alternative 3, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~1,200 linear ft) has migrated landward of the primary dune at the end of Year 4, resulting in impacts to 19 properties (13 improved) and ~250 linear ft of roads and associated water, sewer, and power lines (Figure 5.16). The total assessed value of all properties protected to be newly impacted under Alternative 3 is roughly $3.01 million. The 250 linear feet of anticipated infrastructure replacement cost is valued at approximately $191,000, with a present value ranging from approximately $151,000 (6% discount rate) to $173,000 (2.5% discount rate).

Under Alternative 3, use and non-use values associated with recreation, aesthetics, and the natural environment are generally expected to be enhanced relative to Alternatives 2 and 4 and diminished relative to Alternatives 5 and 6 (Table 5.10). Public recreational values would be affected to the extent that the activities associated with nourishment physically impede and diminish the aesthetic appeal of the East End beach. These effects may result in economic losses associated with diminished use and non-use values and may have adverse effects on ecosystem service values in terms of provisioning and regulating services provided by the affected species and habitats. The principle benefit of Alternative 3 would be the addition of beach width relative to baseline conditions. It is expected that maintenance of a wider beach would confer benefits in the form of improved property values in the immediate vicinity of the project. Improvements in property values can be expected for properties that would otherwise be imminently threatened. As a result, the Holden Beach tax base would be expected to improve.

5.4.4 Alternative 4: Outer Inlet Channel Management and Beach Nourishment

Under Alternative 4, the Town would mitigate East End erosion through relocations of the LFI outer ebb channel and concurrent nourishments of the East End beach with ~120,000 – 180,000 cy of sand every two years. Outer inlet channel relocation events would involve the construction of a new wider and deeper outer channel with a more westerly alignment towards the inlet shoulder of Holden Beach. The new 0.5-mile-long channel would extend seaward from the inlet throat across the LFI ebb tidal delta to the ocean 14-ft (MLW) depth contour. The new channel would be excavated to a uniform depth of 14 ft (MLW), and would have a variable width ranging from ~350 ft at the inlet throat to ~850 ft at the outer 14-ft (MLW) ocean depth contour. Excavation of the new outer channel would require the extraction of ~500,000 cy of sediment

Table 5.10. Alternative 3 scope of costs and benefits.

Costs (Relative to Status Quo)	
Construction and Maintenance	$55.50 M
Construction and Maintenance (Present Value)	$21.97 - $36.32 M
Parcels affected	19
Assessed Tax Value of Affected Parcels	3.01 M
Infrastructure Replacement Costs	$190,699
Infrastructure Replacement Costs (Present Value)	$172,764 - $151,052
Reduction in tax base	Intermediate
Transition costs	Intermediate
Diminished recreation value	Intermediate
Diminished aesthetic value	Intermediate
Environmental Damage	
Public non-use value losses (nature)	Intermediate
Public non-use value losses (Holden Beach)	Intermediate
Benefits (Relative to Status Quo)	
Reduction in future nourishment expense	Intermediate
Enhanced property value	Intermediate
Environmental Improvement	
Enhanced Recreation value	Moderate
Public non-use value (nature)	Intermediate
Public non-use value (Holden Beach)	Intermediate

from the ebb tidal delta. Approximately 120,000 – 180,000 cy of sand would be extracted by a cutterhead or hopper dredge for placement on the East End beach, and the remaining ~320,000 – 380,000 cy would be removed by a side-cast dredge and returned to the adjacent ebb tidal delta via open water disposal. It is anticipated that sand derived from outer inlet channel relocation events would meet all of the East End beach fill requirements under Alternative 4. The beach nourishment footprint, beach profile design, and beach construction methods would be the same as those described under Alternative 3.

5.4.4.1 Marine Benthic Resources

Soft Bottom Communities

Dredging

Direct Impacts

Excavation of the new outer inlet channel would directly impact ~36 ac of soft bottom habitat associated with the ebb tidal delta. Sand extraction would remove the majority of the associated benthic invertebrate infauna and epifauna; resulting in an initial sharp reduction in community levels of abundance, diversity, and biomass within the dredged channel. However, benthic communities would be expected to recover rapidly from the impacts of dredging. Shallow unstable soft bottom habitats such as those associated with the ebb tidal delta are typically dominated by opportunistic benthic invertebrate taxa that recover rapidly from high frequency disturbance (Wilber and Clarke 2007). Furthermore, studies of benthic community recovery in dredged navigation channels along the southeastern coast have reported rapid recovery within two to six months (Van Dolah et al. 1984, 1979; Stickney and Perlmutter 1975; Stickney 1974). These studies indicate that recolonization via slumping of adjacent undisturbed sediments into the dredged channel is an important recovery mechanism. In addition, Van Dolah et al. (1984) attributed quick recovery to rapid infilling of the channel by sediments that were similar in composition to the extracted material and avoidance of spring benthic invertebrate recruitment periods. Relatively rapid rates of recovery (<1 year) at offshore borrow sites have been attributed to similar factors; including relatively rapid infilling by similar sediments (Burlas et al. 2001; Posey and Alphin 2002), recruitment via slumping of material into dredge cuts (Jutte et al. 1999b), and avoidance of spring infaunal recruitment periods (Posey and Alphin 2002).

The ebb tidal delta and outer ebb channel are continuously exposed to strong tidal currents; consequently, as evidenced by the quarterly USACE maintenance dredging cycle, the outer channel is subject to rapid infilling. Furthermore, as indicated by the very small (≤1 percent) fine sediment fraction associated with the ebb tidal delta, silt and clay particles are rapidly dispersed by currents before significant settlement and accumulation can occur. Thus, relatively rapid infilling of the excavated channel by sandy sediments that are similar in composition to the excavated material would be expected. Additionally, the proposed environmental nourishment window (16 November – 30 April) would necessitate the completion of dredging operations prior to the onset of peak spring benthic invertebrate recruitment periods. Therefore, it is anticipated that outer channel relocation events would be followed by relatively rapid benthic community recovery.

Additional direct impacts on soft bottom benthic communities adjacent to the channel would occur through the redeposition of sediments discharged by sidecast dredges. Sediment redeposition can impact soft bottom benthic invertebrates through direct burial and/or adverse effects on the gill-breathing and filter-feeding functions of benthic organisms. However, the absence of a significant fine sediment fraction would likely preclude extensive gill/filter-clogging effects. Reported rates of benthic community recovery from burial at dredged material placement sites along the Atlantic and Gulf coasts range from one month to one year (Wilbur and Clarke 2007). Bishop et al. (2005) studied the impacts of two sediment disposal events on ebb-tidal delta soft bottom communities at Beaufort Inlet. The smaller of the two disposal events (150,000 cy) had no apparent impact on benthic communities; however, the larger disposal event (860,000 cy) was followed by a substantial reduction in Spionid polychaete abundance. The reduction in polychaete abundance at the large disposal site was attributed to a change in substrate composition from fine to coarse sediment. Reductions in abundance were greatest in areas that experienced direct deposition, with impacts attributable to subsequent transport of the material being much reduced. Given the linear nature of the outer channel dredging footprint, the redeposited sediment layer would be potentially thinly spread over a relatively large seafloor area; thus anticipating a limited extent of direct burial impacts. Therefore, it is expected that benthic communities would recover relatively rapidly from redeposition impacts.

Indirect Impacts

As described in detail under Section 5.4.4.2, the CMS modeling results for Alternative 4 show a substantial project-related increase in the inlet tidal prism, which in turn has substantial effects on flow and sediment transport dynamics throughout the inlet and estuarine channels of the Permit Area. As expected, the modeling results at the end of Year 1 show a destabilized ebb tidal delta and a corresponding westward shift in sediment distribution towards the seaward terminus of the new outer channel. However, the new outer ebb channel fails to stabilize and subsequently undertakes an eastward migration that characterizes the remainder of the four-year simulation period. In response to outer channel migration, the ebb tidal delta is continually in a destabilized state of corresponding eastward migration. The projected pattern of ebb delta sediment redistribution would elicit corresponding adjustments in soft bottom benthic community composition. However, based on the opportunistic nature of the dominant benthic taxa and gradual pace of sediment redistribution, it is expected that benthic community adjustments would occur rapidly with only minor, short-term reductions in community levels of abundance, diversity, and/or biomass. The modeling results do not indicate any significant change in the ebb tidal delta sediment volume relative to the future without project condition under Alternative 2 (Table 5.11); therefore, indirect losses of ebb shoal habitat would not be expected.

Direct dredging-induced losses of benthic invertebrates within the new outer channel would constitute a temporary reduction in the availability of prey for predatory demersal fishes. Potential indirect prey-loss effects on demersal fishes could include reduced foraging efficiency within the dredging footprint and/or displacement to adjacent undisturbed soft bottom foraging habitats. The potential for longer-term indirect prey-loss effects on demersal fishes at the community and/or population level is difficult to assess; however, based on the anticipated rapid rates of benthic community recovery, it is anticipated that the indirect effects of prey loss on demersal fishes would be localized and short term. Sandy shoals of capes and offshore bars

Table 5.11. LFI Model-projected ebb shoal sediment volume change (cubic yards).

Alternative	Yr 0	Yr 1	Yr 2	Yr 3	Yr 4
2	14,346,167	13,728,537	13,341,543	13,033,153	12,959,610
3	14,346,167	13,735,874	13,362,521	13,051,699	13,005,674
4	14,175,015	13,548,282	13,244,169	13,066,701	13,030,132
5	14,346,167	13,726,379	13,362,731	13,050,836	12,966,947
6	14,356,826	13,727,674	13,361,240	13,030,027	12,956,458

are designated EFH for Coastal Migratory Pelagics (CMPs). As indicated above, the modeling results do not show any significant change in the ebb tidal delta sediment volume; and therefore, no indirect losses of shoal habitat would be expected. Destabilization would be expected to increase shoal habitat heterogeneity, potentially resulting in beneficial effects on CMPs.

Cumulative Impacts

The potential for temporally-crowded cumulative effects on soft bottom communities under Alternative 4 would depend on the frequency of repeated dredging impacts on soft bottom communities within the outer inlet channel dredging footprint. Specifically, temporally-crowded cumulative effects would be considered likely if the intervals between repeated outer channel dredging events were insufficient to allow for full recovery of benthic communities. The excavation of a wider and deeper outer channel would initially reduce the need for interim federal maintenance dredging, thus initially reducing the frequency of repeated impacts on benthic invertebrate communities relative to the current quarterly federal maintenance dredging regime. However, rapid infilling of the new channel (see Section 5.4.4.2) would likely necessitate the resumption of interim federal dredging during the latter half of the two-year intervals between relocation events. The overall frequency of combined project-related and interim federal dredging events could approach the current quarterly federal dredging cycle, potentially resulting in repeated impacts on benthic communities prior to full recovery from previous events. As a result, benthic invertebrate communities in the outer channel could be held in an early successional stage and/or could experience long-term reductions in levels of infaunal/epifaunal abundance and biomass. However, the initial reduction in dredging frequency under Alternative 4 would reduce the overall number of outer channel dredging events relative to the ongoing quarterly federal LFI dredging cycle, thus reducing the potential for temporally-crowded cumulative effects relative to the continuation of current operations under the No Action alternative.

The potential for spatially-crowded cumulative effects on soft bottom communities would depend on the proximity of spatially-separate dredging actions to the LFI outer ebb channel and the extent of overlap between the project-related and separate action impacts. Spatially-separate dredging actions potentially affecting soft bottom communities along Holden Beach and Oak Island would include federal dredging of the inland LFI channel, Shallotte Inlet channel, and Wilmington Harbor entrance channel. Additional potential borrow site dredging actions would include dredging associated with the Central Reach nourishment project, Lockwoods Folly River Habitat Restoration Phase I – Eastern Channel project, and dredging by the Town of Bald Head Island at Jay Bird Shoals under their proposed long-term beach management plan (see Section 5.2.2). Dredging associated with the Central Reach nourishment project would likely occur at least one year prior to the initiation of project-related dredging activities under Alternative 4, thus allowing for substantial benthic invertebrate community recovery prior to the initiation of project-related dredging activities. In the event of concurrent outer channel/ Bald Head Island dredging projects; the relatively small area (~36 ac) of project-related dredging impact and the distance (~15 miles) between LFI and Frying Pan Shoals/Jay Bird Shoals suggest that any spatially-crowded cumulative effects would be negligible. Concurrent reductions in benthic invertebrate prey densities within the outer and inland LFI navigation channels could potentially have cumulative effects on predatory demersal fishes. However, the combined area of temporary habitat/prey loss (~45 ac) would constitute a small fraction of the available inlet/ocean soft bottom habitat in the vicinity of Holden Beach and Oak Island.

Beach Nourishment

Direct, Indirect, and Cumulative Impacts

Under Alternative 4, the direct, indirect, and cumulative impacts of beach fill placement on soft bottom communities would be the same as those described under the No Action alternative and Alternative 3.

Hardbottom Communities

Direct, Indirect, and Cumulative Impacts

Exposed hardbottom features are associated with areas of thin sediment cover on the lower shoreface and adjacent inner continental shelf; and therefore, would not be expected to occur in association with the deep sediment deposits that make up the ebb tidal delta. However, if deemed necessary through pre-project agency coordination, inlet channel relocation events would be contingent on investigations demonstrating the absence of potential hardbottom features within 500 m of the active dredging area. Similarly, beach nourishment events would be contingent on pre-construction investigations demonstrating the absence of hardbottom features within proposed corridors. Hopper dredges, the preferred dredge for this action, do not have a pipeline from the borrow area to the beach. There will be a transfer station in the nearshore in ~25 ft of water (as close to the beach as possible) where the hopper will hook up and pump to the shore. The USACE BCB conducted an extensive nearshore hardbottom survey in the area confirming no known hardbottom features have been identified along potential pipeline corridors. Therefore, Alternative 4 would not be expected to have any direct, indirect, or cumulative impacts on hardbottom communities.

5.4.4.2 Water Column

Hydrodynamics

Direct and Indirect Impacts

The CMS modeling results for Alternative 4 show substantial project-related effects on flow and current dynamics throughout the inlet and estuarine channels of the Permit Area. The projected hydrodynamic effects are the result of a substantial increase in the inlet tidal prism, which in turn is related to the expanded depth and width of the realigned outer channel. The “tidal prism” refers to the combined total volume of water that flows in and out of the inlet during a single ebb/flood tidal cycle. In the case of Alternative 4, the deeper and wider outer channel has an expanded water volume capacity, which allows more water to move in and out of the inlet. The CMS model was used to project tidal prism volumes across four transects spanning the inlet throat, Eastern Channel, AIWW East channel, and AIWW West channel. As shown in Table 5.12, the majority of the projected volumes across all transects during Years 1 and 2 are on the order of 110 to 154 percent of the corresponding future without project volumes under Alternative 2. The realigned outer channel experiences high rates of infilling throughout the four-year model simulation period, and the resulting loss of water volume capacity is reflected in declining tidal prism volumes during Years 3 and 4. By the end of Year 4, the majority of model-projected tidal prism volumes across the inlet throat, Eastern Channel, and AIWW East transects are comparable to the corresponding volumes under Alternative 2.

The hydrodynamic response of the inlet has substantial corresponding morphological effects throughout the outer ebb channel/delta complex and the inlet throat complex. As expected, model-simulated bathymetry at the end of Year 1 shows a destabilized ebb tidal delta and a westward shift in sediment distribution towards the seaward terminus of the new outer channel. Concurrent with the initial reorganization of the ebb tidal delta, the modeling results show rapid infilling of the new channel by the end of Year 1; including near-complete infilling of the outermost 0.25-mile channel segment. The model-simulated bathymetry at the end of Year 2 shows an eastward shift in the ebb channel concurrent with continued rapid infilling of the new outer channel. The initial westward ebb channel shift at the end of Year 2 is followed by rapid westward ebb channel migration throughout the final 2 years of the model simulation period. By the end of Year 4, the outer channel approximates its original pre-relocation position; and has taken on a similar recurved alignment towards the Oak Island inlet shoulder. As a result of eastward outer ebb channel migration, the ebb tidal delta is in a continual destabilized state of

Table 5.12. Alternative 4 relative tidal prism volumes (percentage of corresponding Alternative 2 volumes).

Year	Inlet		AIWW West		AIWW East		Eastern Channel	
	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb
Spring Tide								
0	103%	102%	111%	154%	102%	101%	101%	101%
1	115%	118%	92%	103%	113%	117%	126%	111%
2	108%	117%	90%	85%	115%	121%	107%	106%
3	100%	112%	75%	98%	109%	108%	97%	100%
4	96%	101%	33%	89%	101%	97%	138%	94%
Neap Tide								
0	104%	103%	112%	134%	102%	101%	102%	101%
1	113%	120%	89%	93%	115%	118%	112%	114%
2	108%	120%	88%	65%	115%	125%	110%	108%
3	95%	107%	59%	62%	101%	105%	96%	96%
4	85%	87%	51%	116%	97%	93%	99%	61%

westward migration during Years 3 and 4. However, the modeling results do not show any significant change in the ebb tidal delta sediment volume relative to Alternative 2. The model-projected ebb delta sediment volume at the end of Year-1 equates to a relative deficit of ~100,000 cy. The relative deficit is reduced to ~25,000 cy by the end of Year 2, and the projections for Years 3 and 4 indicate a slight relative increase in sediment volume. Thus, the modeling results do not indicate any losses of ebb shoal soft bottom habitat.

The simulated inlet throat ebb channel is also highly unstable throughout the four-year simulation period. The principal ebb channel response is one of rapid westward migration; and by the end of Year 2, the channel is beginning to erode the northern inlet shoreline of Holden Beach. Erosion of the Holden Beach inlet shoreline progresses throughout the remaining two years of the simulation period, resulting in additional losses of inlet beach habitat relative to Alternative 2. Westward migration of the ebb channel also has a relative effect on shoal attachment dynamics along the inlet shoulder of Holden Beach. The modeling results for all other action alternatives show the formation and ultimate attachment of an emergent shoal along the inlet shoulder, which increases the width of the inlet shoulder intertidal beach. The emergent shoal also forms under Alternative 4; however, as a result of westward ebb channel migration, the shoal remains detached. In addition to the projected effects of westward ebb channel migration, the LFIX ebb channel segment along the northwest corner of the flood shoal widens, deepens, and dips southward; shifting the pattern of accretion along the flood shoal southward relative to Alternative 2. The AIWW channels generally maintain their pre-project positions; however, there is considerable sediment redistribution within the channels that is not apparent under Alternative 2. As is the case for all of the action alternatives, the modeling results show extensive shoaling in the AIWW West channel and along the margins of the Eastern Channel and AIWW East channel. As previously described, the majority of the projected shoaling in these areas is related to the exclusion of navigation dredging in the model simulations; however, there is some additional shoaling in the AIWW West channel under Alternative 4 that exceeds the projected shoaling under Alternative 2. The additional shoaling is reflected in the AIWW West tidal prism volumes during Years 2 - 4, which are substantially reduced relative to Alternative 2 (Table 5.11). The projected response of the AIWW West channel is an exception to the overall inlet tidal prism response described above.

Cumulative Impacts

The CMS modeling analysis is limited to the four-year period following a one-time inlet channel relocation event; and furthermore, the model simulations do not include federal navigation dredging. Thus, the ability to evaluate potential cumulative effects that might result from repeated relocation events and interactions with separate federal dredging activities over the 30-year project period is limited. However, the failure of the ebb channel to stabilize during the four-year simulation period suggests that repeated relocations every two years would result in chronic hydrological and morphological instability throughout the inlet complex. Projected adverse effects on the Holden Beach inlet and oceanfront shorelines (see Sections 4.4.3 and 4.4.4) could be perpetuated, resulting in cumulative erosional losses over the 30-year life of the project.

<u>Sediment Suspension and Turbidity</u>

Direct, Indirect, and Cumulative Impacts

Dredging

Temporary sediment suspension and associated increases in turbidity during the dredging process can potentially affect the behaviors (e.g., feeding, predator avoidance, habitat selection) and physiological functions (e.g., photosynthesis, gill-breathing, filter-feeding) of pelagic marine organisms. The extent and duration of dredging-induced sediment suspension and associated increases in turbidity are influenced by sediment composition at the borrow site, the type of dredge employed, and hydrodynamic conditions at the dredge site (Wilber et al. 2005). Prolonged sediment suspension and extensive turbidity plumes are primarily associated with the suspension of fine silt/clay particles that have relatively slow settling velocities; whereas sands and gravels that make up the coarse-grained sediment fraction resettle rapidly in the immediate vicinity of the dredge before they can be transported offsite (Schroeder 2009). In reporting the results of turbidity monitoring during navigation dredging in Delaware Bay, Miller et al. (2002) described the turbidity plume associated with overflow hopper dredging in coarse-grained (97 percent sand) sediments as being confined to the dredged channel footprint, with suspended sediment concentrations returning to ambient levels within one hour of the passing of the dredge. Miller et al. (2002) also reported that observed turbidity levels remained within the range of pre-project ambient turbidities throughout the period of dredging in coarse-grained sediments. Among dredge types, side-cast dredges and mechanical (clamshell/bucket) dredges are generally associated with relatively high rates of sediment suspension and dispersal compared to hydraulic hopper and cutterhead dredges (Clarke and Wilber 2000, LaSalle et al. 1991). In comparison to cutterhead dredges, hopper dredges are generally associated with higher rates of suspension and dispersal; primarily due to the surface discharge associated with overflow dredging. In the case of cutterhead dredging, sediment suspension is generally confined to the near-bottom water column in the immediate vicinity of the rotating cutterhead assembly (LaSalle et al. 1991).

Ebb tidal delta sediments at depths corresponding to the proposed outer inlet channel are composed of medium sand with a very small (≤1 percent) fine sediment fraction; thus indicating that the extent and duration of sediment suspension during outer channel dredging would be limited. Dredging operations would involve the use of a sidecast dredge in combination with either a cutterhead or hopper dredge. As indicated above, sidecast and hopper dredges are generally associated with relatively high suspension rates; however, even in the case of overflow hopper dredging, sediment suspension is characteristically localized and short term when the dredged material is composed of clean sand with a small fine sediment fraction (Miller et al. 2002). Furthermore, the ebb tidal delta is exposed to continuous high-velocity tidal currents, thus indicating that any suspended fine particles would be rapidly dispersed. Therefore, it is anticipated that the effects of dredging-induced sediment suspension during inlet channel relocation events would be localized and short term. Sediment suspension and turbidity effects would be temporally limited to periods of active dredging and spatially localized to the immediate vicinity of the active dredging area; and therefore, cumulative impacts would not be expected.

Beach Fill Placement

Direct, Indirect, and Cumulative Impacts

Under Alternative 4, the direct, indirect, and cumulative effects of sediment suspension related to beach fill placement would be the same as those described under the No Action alternative and Alternative 3.

Salinity Intrusion

Existing salinities in the AIWW between LFI and the Lockwoods Folly River range from ~29 to 36 ppt (NCDWQ 2007), and thus are nearly comparable to ocean salinities. Salinity changes were not assessed in the model simulations; however, the projected tidal prism increases suggest that Alternative 4 could increase mean salinities in the AIWW and the lower Lockwoods Folly River.

Underwater Noise

Direct and Indirect Impacts

Under Alternative 4, the potential impacts of underwater dredging noise on marine organisms would be similar to those described for hopper dredging operations at the Central Reach offshore borrow site under Alternative 3. As detailed under Alternative 3, hopper dredging would not be expected to produce noise levels that would result in direct injury to marine mammals [≥180 dB re 1μPa rms (Level A Harassment)]. However, marine mammals within an approximate 800-m radius of the hopper dredge could be exposed to noise levels that would cause behavioral disruption [≥120 dB re 1μPa rms (Level B Harassment)]. Marine mammals that may be present in the vicinity of the outer inlet channel during dredging operations would include Atlantic spotted and bottlenose dolphins, humpback whales, and North Atlantic right whales. The rapid swimming capabilities of dolphins would most likely limit their exposure to noise levels ≥120 dB to very brief periods. The potential effects of dredging noise on the behavior of large whales are not fully known; however, it is assumed that hopper dredging noise could elicit short-term avoidance responses such as diving or an increase in swimming speed. Since large whales are transient within the study area and are not actively engaged in critical feeding or mating behaviors, no significant adverse behavioral effects would be expected. A detailed evaluation of the potential impacts to humpback and right whales under Alternative 4 is included with the assessment of impacts to other federally listed threatened and endangered species in Section 5.4.4.6. Hopper dredging would not be expected to produce noise levels that would have injurious or behavioral effects on sea turtles [≥180 dB re 1μPa rms (Level A Harassment); ≥166 db re 1μPa rms (Level B Harassment)]. Although the potential for dredging noise to cause injury to fishes is not known, dredging is known to elicit an avoidance response by marine fishes (Larson and Moehl 1990, McGraw and Armstrong 1990). Therefore, it is likely that most fish would move away from the slow-moving (~3 knots) dredge long before they are exposed to potentially injurious noise levels.

Cumulative Impacts

The anticipated effects of underwater dredging noise on marine organisms would be non-injurious, localized, and short term. Therefore, noise-related cumulative impacts would not be expected under Alternative 4.

Entrainment

Direct, Indirect, and Cumulative Impacts

Cutterhead, hopper, and sidecast dredges all have the potential to entrain fishes and invertebrates during all life cycle phases; including adults, juveniles, larvae, and eggs. Among adult and juvenile fishes, demersal species that inhabit the near-bottom water column environment are most likely to be entrained (Reine and Clarke 1998); however, studies have also reported the entrainment of pelagic fishes in small numbers (McGraw and Armstrong

1990). Entrainment studies indicate that dredging elicits an avoidance response by demersal and pelagic species and that most juvenile and adult fishes are successful at avoiding entrainment (Larson and Moehl 1990, McGraw and Armstrong 1990). Larson and Moehl (1990) also found that adult and juvenile anadromous fishes were less likely to be entrained in large open water bodies as opposed to constricted waterways. Based on the results of these studies, it is assumed that most juvenile and adult finfish would avoid the outer inlet channel active dredging zone in response to elevated levels of noise and turbidity, thus avoiding entrainment in the dredge intake pipe. Hopper dredges also have the potential to entrain sea turtles; and consequently, the NMFS requires the use of turtle deflecting (rigid deflector) dragheads on all hopper dredges. Navigation channel and sand borrow site hopper dredging projects are also generally restricted to the colder months when most sea turtles have moved offshore to warmer waters. A detailed evaluation of the potential impacts to sea turtles under Alternative 4 is included with the assessment of impacts to other federally listed threatened and endangered species in Section 5.4.4.6.

The planktonic larvae of ocean-spawning/estuarine-dependent fishes and invertebrates would not be able to avoid the dredges; and consequently, those larvae occurring in the immediate vicinity of the dredge intake pipe would be entrained and presumably permanently lost to the pelagic water column community. Ocean-spawning/estuarine-dependent fishes and invertebrates use offshore continental shelf habitats for spawning and estuarine habitats for juvenile development. Successful larval recruitment to estuarine nursery areas is dependent on transport through a relatively small number of narrow tidal inlets. Larval ingress studies indicate that larvae accumulate in the nearshore ocean zone where they are picked up by alongshore currents and transported to the nearest inlet (Churchill et al. 1999). The results of a long-term sampling program at Beaufort Inlet indicate that inlet larval densities are highest from late May to early June and lowest in November (Hettler and Chester 1990). The proposed environmental dredging window (16 November – 30 April) would necessitate avoidance of peak larval ingress periods. As described in section, the maximum dredge water intake rate under Alternative 4 would be 6,123,570 ft^3 per 24-hour period; which equates to 0.004 percent of the daily (24-hour) spring tidal flow and 0.006 percent of the daily neap tidal flow through LFI. Furthermore, model simulated larval entrainment rates in Beaufort Inlet indicate that entrainment rates are very low regardless of inlet larval concentrations and the distribution of larvae within the water column (Settle 2002). Even under worst case conditions when the dredge is assumed to be operating 24 hours/day and all larvae are assumed to be concentrated in the bottom of the navigation channel, the projected entrainment rate barely exceeds 0.1 percent of the daily (24-hour) larval flux through the inlet. Considering the relatively small volume of water that would be entrained, along with the low model-projected rates of larval entrainment and avoidance of the peak May to early June larval ingress period; it is expected that the direct, indirect, and cumulative effects of larval entrainment on estuarine-dependent fish and invertebrate populations would be negligible under Alternative 4.

5.4.4.3 Oceanfront Beach and Dune Communities

<u>Intertidal Beach Communities</u>

Direct Impacts

Under Alternative 4, the direct impacts of beach fill placement on intertidal beach habitats and communities would be similar to those described under the No Action alternative and Alternative 3.

Indirect Impacts

Initial Beach Fill Placement Effects

Under Alternative 4, indirect impacts associated with the initial placement of beach fill; including sediment suspension and benthic infaunal prey-loss effects; would be the same as those described under the No Action alternative and Alternative 3.

Long-Term Model-Projected Effects

Under Alternative 4, the CMS model-projected shoreline and habitat changes along the Oak Island oceanfront beach (Figure 5.17) are essentially the same as the projected future without project changes under Alternative 2 (Figure 5.13). Under both alternatives, the oceanfront shoreline is erosional throughout the four-year model simulation period. The corresponding effect on intertidal beach habitat under both alternatives is a projected loss of ~10 ac (Table 5.3). The similarity in responses indicates that the projected shoreline and habitat changes under Alternative 4 are primarily the result of natural background coastal processes; thus suggesting that Alternative 4 would have little to no effect on intertidal beach habitat on Oak Island. The projected oceanfront shoreline changes on Holden Beach are generally similar in pattern under the two alternatives; however, there are differences between the responses that are related to the hydrodynamic effects of outer channel relocation under Alternative 4. As described in Section 5.4.4.2, the modeling results for Alternative 4 show substantial project-related effects on inlet hydrodynamics, which in turn have substantial morphological effects on the inlet shoulder shoreline. Under Alternative 2, shoal attachment adds intertidal beach habitat along the inlet shoulder; however, under Alternative 4, rapid westward migration of the inlet throat ebb channel prevents the shoal from attaching. As a result, Alternative 4 increases intertidal beach habitat loss by ~2 ac in relation to Alternative 2.

Cumulative Impacts

Under Alternative 4, potential cumulative impacts on intertidal beach communities would be similar to those described under the No Action alternative and Alternative 3.

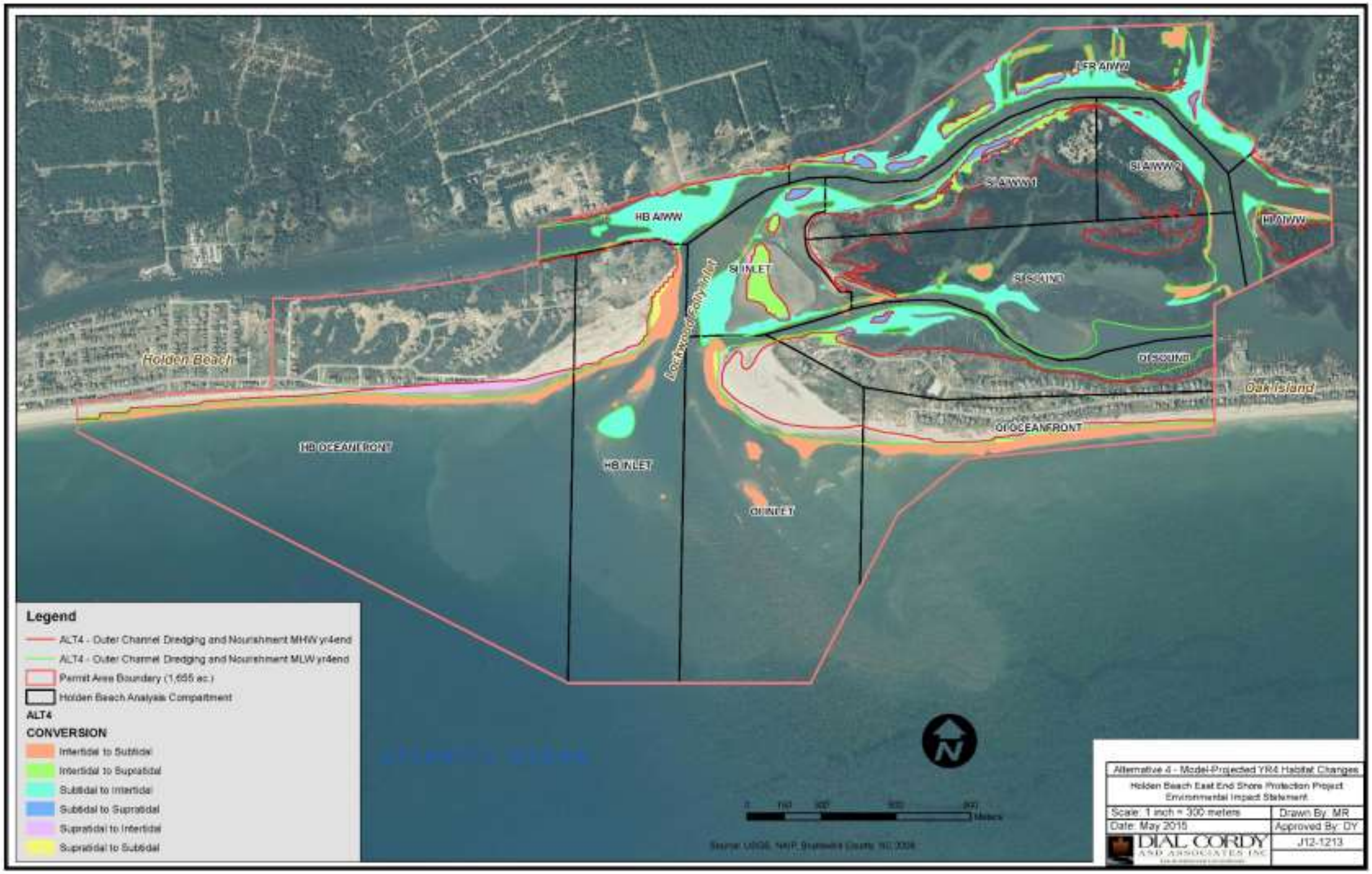

Figure 5.17. Alternative 4 – Model-Projected YR4 Habitat Changes

Dry Beach and Dune Communities

Direct Impacts

Under Alternative 4, the direct impacts of beach fill placement on dry beach and dune communities would be similar to those described under the No Action alternative and Alternative 3.

Indirect Impacts

Initial Beach Fill Placement Effects

Under Alternative 4, indirect habitat modification effects resulting from the placement of beach fill would be the same as those described under Alternative 3.

Long-Term Model-Projected Effects

The CMS model-projected oceanfront shoreline response on the west end of Oak Island under Alternative 4 is essentially the same as the projected future without project response under Alternative 2. Corresponding effects on dry beach and dune habitats under Alternatives 4 (Figure 5.17) and 2 (Figure 5.13) are also the same, with projected losses of ~3 ac occurring under both alternatives (Table 5.3). On Holden Beach, the influence of beach fill placement and outer channel relocation under Alternative 4 are reflected in a wider (MSL 0-m) East End beach and a seaward extended MHW line relative to Alternative 2. The corresponding effect on the quantity of dry beach habitat at the end of Year 4 is an increase of ~2 ac relative to Alternative 2 (Table 5.3).

Cumulative Impacts

Under Alternative 4, cumulative impacts on dry beach and dune communities would be similar to those described under Alternative 3.

5.4.4.4 Inlet Complex

Intertidal Flats and Shoals

Direct Impacts

Under Alternative 4, the direct impacts of beach fill placement on intertidal flats and shoals would be similar to those described under the No Action alternative and Alternative 3. Outer inlet channel dredging would occur seaward of the inlet throat; and therefore, direct dredging-induced impacts on intertidal flats and shoals would not be expected under Alternative 4.

Indirect Impacts

The CMS model-projected inlet response under Alternative 4 (Figure 5.17) is generally similar in pattern to the projected future without project response under Alternative 2 (Figure 5.13); however, there are a number of significant differences between the responses that are related to the hydrodynamic effects of outer channel relocation under Alternative 4. The relationship between the projected hydrological and morphological inlet responses under Alternative 4 were detailed in Section 5.4.4.2. As described above in the analysis of oceanfront beach impacts, rapid westward migration of the inlet throat ebb channel under Alternative 4 prevents the process of shoal attachment along the inlet shoulder that is projected under Alternative 2. As a result, losses of intertidal inlet beach habitat on Holden Beach under Alternative 4 are increased relative to Alternative 2. Westward channel migration under Alternative 4 also increases the extent of erosion along the remainder of the Holden Beach inlet shoreline to the north, further increasing intertidal habitat loss relative to Alternative 2. Overall, the quantity of intertidal inlet beach habitat on Holden Beach under Alternative 4 is reduced by ~3 ac relative to Alternative 2 (Table 5.3).

The model-projected response of the Oak Island inlet shoreline under Alternative 4 is essentially the same as the projected response under Alternative 2. Under both alternatives, erosion of the inlet shoreline over the course the four-year model simulation period results in the loss of ~7 ac of intertidal inlet beach habitat (Table 5.3). The similarity in responses indicates that the projected shoreline and habitat changes under Alternative 4 are primarily the result of background coastal processes; thus suggesting that Alternative 4 would have little effect on the Oak Island intertidal inlet beach. The general pattern of projected flood shoal response is also similar under Alternatives 4 and 2. Under both alternatives, accretion along the western margin of the flood shoal results in substantial new intertidal habitat formation, and sediment deposition on the existing flood shoal results in substantial intertidal-to-supratidal habitat conversion. However, there are differences between the flood shoal responses that are related to the hydrodynamic effects of outer channel relocation under Alternative 4. Under Alternative 4, the LFIX channel along the northwest corner of the flood shoal widens, deepens, and dips southward; shifting the pattern of westward accretion southward relative to Alternative 2. As a result, the extent of westward accretion and new intertidal habitat formation increases by ~4 ac relative to Alternative 2; whereas the extent of deposition and intertidal-to-supratidal habitat conversion decreases by ~2 ac relative to Alternative 2. The net effect of these differences on the quantity of intertidal shoal habitat under Alternative 4 is an increase of ~6 ac relative to Alternative 2. Although the relative increase under Alternative 4 is suggestive of beneficial effects on the flood shoal, there is an ~7-ac relative decrease in the quantity of supratidal shoal habitat under Alternative 4. Thus, the overall combined quantity of intertidal and supratidal shoal habitat under the two alternatives is approximately the same at the end of Year 4. The projected flood shoal sediment volumes under the two alternatives at the end of Year 4 are also similar, with only a slight relative reduction in volume of ~15,000 cy under Alternative 4.

Cumulative Impacts

The CMS modeling analysis is limited to the four-year period following a one-time inlet channel relocation event; and furthermore, the model simulations do not include federal navigation dredging. Thus, the ability to evaluate potential cumulative effects that might result from repeated relocation events and interactions with separate federal dredging activities over the 30-year project period is limited. However, the failure of the ebb channel to stabilize during the four-year simulation period suggests that repeated relocations every two years would result in chronic hydrological and morphological instability throughout the inlet complex. Projected adverse effects on the Holden Beach inlet shoreline could be perpetuated, resulting in cumulative erosional losses over the 30-year life of the project.

<u>Inlet Dry Beach and Dune Communities</u>

Direct Impacts

Under Alternative 4, the direct impacts of beach fill placement on inlet dry beach and dune communities would be the same as those described under Alternative 3. Outer inlet channel dredging would occur seaward of the inlet throat; and therefore, direct dredging-induced impacts on inlet dry beach and dune communities would not be expected under Alternative 4.

Indirect Impacts

As described above, the CMS model-projected response of the Oak Island inlet shoreline under Alternative 4 (Figure 5.17) is essentially the same as the projected future without project response under Alternative 2 (Figure 5.13). Corresponding effects on inlet dry beach and dune habitats are also the same, with projected losses of ~1 ac occurring on Oak Island under both alternatives (Table 5.3). On Holden Beach, the projected increase in shoreline erosion under Alternative 4 has minor effects on inlet dry beach habitat, resulting in a projected decrease of ~1 ac relative to Alternative 2. As described above, there are differences between the projected flood shoal responses under the two alternatives that are related to the hydrodynamic effects of channel relocation under Alternative 4. Under Alternative 4, the extent of new supratidal shoal habitat creation via westward accretion and the extent of intertidal-to-supratidal shoal habitat conversion are both reduced relative to Alternative 2. The result is a relative decrease in supratidal shoal habitat of ~7 ac under Alternative 4. Although the relative decrease under Alternative 4 is suggestive of adverse flood shoal effects, there is an ~6-ac relative increase in the quantity of intertidal shoal habitat under Alternative 4. Thus, the overall combined quantity of intertidal and supratidal shoal habitat under the two alternatives is approximately the same. Furthermore, as stated above, the overall model-projected flood shoal sediment volumes at the end of Year 4 are approximately the same under Alternatives 4 and 2.

Cumulative Impacts

The potential for cumulative effects on inlet dry beach and dune communities under Alternative 4 would be similar to that described above for inlet intertidal communities.

5.4.4.5 Estuarine Resources

<u>Shellfish</u>

Direct Impacts

Outer inlet channel dredging would occur seaward of the inlet throat, whereas shellfish beds are primarily associated with protected estuarine waters. Therefore, direct dredging-induced impacts on shellfish would not be expected under Alternative 4.

Indirect Impacts

During active dredging, suspended sediments that are dispersed and redeposited outside of the active dredging footprint can potentially impact shellfish through smothering and/or interference with filter feeding. However, shellfish beds are primarily associated with estuarine habitats that are removed from the seaward outer inlet channel. Furthermore, sediments associated with the ebb tidal delta dredging footprint have a very small fine sediment fraction (≤1 percent); thus indicating that sediment dispersal would be minimal. Therefore, indirect dredging-induced impacts on shellfish would not be expected under Alternative 4.

Cumulative Impacts

In the absence of anticipated direct and indirect impacts, cumulative effects on shellfish would not expected under Alternative 4.

<u>SAV</u>

Direct Impacts

Outer inlet channel dredging would occur seaward of the inlet throat, whereas SAV beds are confined to protected estuarine waters. Therefore, direct dredging-induced impacts on SAV would not be expected under Alternative 4.

Indirect and Cumulative Impacts

Potential indirect and cumulative effects on SAV under Alternative 4 would be the same as those described above for shellfish.

Tidal Marsh Communities

Direct Impacts

Outer inlet channel dredging would occur seaward of the inlet throat whereas tidal marshes are confined to interior estuarine waters. Therefore, direct dredging-induced impacts on tidal marshes would not be expected under Alternative 4.

Indirect and Cumulative Impacts

The model-projected tidal marsh response under Alternative 4 is the same as the projected future without project response under Alternative 2, with both alternatives resulting in tidal marsh losses of ~2 ac at the end of the four-year simulation period. The similarity of the responses indicates that the projected losses under Alternative 4 are primarily the result of natural background coastal processes; thus suggesting that Alternative 4 would have little effect on tidal marsh communities. In the absence of anticipated direct and indirect impacts, cumulative effects on tidal marshes would not expected under Alternative 4.

5.4.4.6 Threatened and Endangered Species

North Atlantic Right Whale and Humpback Whale

Direct, Indirect, and Cumulative Impacts

Outer inlet channel dredging operations would potentially coincide with North Atlantic right whale and humpback whale migration periods along the NC coast. Right and humpback whales routinely swim close to shore during winter migration periods along the NC coast; and therefore, both species could be present in offshore waters of the Permit Area during potential East End dredging operations. Dredging can potentially impact large whales through acoustic disturbance and vessel collisions. The NMFS currently uses generic noise exposure thresholds to define two levels of acoustic “take” under the MMPA. Actions that may expose marine mammals to rms SPL ≥180 dB re 1μPa rms constitute Level A harassment with the potential to cause injury, and actions that may expose marine mammals to impulse noise levels ≥140 dB re 1μPa rms or continuous noise levels ≥120 dB re 1μPa constitute Level B harassment with the potential to cause behavioral disruption. Excavation of the new outer inlet channel would employ either a cutterhead or hopper dredge in combination with a sidecast dredge. According to a study by Clarke et al. (2002), cutterhead dredges produce peak sound levels in the range of 100 to 110 dB re 1μPa rms, with rapid attenuation occurring at short distances from the dredge and sound levels becoming essentially inaudible at a distance of ~500 m. Therefore, dredging operations under Alternative 4 would not be expected to produce noise levels at or above the thresholds described above for injurious or behavioral effects on marine mammals or sea turtles. Although the potential for dredging noise to cause injury to fishes is not known, dredging is known to elicit an avoidance response by marine fishes (Larson and Moehl 1990, McGraw and Armstrong 1990). Therefore, considering that cutterhead dredges are anchored during the active dredging process, it is likely that most fish would move away from the dredge long before they are exposed to potentially injurious noise levels.

Clarke et al. (2002) reported hopper dredge noise levels ranging from 120 to 140 dB re 1µPa rms at a distance of 40 m during navigation dredging in Mobile Bay, AL. The NMFS has used the data collected by Clarke et al. (2002) as the basis for evaluating hopper dredging noise impacts at ocean sand borrow sites, citing the similarity in substrate (i.e., sand) and the use of metrics that are consistent (i.e., SPL rms values) with established marine mammal noise impact thresholds (NMFS 2010b). Based on the results of a noise impact analysis for dredging at an offshore sand borrow site in VA, NMFS determined that marine mammals within a 794-m radius of the dredge could be exposed to noise levels at or above the Level B harassment threshold for continuous noise (i.e., ≥120 dB re 1µPa rms). The highest predicted sound level was 164 dB re 1µPa rms at a distance of one meter from the dredge, which is well below the ≥180 dB re 1µPa rms threshold for Level A harassment. Based on these studies, hopper dredging under Alternative 4 would not be expected to have any injurious acoustic effects on right or humpback whales. However, right and humpback whales could be exposed to noise levels ≥120 dB re 1µPa rms (Level B Harassment) within an approximate 800-m radius of the hopper dredge. The potential behavioral effects of dredging noise on large whales are not fully known; however, it is assumed that hopper dredging noise could elicit short-term avoidance responses such as diving or an increase in swimming speed. Since large whales are transient within the study area and are not actively engaged in critical feeding or mating behaviors, it is anticipated that behavioral effects would be minor. In comparison to hopper and cutterhead dredges, which are used for more rigorous deep draft dredging and beach nourishment projects, the dredge pumps on shallow draft sidecast dredges are substantially reduced in terms of size and horsepower (hp). The pump engines on sidecast dredges that are currently operated by the Wilmington District have a maximum output of ≤400 hp, whereas the pump engines on the cutterhead and hopper dredges that were monitored by Clarke et al. (2002) can produce up to 10,000 hp and 15,000 hp, respectively. Therefore, sidecast dredging would not be expected to have any adverse acoustic impacts on right or humpback whales.

Instances of lethal whale-dredge interactions (i.e., vessel collisions) have not been documented; however, a non-lethal interaction was reported in 2005 when a hopper dredge collided with an apparent North Atlantic right whale along the GA coast near the Brunswick Harbor entrance channel (NMFS 2012a). The risk of collisions between dredges and large whales during operations in the outer channel would be low, as hopper and sidecast dredges travel at slow speeds (≤3 knots) during the active dredging process and cutterhead dredges are relatively stationary. In the case of hopper dredging, operations would also include transits between the outer channel and nearshore pump-out stations along the East End beach. The maximum unloaded speed of a hopper dredge is ~17 knots; and therefore, the risk of collisions would increase during transit. Dredging contracts would incorporate standard conservation measures to minimize the risk of large whale collisions; including speed limits (≤10 knots), 24-hour presence (during active dredging and transit) of protected species observers with at-sea large whale identification experience, and compliance with federal regulations [50 CFR 224.103(c)] prohibiting the approach of any vessel within 500 yards of a right whale. Considering the relatively small East End beach fill volume requirements (~100,000 – 150,000 cy) and the short distance between the outer channel and the East End beach, the number and duration of transits would be minimal. Therefore, it is expected that the proposed conservation measures would reduce the risk of collisions to negligible levels.

The essential features of proposed critical habitat for the right whale within the Permit Area are those associated with calving habitat; including sea surface temperature, water depth, and sea state (roughness). Dredging and beach fill placement operations under Alternative 4 would not affect any of these essential features; and furthermore, based on the proposed conservation measures described above, neither inlet relocation dredging nor supplemental dredging at the Central Reach offshore borrow site would preclude right whales from accessing or using the proposed critical habitat areas. Therefore, no adverse effects on proposed critical habitat would be expected under Alternative 4.

<u>West Indian Manatee</u>

Direct, Indirect, and Cumulative Impacts

The potential direct, indirect, and cumulative impacts on manatees under Alternative 4 would be similar to those described under the No Action alternative and Alternative 3.

<u>Piping Plover</u>

Direct Impacts

Under Alternative 4, the potential direct impacts of beach fill placement operations on piping plovers would be the same as those described under the No Action alternative and Alternative 3. Outer inlet channel dredging would occur seaward of the inlet throat; and therefore, direct dredging-induced impacts on piping plovers would not be expected under Alternative 4.

Indirect and Cumulative Impacts

Beach Fill Placement

Under Alternative 4, the potential indirect and cumulative impacts of beach fill placement operations on piping plovers would be the same as those described under the No Action alternative and Alternative 3.

Outer Inlet Channel Relocation

Under Alternative 4, the CMS model-projected inlet morphological response to outer channel relocation (Figure 5.17) is generally similar in pattern to the projected future without project response under Alternative 2 (Figure 5.13). The previously described model-projected effects of outer channel relocation on East End inlet shoulder shoaling processes indicate a reduction in potential intertidal foraging habitat of ~3 ac relative to Alternative 2. The modeling results do not show any indication of project-related effects on the Oak Island inlet shoreline; thus indicating that Alternative 4 would not affect associated critical habitat for the piping plover. The general pattern of projected flood shoal response is similar under Alternatives 4 and 2, with accretion along the western margin of the flood shoal resulting in substantial new intertidal habitat formation, and sediment deposition on the existing flood shoal resulting in substantial intertidal-to-supratidal shoal habitat conversion. However, there are differences between the flood shoal responses that are related to the hydrodynamic effects of outer channel relocation under Alternative 4. Under Alternative 4, the LFIX channel along the northwest corner of the flood shoal widens, deepens, and dips southward; shifting the pattern of westward accretion southward relative to Alternative 2. As a result, the extent of westward accretion and new intertidal habitat formation increases by ~4 ac relative to Alternative 2. Conversely, the extent of depositional intertidal-to-supratidal habitat conversion on the existing flood shoal decreases by ~2 ac relative to Alternative 2. The net effect of these differences on the quantity of intertidal shoal habitat under Alternative 4 is an increase of ~6 ac relative to Alternative 2. Although the relative increase under Alternative 4 is suggestive of beneficial effects on the quantity of shoal habitat, there is a ~7 ac increase in the quantity of supratidal shoal habitat under Alternative 2. Thus, the overall combined quantity of intertidal and supratidal shoal habitat under the two alternatives are approximately the same at the end of Year 4. The projected flood shoal sediment volumes under the two alternatives at the end of Year 4 are also similar, with only a slight relative reduction in volume of ~15,000 cy under Alternative 4. Although Alternative 4 would decrease the quantity of potential flood shoal supratidal nesting habitat relative to Alternative 2, the relative increase in intertidal shoal habitat may have indirect beneficial effects on migrating and wintering plovers. Migrating plovers are dependent on large areas of intertidal foraging habitat with abundant prey resources, and such areas are an essential element of the designated critical habitat units for the wintering population.

Red Knot

Under Alternative 4, potential direct, indirect, and cumulative impacts on red knots would be similar to those described above for the piping plover.

Wood Stork

Under Alternative 4, potential direct, indirect, and cumulative impacts on wood storks would be comparable to those described under the No Action alternative and Alternative 3.

Sea Turtles

Beach Fill Placement

Direct Impacts

As described previously, critical habitat has been designated for nesting sea turtles within Unit LOGG-T-NC-08 which encompasses the dry beach habitat along Holden Beach. Should the erosion continue along the inlet beaches within the East End of Holden Beach, the critical habitat for nesting sea turtles could be impacted. Under Alternative 4, the direct impacts of beach fill placement on sea turtles would be the same as those described under the No Action alternative and Alternative 3.

Indirect Impacts

Under Alternative 4, indirect nesting habitat modification effects associated with the initial placement of beach fill would be the same as those described under the No Action alternative and Alternative 3.

As previously described, the CMS model-projected oceanfront shoreline response on the west end of Oak Island under Alternative 4 (Figure 5.17) is essentially the same as the projected response under Alternative 2 (Figure 5.13). Corresponding effects on dry beach and dune habitats are also the same, with projected losses of ~3 ac occurring under both alternatives (Table 5.3). Thus, the modeling results for Alternative 4 suggest that East End nourishment would not affect sea turtle nesting habitat on Oak Island. In the case of Holden Beach, the performance of the beach fill under Alternative 4 is reflected in a relative increase in beach width at the end of Year 4. As a result, dry beach habitat loss under Alternative 4 is reduced by ~2 ac relative to Alternative 2 (Table 5.3). Thus, the modeling results for Alternative 4 suggest the potential for minor beneficial effects on sea turtles via an increase in available dry beach nesting habitat on Holden Beach.

Cumulative Impacts

Under Alternative 4, the cumulative impacts of beach fill placement operations on sea turtles would be similar to those described under the No Action alternative and Alternative 3.

Dredging

Direct, Indirect, and Cumulative Impacts

Excavation of the new outer inlet channel would employ either a cutterhead or hopper dredge in combination with a sidecast dredge. Cutterhead pipeline dredges are not known to entrain sea turtles; however, sea turtles are susceptible to entrainment by hopper dredges. Consequently, the NMFS requires the use of turtle deflecting (rigid deflector) dragheads on hopper dredges, and hopper dredging projects are generally restricted to the colder months when most sea turtles have moved to warmer offshore waters. Sea turtle entrainment rates are dramatically reduced when rigid deflector dragheads are used and deployed correctly (Dickerson et al. 2004). The rigid deflector draghead creates a V-shaped sand ridge in front of the draghead as it is drawn along the seafloor, thus providing for the deflection of sea turtles while avoiding direct contact with draghead. The distribution of sea turtles along the NC coast is characterized by a seasonal pattern of inshore migration during the spring and offshore migration during the fall. Aerial surveys indicate that inshore and nearshore sea turtle occurrences are strongly correlated with sea surface temperatures ≥11°C (Goodman et al. 2007, Epperly et al. 1995c). The temporal distribution of sea turtle observations reported by Goodman et al. (2007) included a range of 16 April to 20 November for inshore waters and a range of 23 April to 27 November for nearshore ocean waters. Under Alternative 4, rigid deflector dragheads would be required on all hopper dredges, thus reducing the potential for sea turtle entrainment. The proposed environmental hopper dredging window (16 November to 31 March) would limit dredging to periods when most sea turtles have moved to warmer offshore waters, thus further reducing the potential for sea turtle entrainment. Considering the relatively small East End beach fill volume requirements (~120,000 – 180,000 cy), the temporal extent of hopper dredging operations would be relatively limited. Therefore, it is expected that the use of rigid deflector dragheads and adherence to the proposed environmental hopper dredging window would reduce the risk of sea turtle entrainment to negligible levels.

In comparison to larger commercial hopper and cutterhead dredges, which are used for more rigorous deep draft dredging and beach nourishment projects, shallow draft sidecast dredges use relatively small California style dragheads and dredge pumps that are substantially reduced in terms of size and hp. As a result, the intake velocity and suction field are also substantially reduced. The draghead opening on sidecast dredges is also subdivided by a grid into smaller openings (max = 5 x 8 inches), thus further restricting the size of objects that can be drawn through the draghead (USACE 2008). During testing performed by the USACE on a dead juvenile sea turtle, the low suction velocity and small draghead openings associated with a sidecast dredge prevented the sea turtle from being retained. Furthermore, the test results indicate that turtles impinged against the draghead would soon be broken free by the motion of the draghead (NMFS 1999). Based on the limited entrainment potential, sidecast dredging under Alternative 4 would not be expected to have any direct impact on sea turtles.

The NMFS currently uses generic noise exposure thresholds to evaluate potential acoustic impacts on sea turtles. Actions that may expose sea turtles to rms SPL ≥180 dB re 1μPa rms constitute Level A harassment with the potential to cause injury, and actions that may expose sea turtles to continuous noise levels ≥166 dB re 1μPa constitute Level B harassment with the potential to cause behavioral disruption (NMFS 2010b, McCauley 2000). As described in Section 5.4.4.2, none of the dredges that could be used in the outer channel would be expected to produce noise levels ≥166 db re 1μPa rms; and therefore, based on the noise thresholds described above, acoustic effects on sea turtles would not be expected under Alternative 4.

Atlantic and Shortnose Sturgeons

Direct, Indirect, and Cumulative Impacts

Dredging operations can potentially impact Atlantic and shortnose sturgeons directly through entrainment and/or indirectly through sediment suspension and soft bottom habitat modification. Between 1990 and 2007, federal navigation dredging operations along the Atlantic Coast resulted in the take of 11 Atlantic sturgeons and 11 shortnose sturgeons (USACE 2008). All of the shortnose sturgeon takes occurred along the North Atlantic Coast in the Delaware and Kennebec Rivers, whereas all but one of the Atlantic sturgeon takes occurred along the South Atlantic Coast. Shortnose sturgeons were taken by hopper, cutterhead, and clamshell dredges; whereas Atlantic sturgeons were taken by hopper and clamshell dredges. Atlantic sturgeon takes at Wilmington Harbor included one by a hopper dredge and one by a clamshell dredge. The shortnose sturgeon is typically found in the upper portions of rivers above the freshwater-saltwater interface; and therefore, its presence in the outer inlet channel during dredging operations would not be expected. Based on its low probability of occurrence and the absence of reported dredge interactions along the South Atlantic Coast, direct impacts on shortnose sturgeon would not be expected under Alternative 4.

Atlantic sturgeon could potentially be present in the vicinity of the outer inlet channel during dredging operations. As indicated above, cutterhead and sidecast dredges are not known to entrain Atlantic sturgeon; and therefore, direct impacts resulting from the use of these dredge types in the outer channel would not be expected under Alternative 4. As indicated above, hopper dredges are known to entrain Atlantic sturgeon; however, all of the reported incidents along the South Atlantic Coast occurred in relatively confined rivers and harbors, where it has been suggested that restrictions on sturgeon movements may result in the highest risk of entrainment (NMFS 2012b). Therefore, considering that the outer channel is located in the open ocean, it is anticipated that the risk of entrainment would be very low. The use of rigid deflector dragheads on hopper dredges would be expected to further reduce the risk of Atlantic sturgeon entrainment; and considering the relatively small East End beach fill volume requirements (~120,000 – 180,000 cy), the duration of hopper dredging operations and the associated risk of entrainment would be of short duration. Therefore, it is anticipated that the Atlantic sturgeon entrainment risk under Alternative 4 would be negligible.

Seabeach Amaranth

Direct, Indirect, and Cumulative Impacts

Under Alternative 4, direct, indirect, and cumulative impacts on seabeach amaranth would be similar to those described under the No Action alternative and Alternative 3.

5.4.4.7 Cultural Resources

Direct Impacts

The remains of four Civil War vessels at LFI are listed in the NRHP under the Cape Fear Civil War Shipwreck District. The U.S.S. *Iron Age* and two sidewheel steamer blockade-runners (*Elizabeth* and *Bendigo*) are located in a line across the mouth of the inlet, and a third sidewheel blockade-runner (*Ranger*) is located ~1 mile west of the inlet (Tidewater Atlantic Research 2011). Among these shipwrecks, the nearest to the proposed new outer channel is the Bendigo, located ~400 ft to the east. The *Iron Age* and the *Elizabeth* are located ~1,000 ft and ~1,700 ft east of the proposed new outer channel, respectively. Based on the distance between these shipwrecks and the proposed channel, direct impacts on NRHP-listed vessels would not be expected under Alternative 4.

Indirect and Cumulative Impacts

As described in Section 5.4.4.2, the modeling results project eastward migration of the inlet ebb channel over the majority of the four-year simulation period, thus indicating that the ebb channel could eventually intersect one or more of the known Civil War vessels at LFI. However, project-related ebb channel changes would be consistent with natural fluctuations and the dynamic nature of the inlet; and therefore, no indirect or cumulative effects on underwater archaeological resources would be expected under Alternative 4.

5.4.4.8 Public Interest Factors

<u>Public Safety</u>

Under Alternative 4, direct, indirect, and cumulative impacts on public safety would be comparable to those described under Alternative 3.

<u>Aesthetics and Recreation</u>

Under Alternative 4, direct, indirect, and cumulative impacts on aesthetics and recreation would be comparable to those described under Alternative 3.

<u>Navigation</u>

The existing federal inlet channel would be maintained during construction of the new outer channel, with the existing and new channels being joined at the end of the channel relocation process. Furthermore, USACE maintenance dredging of the ebb channel would continue during the interim periods between channel relocation events; therefore, no direct, indirect, or cumulative impacts on navigation would be expected under Alternative 4.

Infrastructure

Under Alternative 4, the CMS model-projected response of the developed East End oceanfront beach is one of recession throughout the four-year simulation period. By the end of Year 4, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~1,200 linear ft) has migrated landward of the existing primary dune, resulting in impacts to 19 oceanfront properties and ~230 ft of roads and associated linear utilities (Figure 5.18). In comparison, the projected future without project East End beach response under Alternative 2 follows a similar erosional pattern; however, the landward extent of shoreline recession at the end of Year 4 exceeds that of Alternative 4 by an average ~19 ft. Under Alternative 2, the MHW line between Avenue B and the eastern terminus of McCray Street (~1,700 linear ft) has migrated landward of the primary dune by the end of Year 4, resulting in impacts to 28 oceanfront properties and ~800 ft of roads and linear utilities (Figure 5.14). Thus, the modeling results suggest a relative reduction in property, road, and utility impacts under Alternative 4.

Economics

Under Alternative 4, construction and maintenance costs would include those associated with periodic beach nourishment and outer inlet channel relocation; including the costs of beach fill, channel relocation dredging, mobilization/demobilization, monitoring, surveying, and permitting. Additional costs would be associated with risk to properties and infrastructure, loss of recreational opportunities, loss of habitat, and environmental impacts associated with outer channel excavation, inlet modification, and periodic nourishment borrow site dredging activities. Over a 30-year planning horizon, assuming outer channel relocation and nourishment of the East End Beach with approximately 150,000 cy of sand every 2 years, and an annual 4 percent increase in fill costs, Alternative 4 is expected to involve total construction costs of approximately $55.50 million. In present value terms, construction costs range from $21.97 million (6% discount rate) to approximately $36.32 million (2.5% discount rate). Potential erosional impacts to properties and infrastructure were projected based on the model-predicted shoreline changes. Specifically, properties and infrastructure that fall within 25 ft of the model-projected MHW at the end of the four-year simulation were considered to be impacted. Costs associated with these impacts were based on the assessed tax value of properties and the estimated cost of infrastructure replacement. Under Alternative 4, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~1,200 linear ft) has migrated landward of the primary dune at the end of Year 4, resulting in impacts to 19 properties (13 improved) and ~228 linear ft of roads and associated water, sewer, and power lines (Figure 5.18). The total assessed value of all properties protected to be newly impacted under Alternative 4 is roughly $3.01 million. The 250 linear ft of anticipated infrastructure replacement cost is valued at approximately $176,321, with a present value ranging from approximately $139,663 (6% discount rate) to $159,738 (2.5% discount rate).

Figure 5.18. Alternative 4 – Projected Properties at Risk and Infrastructure Impacts at YR4 End

To the extent that the activities associated with nourishment physically impede and diminish the aesthetic appeal of the East End beach, these effects may result in economic losses associated with diminished use and non-use values and may have adverse effects on ecosystem service values in terms of provisioning and regulating services provided by the affected species and habitats (Table 5.13). Additional adverse effects on use and non-use values would be expected as a result of channel relocation and inlet instability. The principle benefit of Alternative 4 would be the addition of beach width relative to baseline conditions. It is expected that maintenance of a wider beach would confer benefits in the form of improved property values in the immediate vicinity of the project. Improvements in property values can be expected for properties that would otherwise be imminently threatened. As a result, the Holden Beach tax base would be expected to improve.

Table 5.13. Alternative 4 scope of costs and benefits.

Costs (Relative to Status Quo)	
Construction and Maintenance	$55.50 M
Construction and Maintenance (Present Value)	$21.97 M - $36.32 M
Parcels affected	19
Assessed Tax Value of Affected Parcels	3.01 M
Infrastructure Replacement Costs	$176,321
Infrastructure Replacement Costs (Present Value)	$159,738 $139,663
Reduction in tax base	Intermediate
Transition costs	Intermediate
Diminished recreation value	High
Diminished aesthetic value	High
Environmental Damage	
Public non-use value losses (nature)	High
Public non-use value losses (Holden Beach)	Intermediate
Benefits (Relative to Status Quo)	
Reduction in future nourishment expense	Low
Enhanced property value	Intermediate
Enhanced Recreation value	Moderate
Environmental Improvement	
Public non-use value (nature)	Low
Public non-use value (Holden Beach)	Intermediate

5.4.5 Alternative 5: Short Terminal Groin and Beach Nourishment

Under Alternative 5, the Town would assume responsibility for East End shore protection through the construction of an ~800-ft-long short terminal groin at the eastern end of the oceanfront beach between Stations 10+00 and 20+00 and the implementation of an independent 30-year beach nourishment plan. The main stem of the short terminal groin would include a 550-ft-long segment extending seaward from the toe of the primary dune and a ~250-ft-long anchor segment extending landward from the toe of the primary dune. The groin would also include a 250-ft-long shore-parallel T-Head segment centered on the seaward terminus of the main stem. The 250-ft anchor segment is designed to prevent flanking of the groin in the event of shoreline migration landward of the primary dune. The anchor segment would be entirely buried at the completion of groin construction, and the majority of the anchor segment is designed to remain buried based on historical shoreline analyses back to 1938. The short groin is designed to be a relatively low profile structure, both to promote sand over-passing and to minimize impacts to beach recreation and aesthetics. In addition to the 250-ft anchor segment, a portion of the adjoining groin segment across the upper dry beach would also be completely buried, thus maintaining recreational beach access across the groin. The relatively low profile of the groin would allow some sand over-passing even under eroded conditions at the end of the four-year nourishment cycle.

The short terminal groin would be constructed of 4- to 5-ft-diameter granite armor stone; and unlike conventional jetties and groins, would not have a core component of smaller diameter stone. The use of only larger armor stone would allow for construction of the groin to the design 25 percent void ratio, thus providing the “leaky” characteristic that allows sand to pass through the structure. To prevent settlement of the stone, and if necessary to facilitate modification or removal of the groin, a base later of geo-textile matting (1-ft thick) would be installed below grade prior to armor stone placement. The rubble mound (i.e., armor stone) component of the short groin would have a crest width of ~5 ft and a base width of ~40 ft, whereas the underlying geo-textile base layer would have a slightly greater width of ~45 ft. The relatively short length of the groin and the large tidal range at Holden Beach would allow for construction of the groin entirely from shore. It is anticipated that the East End public access parking lot would provide the necessary beach access, staging, and storage areas for construction activities.

Nourishment events would place ~120,000 – 180,000 cy of sand on the East End beach every four years. The beach nourishment footprint and the basic dune/berm/toe profile design would be similar to those associated with Alternatives 3 and 4; however, the initial nourishment event would also include the construction of a “groin fillet” that would establish a gradual transitional shoreline between the western end of the beach fill footprint and the seaward terminus of the short groin. The seaward terminus of the short groin would extend ~300 ft beyond the MHW line position associated with the eroded 2012 East End beach, which is considerably landward of the historical range of seaward shoreline positions at the eastern terminus of the oceanfront beach. Accounting for sand losses during beach construction, the projected borrow site dredging regime under Alternative 5 would involve the extraction of ~120,000 – 180,000 cy of sand from the preferred LFIX/Bend-Widener borrow site every four years, with the addition of potential supplemental sand acquisition from the inland LFI navigation channel and Central Reach offshore borrow site.

5.4.5.1 Marine Benthic Resources

<u>Soft Bottom Communities</u>

Dredging

Direct Impacts

The anticipated borrow site dredging regime under Alternative 5 would involve extractions of ~120,000 – 180,000 cy of sand from the LFIX channel and associated 400-ft bend widener every four years (in contrast to every two years for the No Action alternative and Alternative 3). In the case of a shortfall in sand volume, supplemental sand would be acquired firstly from the inland LFI channel and secondarily from the Central Reach offshore borrow site. Under Alternative 5, the direct impacts of dredging operations in the LFIX, bend widener, and inland LFI channels would be similar to those described under the No Action alternative and Alternative 3. However, relative to the No Action alternative, Alternative 5 would increase the frequency of bend widener events, thus increasing the frequency of repeated dredging impacts on the associated benthic communities in the bend widener. Conversely, relative to Alternative 3, Alternative 5 would reduce the frequency of bend widener events, thus decreasing the frequency of repeated dredging impacts on the associated benthic communities. In the case of supplemental dredging at the Central Reach offshore borrow site under Alternative 5, direct impacts on soft bottom communities would be the same as those described under Alternative 3. Assuming increased beach fill longevity (i.e., fewer dredging events over a 30 year timespan), reduced impacts to the Central Reach borrow area would be anticipated.

Indirect Impacts

Under Alternative 5, the indirect impacts of dredging operations in the LFIX, bend widener, and inland LFI channels would be similar to those described under the No Action alternative and Alternative 3. However, relative to the No Action alternative, the additional bend widener dredging events under Alternative 5 would result in additional periods of suppressed benthic infaunal prey densities; thus increasing the overall temporal extent of indirect prey-loss effects on demersal fishes. Conversely, relative to Alternative 3, the reduction in bend widener dredging frequency under Alternative 5 would reduce the overall temporal extent of indirect prey-loss effects on demersal fishes. In the case of supplemental dredging at the Central Reach offshore borrow site under Alternative 5, indirect impacts on soft bottom communities would be the same as those described under Alternative 3. Assuming increased beach fill longevity (i.e., fewer dredging events over a 30 year timespan), reduced impacts to the Central Reach borrow area would be anticipated.

Cumulative Impacts

Under Alternative 5, the potential cumulative impacts of dredging operations in the LFIX, bend widener, and inland LFI channels would be the same as those described under the No Action alternative and Alternative 3. In the case of supplemental dredging at the Central Reach offshore borrow site under Alternative 5, potential cumulative impacts on soft bottom communities would be the same as those described under Alternative 3. Assuming increased beach fill longevity (i.e., fewer dredging events over a 30 year timespan), reduced impacts to the Central Reach borrow area would be anticipated.

Terminal Groin and Beach Nourishment

Direct Impacts

Construction of the conceptual short terminal groin under Alternative 5 would directly impact ~0.6 ac of subtidal soft bottom habitat, resulting in the permanent loss of the associated benthic infaunal/epifaunal communities. The direct impacts of individual East End beach fill placement events on soft bottom communities would be the same as those described under the No Action alternative and Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would reduce the frequency of repeated beach fill placement impacts on soft bottom benthic communities.

Indirect Impacts

Under Alternative 5, the indirect impacts of individual beach fill placement events on soft bottom communities and surf zone fishes would be similar to those described under the No Action alternative and Alternatives 3 and 4. However, under Alternative 5, the extended four-year nourishment interval and corresponding reduction in the frequency of repeated direct impact events would reduce the overall temporal extent of indirect prey-loss effects on surf zone fishes.

Cumulative Impacts

Under Alternative 5, the potential cumulative effects of beach fill placement on soft bottom communities would be similar to those described under the No Action alternative and Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would lessen the potential for temporally- and spatially-crowded cumulative effects on soft bottom communities.

Hardbottom Communities

Direct, Indirect, and Cumulative Impacts

Exposed hardbottom features are associated with areas of thin sediment cover on the lower shoreface and adjacent inner continental shelf, which are located well seaward of the beach fill and short terminal groin footprints and the LFIX/bend widener and inland LFI channels. In the case of the Central Reach offshore borrow site, compliance with the state 500-m hardbottom buffer rule was confirmed through remote sensing surveys conducted in 2011 (Tidewater Atlantic Research 2011). Therefore, Alternative 5 would not be expected to have any direct, indirect, or cumulative impacts on hardbottom communities. Submerged portions of the short terminal groin would provide many of the same habitat functions that are associated with natural hardbottom habitats. The fish communities that are associated with groins and jetties in NC are typically a subset of the species found on natural ocean hardbottoms and estuarine oyster reefs (Lindquist et al. 1985; Hay and Sutherland 1988). Taxa reported from groins and jetties in NC and SC include small cryptic resident fishes (e.g., blennies and gobies), numerically dominant fishes that migrate offshore in winter (e.g., pinfish, spottail pinfish, black sea bass, and pigfish), predatory pelagic fishes (e.g., bluefish, Spanish mackerel, and king mackerel), fishes attracted to jetties during their seasonal migrations [e.g., smooth dogfish (*Mustelus canis*)], and tropical fishes occurring as strays during the summer (e.g., butterflyfishes and surgeonfishes) (Hay and Sutherland 1988). Therefore, the additional hardbottom habitat created by the short terminal groin would be expected to have beneficial effects on hardbottom communities.

5.4.5.2 Water Column

Hydrodynamics

Direct and Indirect Impacts

Dredging

Under Alternative 5, the potential direct and indirect hydrodynamic effects of dredging in the LFIX/bend widener and inland LFI channels would be similar to those described under the No Action alternative and Alternative 3. The potential direct and indirect hydrodynamic effects of dredging at the Central Reach offshore borrow site would be the same as those described under Alternative 3.

Short Terminal Groin and Nourishment

The CMS model-projected inlet and estuarine hydrodynamic responses to beach nourishment and groin construction under Alternative 5 are essentially the same as the projected future without project responses under Alternative 2. Simulated tidal prism volumes and current velocities for the inlet throat, AIWW east channel, AIWW west channel, and Eastern Channel are consistently within +/-10 percent of the corresponding Alternative 2 values during the four-year model simulation period (Table 5.14). The common pattern of hydrodynamic response under the two alternatives is generally one of steadily decreasing tidal prism volumes and current velocities across all four of the inlet/estuarine transects. Corresponding model-projected changes in channel morphology under Alternative 5 are also essentially the same as those associated with Alternative 2. The similarity of the responses under the two alternatives suggests that the model-projected inlet and estuarine hydrodynamic responses under Alternative 5 are primarily the result of natural background coastal processes; thus indicating that the short groin and associated nourishment activities under Alternative 5 would have little effect on inlet and estuarine hydrodynamics.

The model-projected nearshore ocean hydrodynamic response along Holden Beach indicates that groin-related effects on longshore current dynamics are highly localized to the groin structure. Under flood tide conditions, the potential for any deflection of longshore currents by the groin is overridden by the large tidal push of water into the inlet; and consequently, easterly longshore currents along the Holden Beach oceanfront shoreline are driven tightly around the groin and into the inlet where they resume their normal pattern of flow (Figure 5.19). Similarly, the large tidal push of water out of the inlet during ebb tide conditions drives westerly longshore currents from the inlet tightly around the groin and along the Holden Beach oceanfront shoreline (Figure 5.20). Therefore, adverse effects on longshore currents would not be expected under Alternative 5. The filled East End beach in combination with the groin fillet would establish a gradual transitional shoreline between the western end of the beach fill footprint and the seaward terminus of the terminal groin, thus minimizing the potential for effects on longshore currents. Furthermore, the groin would extend the oceanfront shoreline seaward by only ~300 ft relative to the eroded 2012 MHW line position, which is considerably landward of the historical range of seaward shoreline positions associated with the eastern terminus of oceanfront beach.

Other potential hydrodynamic-effects that are generally associated with terminal groins include the potential for rip current formation along the groin structure and the potential for interference with the transport of estuarine-dependent fish and invertebrate larvae from the updrift nearshore ocean zone to the inlet. The minimal model-projected effects on longshore current dynamics indicate that larval transport is unlikely to be significantly impeded by the groin. Additional larval transport modeling analyses were conducted using the CMS hydrodynamic and sediment transport model to further evaluate potential impacts to larval transport. The CMS model was used to compare changes in particle concentrations (representing larvae) along the East End beach under Alternatives 2 and 5. The only differences between the projected particle concentration changes under the two alternatives correspond to areas of subtidal/intertidal to supratidal beach conversion within the beach fill footprint (Figure 5.21), thus indicating that the differences are related to the displacement of water by beach fill under Alternative 5. Thus, the modeling results indicate only localized groin-related effects on larval transport. The T-head feature of the groin is designed to minimize rip current formation, and the CMS current vector modeling results do not show any rip current activity along the groin structure. However, the modeling results do show a general increase in rip current activity along the adjacent East End

Table 5.14. Alternative 5 relative tidal prism volumes (percentage of corresponding Alternative 2 volumes).

Year	Inlet		AIWW West		AIWW East		Eastern Channel	
	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb
Spring Tide								
0	100%	100%	99%	97%	100%	100%	100%	100%
1	97%	97%	95%	95%	100%	100%	100%	100%
2	97%	96%	94%	78%	100%	100%	99%	100%
3	99%	97%	88%	97%	101%	97%	98%	100%
4	103%	97%	101%	100%	104%	101%	118%	96%
Neap Tide								
0	100%	100%	99%	98%	100%	100%	100%	100%
1	97%	97%	90%	88%	100%	100%	100%	100%
2	97%	92%	92%	95%	100%	101%	99%	74%
3	98%	99%	87%	66%	99%	101%	98%	100%
4	105%	101%	116%	113%	110%	106%	113%	95%

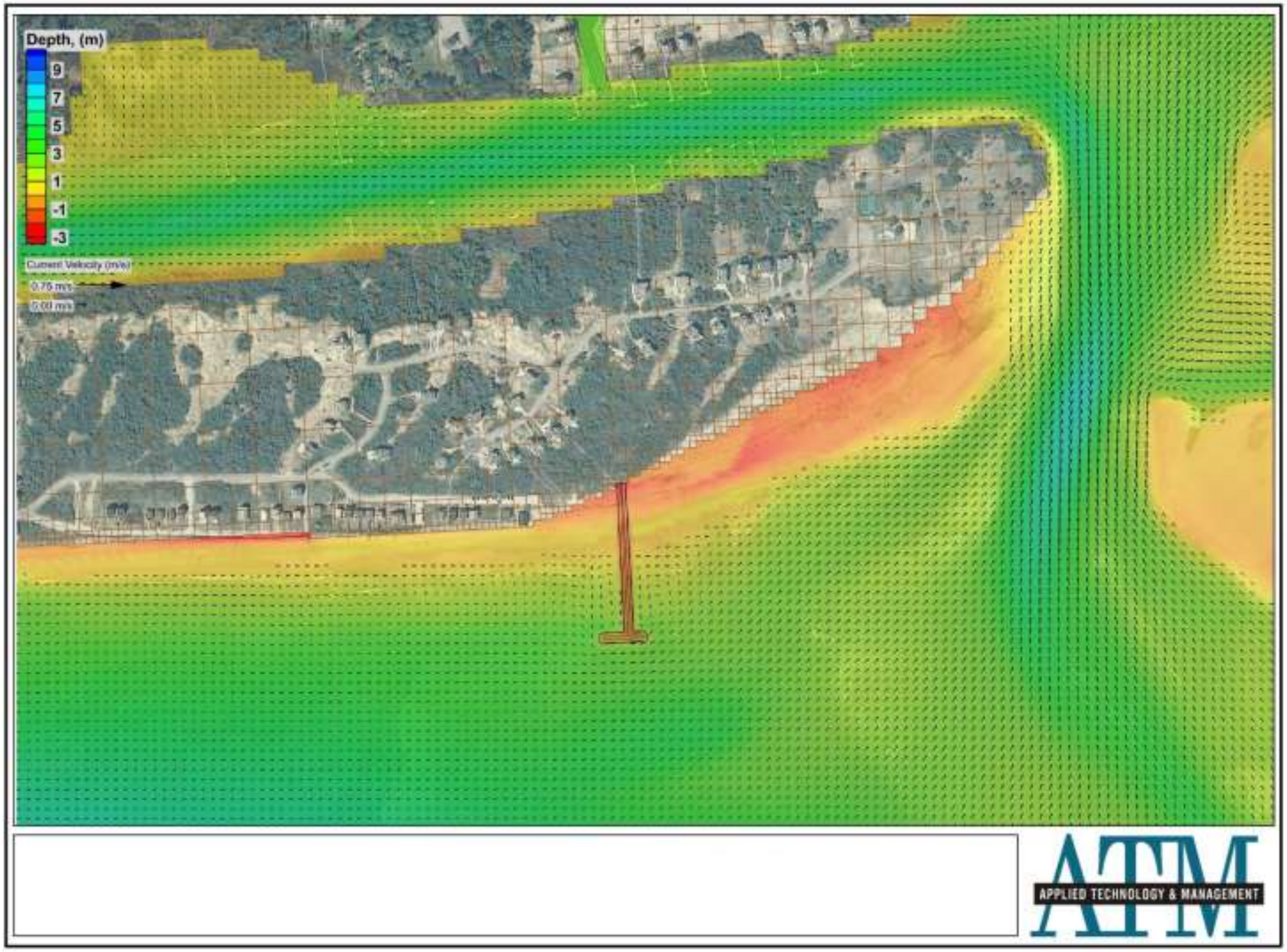

Figure 5.19. Alternative 5 - Typical Flood Tide Current Vector Diagram

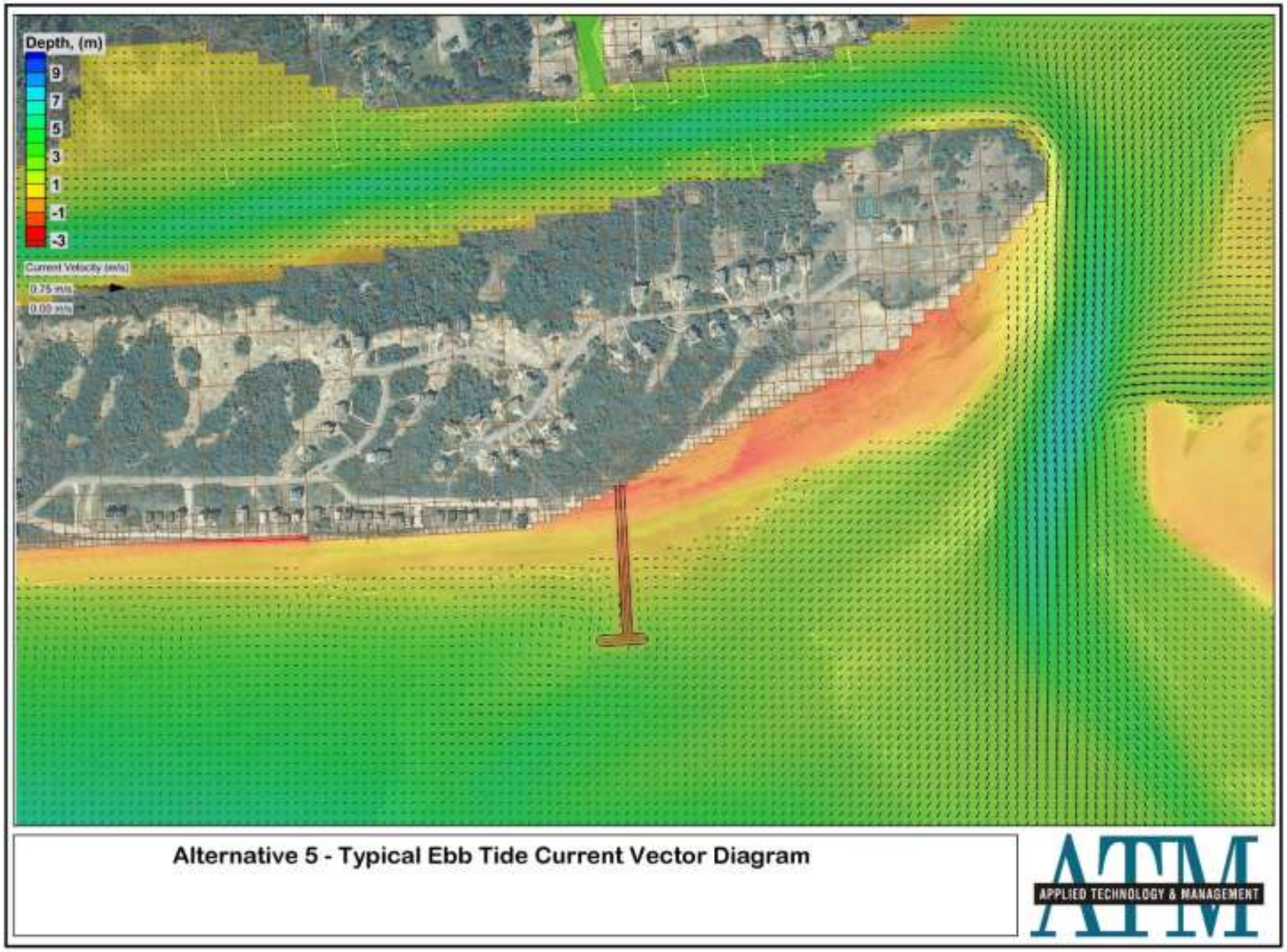

Figure 5.20. Alternative 5 - Typical Ebb Tide Current Vector Diagram

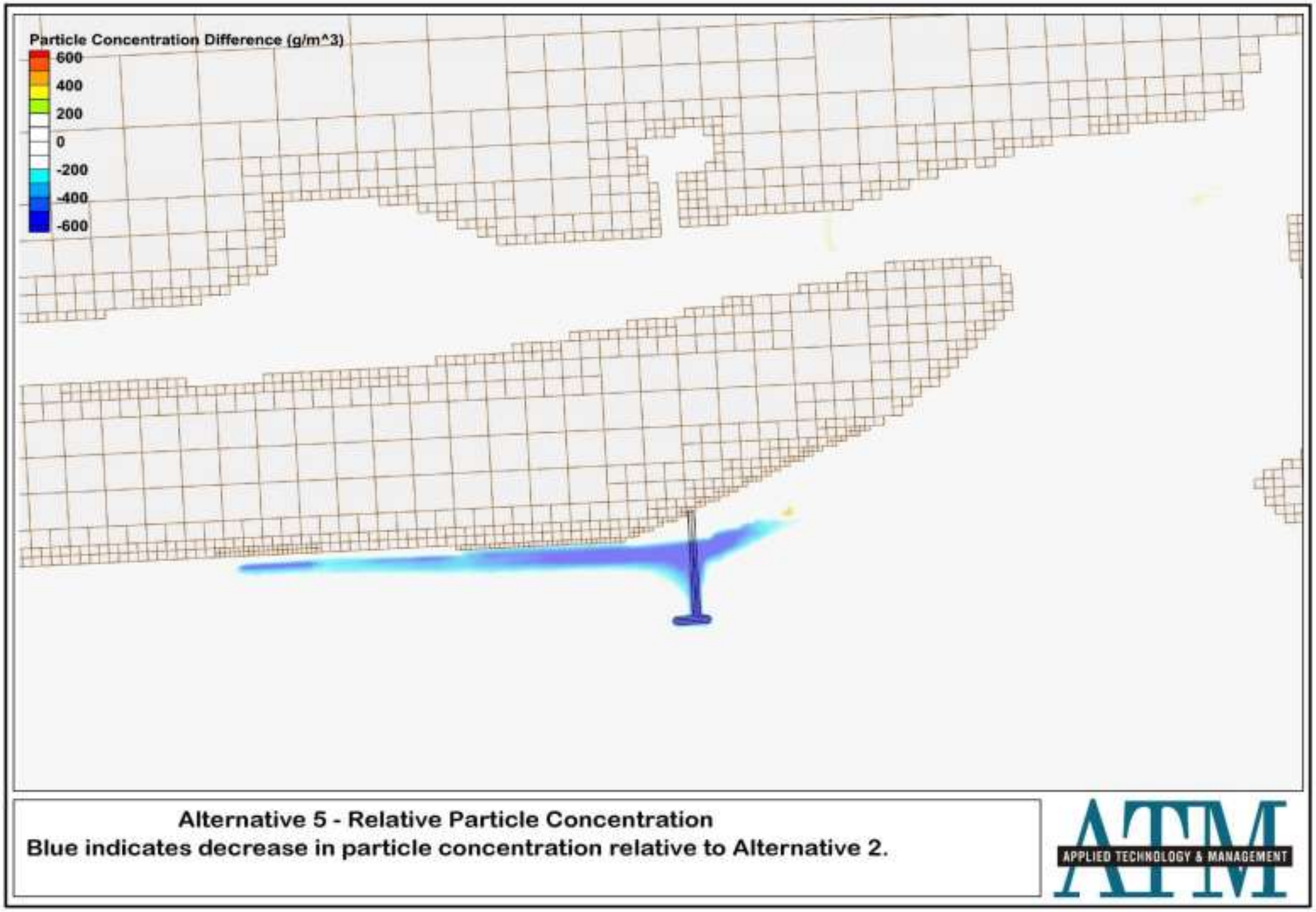

Figure 5.21. Alternative 5 - Relative Particle Concentration

beach during ebb tidal conditions, thus suggesting a greater risk of rip current formation along the East End beach under Alternative 5. However, existing hydrodynamic conditions along the East End beach are also conducive to rip current formation when inlet ebb tidal current velocities exceed 5 ft per second.

Cumulative Impacts

The CMS modeling results for Alternative 5 suggest that project-related direct and indirect effects on hydrodynamics would be minor and highly localized to the groin structure. Therefore, cumulative impacts on hydrodynamics would not be expected under Alternative 5.

<u>Sediment Suspension and Turbidity</u>

Direct, Indirect, and Cumulative Impacts

Dredging

Under Alternative 5; the direct, indirect, and cumulative effects of dredging-induced sediment suspension on water quality and pelagic communities would be similar to those described under the No Action alternative and Alternative 3. Although project related dredging for nourishment purposes would occur less frequently under Alternative 5, it is assumed that continuing interim federal maintenance dredging would maintain a similar LFIX dredging regime, thereby resulting in similar sediment suspension effects within the water column.

Short Terminal Groin and Nourishment

Construction of the short groin would be conducted entirely from shore, and the extent of subtidal/intertidal substrate disturbance would be minimal (~0.3 ac). Therefore, it is expected that the direct and indirect impacts of groin-related sediment suspension would be short-term, localized, and minor. Direct and indirect sediment suspension effects associated with East End beach fill placement events would be similar to those described under the No Action alternative and Alternatives 3 and 4. Sediment suspension effects associated with groin construction and periodic nourishment would be short term and localized to the East End beach; and therefore, cumulative impacts would not be expected under Alternative 5.

<u>Underwater Noise</u>

Direct, Indirect, and Cumulative Impacts

Under Alternative 5; the direct, indirect, and cumulative impacts of underwater noise produced by dredging operations in the LFIX, bend widener, and inland LFI channels would be the same as those described under the No Action alternative and Alternative 3. In the case of supplemental dredging at the Central Reach offshore borrow site; the potential direct, indirect, and cumulative impacts of underwater noise would be the same as those described under Alternative 3.

Entrainment

Direct, Indirect, and Cumulative Impacts

Under Alternative 5; the direct, indirect, and cumulative impacts of entrainment would be comparable to those described under Alternative 3.

5.4.5.3 Oceanfront Beach and Dune Communities

Intertidal Beach Communities

Direct Impacts

Under Alternative 5, construction of the short terminal groin would directly impact ~0.2 ac of intertidal beach habitat, resulting in the permanent loss of the associated benthic infaunal/epifaunal communities. The direct impacts of individual East End beach fill placement events on intertidal beach communities would be similar to those described under the No Action alternative and Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would reduce the frequency of repeated beach fill placement impacts on intertidal benthic communities.

Indirect Impacts

Under Alternative 5, the indirect impacts of individual beach fill placement events on intertidal beach communities would be similar to those described under the No Action alternative and Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would reduce the overall temporal extent of indirect benthic infaunal prey-loss effects on shorebirds and surf zone fishes. Based on the minimal area of permanent groin-related intertidal habitat loss (~0.2 ac), associated indirect effects on shorebirds and surf zone fishes would be negligible.

Under Alternative 5, the CMS model-projected response of the Oak Island west-end oceanfront shoreline (Figure 5.22) is essentially the same as the projected future without project shoreline response under Alternative 2 (Figure 5.13). Under Alternative 5, a minor reduction in shoreline erosion over the course of the four-year model simulation period slightly reduces intertidal beach habitat loss by ~1 ac in relation to Alternative 2 (Table 5.3). The similarity of the Oak Island responses indicates that the projected shoreline and intertidal beach habitat changes under Alternative 5 are primarily the result of natural background coastal processes; thus suggesting that beach nourishment and groin construction under Alternative 5 would not affect intertidal beach habitat on Oak Island. The projected responses of the East End oceanfront shoreline on Holden Beach under Alternatives 2 and 5 are similar in pattern; however, there are

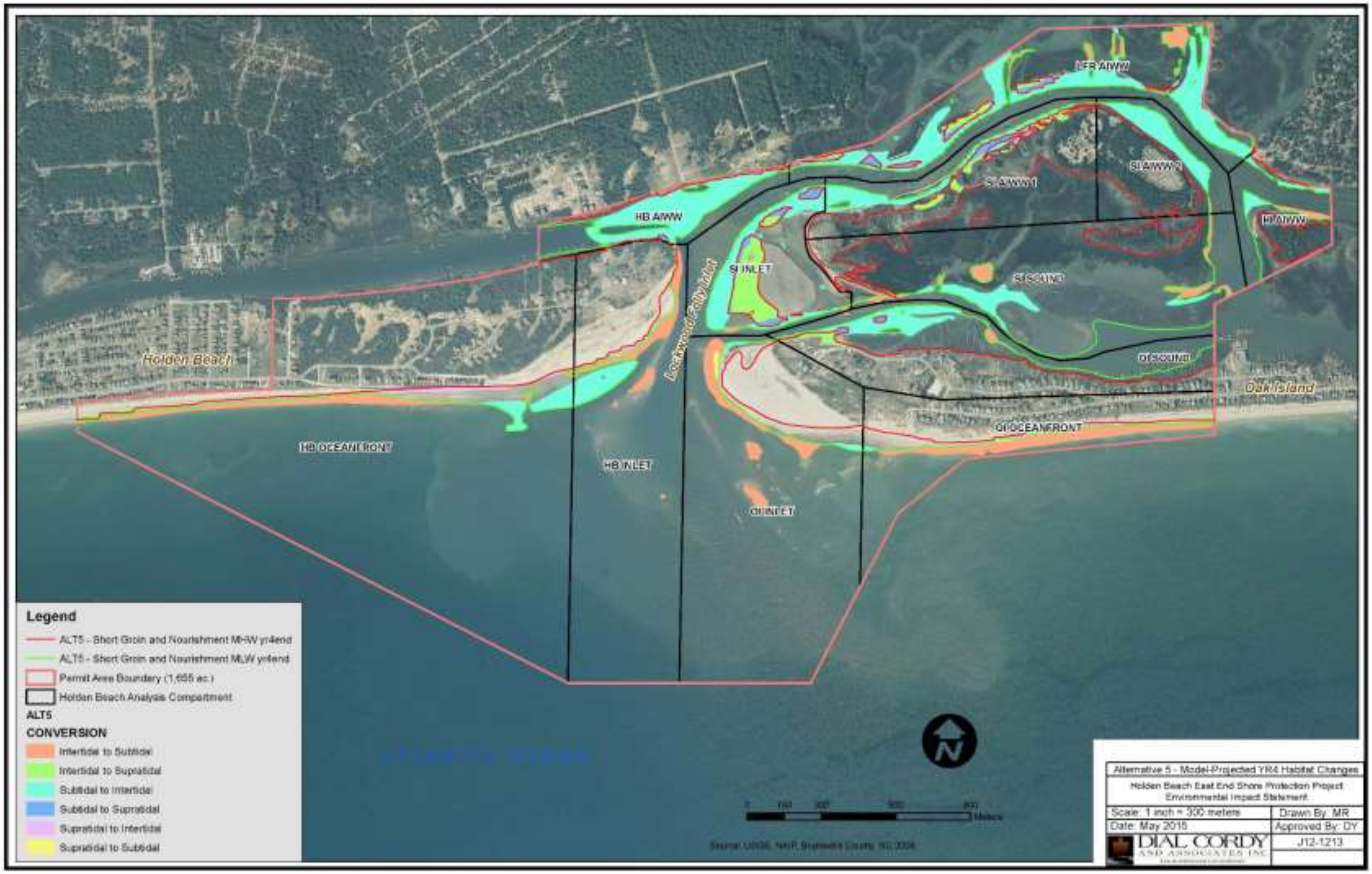

Figure 5.22. Alternative 5 – Model-Projected YR4 Habitat Changes

differences between the responses that are related to the performance of the beach fill and the sand trapping function of the groin under Alternative 5. The entire East End beach to the west of the groin is erosional under both alternatives; however, under Alternative 5, the performance of the beach fill is reflected in a relative increase in beach width at the end of Year 4. The response of the remaining East End beach to the east of the groin is characterized by accretional shoal attachment under both alternatives; however, under Alternative 5, more of the shoal is retained by the groin, resulting in a relative increase in beach width at the end of Year 4. As a result of beach fill performance and groin effects, the nourished East End beach under Alternative 5 is on average ~36 ft wider than the corresponding East End beach under Alternative 2 at the end of Year 4 (Table 5.4). The corresponding effect on the quantity of intertidal beach habitat under Alternative 5 is an increase of ~5 ac relative to Alternative 2 (Table 5.3).

Cumulative Impacts

Under Alternative 5, cumulative impacts on intertidal beach communities would be similar to those described under the No Action alternative and Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would lessen the potential for temporally- and spatially-crowded cumulative effects on intertidal beach communities.

<u>Dry Beach and Dune Communities</u>

Direct Impacts

Under Alternative 5, construction of the short terminal groin would permanently impact ~0.2 ac of dry beach and dune habitat. The direct impacts of individual East End beach fill placement events on dry beach and dune communities would be similar to those described under Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would reduce the frequency of repeated impacts on dry beach and dune communities.

Indirect Impacts

The indirect impacts of individual East End beach fill placement events on dry beach and dune communities would be similar to those described under Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would reduce the overall temporal extent of indirect physical habitat modification effects on dry beach and dune communities. The majority of the short groin dry beach segment and the entirety of the landward anchor segment through the dunes would be completely buried; thus minimizing the potential for indirect physical habitat modification effects. Based on the minimal area of permanent groin-related dry beach habitat loss (~0.2 ac), associated indirect effects on dry beach communities would be negligible.

As described above, the CMS model-projected responses of the Oak Island oceanfront shoreline are the same under Alternatives 5 (Figure 5.22) and 2 (Figure 5.13). Corresponding dry beach/dune habitat changes on Oak Island are also the same, with projected losses of ~3 ac occurring under both alternatives (Table 5.3). The similarity of the Oak Island responses indicates that the projected dry beach and dune habitat changes under Alternative 5 are primarily the result of natural background coastal processes; thus suggesting that beach nourishment and groin construction under Alternative 5 would not affect dry beach and dune habitats on Oak Island.

In the case of Holden Beach, the projected relative increase in beach width under Alternative 5 corresponds to an increase in dry beach/dune habitat of ~3 ac relative to Alternative 2 (Table 5.3); thus suggesting a beneficial relative increase in habitat under Alternative 5.

Cumulative Impacts

Under Alternative 5, potential cumulative impacts on dry beach and dune communities would be similar to those described under Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would lessen the potential for temporally- and spatially-crowded cumulative effects on dry beach and dune communities.

5.4.5.4 Inlet Complex

Intertidal Flats and Shoals

Direct Impacts

Direct impacts on intertidal flats and shoals under Alternative 5 would be similar to those described under the No Action alternative and Alternative 3.

Indirect Impacts

Initial Beach Fill Placement and Dredging

The indirect impacts of dredging and beach nourishment on intertidal flats and shoals under Alternative 5 would be similar to those described under the No Action alternative and Alternative 3.

Long-Term Model-Projected Effects

The CMS model-projected inlet response under Alternative 5 (Figure 5.22) is essentially the same as the projected future without project inlet response under Alternative 2 (Figure 5.13). The only dissimilarity between the projected inlet responses under the two alternatives is a minor difference in the pattern of shoal attachment along the inlet shoulder of Holden Beach. The inlet response under both alternatives includes the same general pattern of shoal formation and attachment along the inlet shoulder; resulting in net accretion along the adjoining ~500-ft segment of the inlet shoreline at the end of Year 4. However, under Alternative 5, a larger quantity of the shoal sediment volume is retained by the short groin, resulting in a relative increase in intertidal habitat of ~2 ac at the end of Year 4 (Table 5.3). Otherwise, the projected inlet response and the associated losses and gains of intertidal habitat under Alternative 5 are essentially the same as those described under Alternative 2. The similarity of the inlet responses under the two alternatives indicates that the projected changes under Alternative 5 are primarily the result of natural background coastal processes; thus suggesting that beach nourishment and groin construction under Alternative 5 would have little effect on inlet intertidal habitats.

Cumulative Impacts

In the absence of direct and indirect effects, potential cumulative impacts on intertidal flats and shoals would not be expected under Alternative 5.

<u>Inlet Dry Beach and Dune Communities</u>

Direct

Direct impacts on inlet dry beach and dune communities under Alternative 5 would be similar to those described under the No Action alternative and Alternative 3.

Indirect

Under Alternatives 5, the CMS model-projected changes in the distribution and quantity of inlet dry beach and dune habitats (Figure 5.22) are the same as the projected future without project changes under Alternative 2 (Figure 5.13). The similarity of the responses indicates that the projected changes under Alternative 5 are primarily the result of natural background coastal processes; thus suggesting that Alternative 5 would not have any effect on inlet dry beach and dune habitats.

Cumulative Impacts

In the absence of direct and indirect effects, potential cumulative impacts on inlet dry beach and dune communities would not be expected under Alternative 5.

5.4.5.5 Estuarine Resources

<u>Shellfish</u>

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 5 on shellfish would be the same as those described under the No Action alternative and Alternative 3.

SAV

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 5 on SAV would be the same as those described under the No Action alternative and Alternative 3.

Tidal Marsh Communities

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 5 on tidal marshes would be the same as those described under the No Action alternative and Alternative 3.

5.4.5.6 Threatened and Endangered Species

North Atlantic Right Whale and Humpback Whale

Direct, Indirect, and Cumulative Impacts

The potential direct, indirect, and cumulative impacts of dredging and beach fill placement operations on right and humpback whales and proposed right whale critical habitat under Alternative 5 would be the same as those described under Alternative 3. The short groin structure would be confined to relatively shallow waters (<6 m). Considering that the essential features of proposed right whale critical habitat within the study area include a water depth $\geq$6 m, no adverse effects on critical habitat would be expected under Alternative 5.

West Indian Manatee

Direct, Indirect, and Cumulative Impacts

Under Alternative 5, potential direct, indirect, and cumulative impacts on the West Indian manatee would be the same as those described under the No Action alternative and Alternative 3.

Piping Plover

Direct, Indirect, and Cumulative Impacts

As described in Section 5.4.5.4, the modeling results for Alternative 5 do not show any project-related effects on the inlet habitats that are likely to be used by piping plovers. Therefore, potential direct, indirect, and cumulative impacts on piping plovers under Alternative 5 would be comparable to those described under the No Action alternative and Alternative 3.

Red Knot

Under Alternative 5; the potential direct, indirect, and cumulative impacts on red knots would be similar to those described under the No Action alternative and Alternative 3. However, Alternative 5 would maintain a consistently wider East End oceanfront beach while reducing the frequency of periodic nourishment impact events, thus suggesting the potential for additional beneficial effects on red knots via habitat enhancement.

Wood Stork

Under Alternative 5; the potential direct, indirect, and cumulative impacts on wood storks would be the same as those described under the No Action alternative and Alternatives 3 and 4.

Sea Turtles

Direct Impacts

Under Alternative 5; the potential direct impacts of beach fill placement and dredging on sea turtles would be comparable to those described under Alternative 3. Groin construction would adhere to the proposed environmental window, thus avoiding the sea turtle nesting season. Direct impacts on sea turtles in the water would not be expected, as groin construction would occur entirely from shore.

Indirect and Cumulative Impacts

Initial Beach Fill Placement, Dredging, and Groin Construction

The potential indirect impacts of beach fill placement and dredging operations on sea turtles would be comparable to those described under Alternative 3. Groin construction would result in minimal (~0.2 ac) permanent loss of potential dry beach nesting habitat; and the majority of the groin segment across the dry beach would be buried, thus minimizing the potential for indirect physical habitat modification effects. Furthermore, based on the groin's location near the eastern terminus of the oceanfront beach, and its perpendicular alignment relative to the beach, effects on sea turtle access to dry beach nesting habitats would not be expected. Therefore, the short groin would not be expected to have adverse indirect or cumulative effects on sea turtles via modification of potential nesting habitat. The filled East End beach in combination with the groin fillet would establish a gradual transitional shoreline between the western end of the beach fill footprint and the seaward terminus of the terminal groin, thus minimizing the potential for effects on sea turtle movements in the water. Furthermore, the short groin would extend the oceanfront shoreline seaward by only ~300 ft relative to the eroded 2012 MHW line position, which is considerably less than the historical range of seaward shoreline positions along the eastern terminus of the oceanfront beach. Therefore, the short groin would not be expected to have any adverse indirect or cumulative effects on sea turtles in the water. The modeling results indicate an increase in ocean dry beach habitat of ~4 acres along the East End relative to Alternative 2 at the end of Year 4, thus suggesting the potential for beneficial effects on sea turtles via enhancement of nesting habitat.

Atlantic and Shortnose Sturgeons

Direct, Indirect, and Cumulative Impacts

Under Alternative 5; direct, indirect, and cumulative impacts on Atlantic and shortnose sturgeons would be similar to those described under Alternative 3. However, the bend widener would be dredged less frequently under Alternative 5, thus reducing the frequency of repeated impacts on the associated benthic invertebrate communities. Thus, the overall temporal extent of potential indirect benthic infaunal prey-loss effects under Alternative 5 would be reduced relative to Alternative 3.

Seabeach Amaranth

Under Alternative 5; the direct and indirect impacts of individual beach fill placement events on seabeach amaranth would be similar to those described under the No Action alternative and Alternatives 3 and 4. However, the extended four-year nourishment interval under Alternative 5 would reduce the frequency of repeated beach fill placement impacts on dry beach habitats, thus reducing the frequency and overall temporal extent of potential adverse impacts on seabeach amaranth relative to the No Action alternative and Alternatives 3 and 4. Similarly, the reduction in the frequency and temporal extent of beach fill placement impacts would lessen the potential for adverse cumulative effects. The maintenance of a wider dry beach would potentially have beneficial indirect effects on seabeach amaranth via habitat enhancement. The modeling results indicate an increase in ocean dry beach habitat of ~4 ac along the East End relative to Alternative 2 at the end of Year 4, thus suggesting the potential for beneficial effects on sea beach amaranth via habitat enhancement.

5.4.5.7 Cultural Resources

Direct, Indirect, and Cumulative Impacts

Under Alternative 5, potential direct, indirect, and cumulative impacts of beach fill placement and dredging on cultural resources would be the same as those described under Alternative 3. The short groin would extend only ~300 ft seaward of the MHW line, and the groin footprint would be evaluated for the presence of potential marine debris and archaeological resources prior to construction. Therefore, construction of the short groin would not be expected to have any direct, indirect, or cumulative effects on cultural resources.

5.4.5.8 Public Interest Factors

Public Safety

Direct, Indirect, and Cumulative Impacts

Under Alternative 5, the potential direct, indirect, and cumulative impacts of beach nourishment and dredging on public safety would be the same as those described under the No Action alternative and Alternative 3. In general, groin-related public safety concerns are related to the creation of a potential hazard to navigation and the potential for an increase in rip current activity along the groin structure. The short terminal groin would not be located in a navigation channel, but would constitute a potential hazard to small recreational watercraft operating in close proximity to the shoreline. As a potential hazard to navigation, the short terminal groin would be subject to USCG approval and marking requirements in accordance with 33 CFR 64. Marking requirements would be determined by the USCG, and once established would be maintained until the groin is removed. The T-head feature of the groin is designed to minimize rip current formation, and the CMS current vector modeling results do not show any rip current activity along the groin structure. However, the modeling results do show a general increase in rip current activity along the immediately adjacent East End beach during ebb tidal conditions, thus suggesting a greater risk of rip current formation along the East End beach under Alternative 5. However, existing hydrodynamic conditions along the East End beach are also conducive to rip current formation when inlet ebb tidal current velocities exceed 5 ft per second (ATM 2013).

Aesthetics and Recreation

Direct, Indirect, and Cumulative Impacts

Under Alternative 5, potential direct, indirect, and cumulative impacts of beach fill placement and dredging on aesthetics and recreation would be similar to those described under the No Action alternative and Alternative 3. However, the extended four-year nourishment interval under Alternative 5 would reduce the overall temporal extent of beach construction activities and associated adverse effects on aesthetics and recreation relative to the No Action alternative and Alternative 3. The short terminal groin would not provide a natural beach aesthetic environment, and thus may detract from the aesthetic quality of the beach for some beachgoers. However, the groin is designed to be a low profile structure with minimal exposure on the recreational beach, in part to minimize aesthetic effects. However, to the extent that the terminal groin structure itself may be viewed as aesthetically unappealing, aesthetic quality may be reduced relative to that which would exist with a natural and stable shoreline. However, given that a natural and stable shoreline may not be feasible by other means, an aesthetically lacking but stable shoreline may be seen as preferable.

Navigation

Direct, Indirect, and Cumulative Impacts

Under Alternative 5, the potential direct, indirect, and cumulative impacts of beach nourishment and dredging on navigation would be similar to those described under the No Action alternative and Alternative 3. The short groin would not be located in a navigation channel and would extend only ~300 ft seaward of the MHW line. As described in Section 5.2, the CMS current vector analyses do not show any hydrodynamic changes that would affect navigation. Furthermore, as described above, the potential structural hazard to small recreational watercraft operating in close proximity to the shoreline would be mitigated through adherence to the marking requirements of 33 CFR 64. Therefore, no direct, indirect, or cumulative groin-related impacts on navigation would be expected under Alternative 5.

Infrastructure

Under Alternative 5, the CMS model-projected response of the developed East End oceanfront beach is one of recession throughout the four-year simulation period. By the end of Year 4, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~800 linear ft) has migrated landward of the existing primary dune, resulting in impacts to 10 oceanfront properties (Figure 5.23). No roads or linear utilities are affected. In comparison, the projected future without project East End beach response under Alternative 2 follows a similar erosional pattern; however, the landward extent of shoreline recession at the end of Year 4 exceeds that of Alternative 5 by an average ~36 ft. Under Alternative 2, the MHW line between Avenue B and the eastern terminus of McCray Street (~1,700 linear ft) has migrated landward of the primary dune by the end of Year 4, resulting in impacts to 28 oceanfront properties and ~800 ft of roads and linear utilities (Figure 5.14). Thus, the modeling results suggest a relative reduction in property, road, and utility impacts under Alternative 5.

Economics

Under Alternative 5, construction and maintenance costs would include those associated with construction and maintenance of the short groin and periodic beach nourishment; including the costs of beach fill and groin materials, mobilization/demobilization, monitoring, surveying, and permitting. Additional costs would be associated with risk to properties and infrastructure, loss of recreational opportunities, loss of habitat, and environmental impacts associated with the groin and periodic nourishment and dredging activities. Over a 30-year planning horizon, assuming $2.5 million for initial groin construction and nourishment of the East End Beach with approximately 150,000 cy of sand every four years, and an annual four percent increase in fill costs, Alternative 5 is expected to involve total construction costs of approximately $34.41 million. In present value terms, construction costs range from $15.24 million (6% discount rate) to approximately $23.43 million (2.5% discount rate). Potential erosional impacts to properties and infrastructure were projected based on the model-predicted shoreline changes.

Figure 5.23. Alternative 5 – Projected Properties at Risk and Infrastructure Impacts at YR4 End

Specifically, properties and infrastructure that fall within 25 ft of the model-projected MHW at the end of the four-year simulation were considered to be impacted. Costs associated with these impacts were based on the assessed tax value of properties and the estimated cost of infrastructure replacement. Under Alternative 5, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~800 linear ft) has migrated landward of the primary dune at the end of Year 4, resulting in impacts to 11 properties (6 improved) (Figure 5.23). The total assessed value of all properties protected to be newly impacted under Alternative 5 is roughly $994,000. Projected shoreline changes under Alternative 5 do not result in any impacts to infrastructure.

Under Alternative 5, use and non-use values associated with recreation, aesthetics, and the natural environment are generally expected to be enhanced relative to Alternatives 2, 3, and 4 and similar to those projected under Alternative 6 (Table 5.15). Public recreational values would be affected to the extent that the activities associated with nourishment physically impede and diminish the aesthetic appeal of the East End beach. These effects may result in economic losses associated with diminished use and non-use values and may have adverse effects on ecosystem service values in terms of provisioning and regulating services provided by the affected species and habitats. To the extent that the terminal structure itself may be viewed as aesthetically unappealing, properties with views of the structure may have reduced amenity value relative to that which would exist with a natural and stable shoreline. However, given that a natural and stable shoreline may not be feasible by other means, an aesthetically lacking but stable shoreline would likely be seen as preferable relative to the alternative condition. Furthermore, to the extent that the structure would attract recreationists (i.e. anglers) or inhibit movement along the shoreline, property owners in the vicinity of the groin could suffer economic losses due to inconvenience and crowding. The use of a hardened structure to mitigate erosion would confer economic losses on the segment of the population that values unfettered ecosystem function. Even if harmful effects are never realized, some people could remain opposed to the use of hardened structures for shoreline erosion control. In the case of the proposed terminal groin on Holden Beach, such sentiments may be partially mitigated by the understanding that the required frequency of beach nourishment events would be reduced, thereby lessening the environmental impacts of dredging and sand placement over the lifetime of the structure.

The principle benefits of Alternative 5 would be associated with enhanced shoreline stability and increased beach width relative to baseline conditions. To the extent that the public views the terminal structure as reducing the risk of future erosion, this added stability would serve to enhance property values along the Holden Beach East End shoreline. Based on the literature (see Appendix Q), it is reasonable to expect that properties up to 300 m inland of the shoreline would realize improvements in market value. Associated benefits would likely include increased rental revenues and higher municipal tax revenues. As noted in Parsons and Powell (2001), active mitigation efforts such as beach armoring may also serve to encourage additional use and/or development and generate additional economic impacts relative to the status quo in the form of increased municipal tax revenues as well as temporary construction employment and spending. The terminal groin may create enhanced recreation values as a result of the

Table 5.15. Alternative 5 scope of costs and benefits.

Costs (Relative to Status Quo)	
Construction and Maintenance	$34.41 M
Construction and Maintenance (Present Value)	$21.97 M – $36.32 M
Parcels affected	11
Assessed Tax Value of Affected Parcels	$994,480
Infrastructure Replacement Costs	$0
Infrastructure Replacement Costs (Present Value)	$0
Reduction in tax base	Low/None
Transition costs	Low
Diminished recreation value	Low
Diminished aesthetic value	Intermediate
Environmental Damage	
Public non-use value losses (nature)	High
Public non-use value losses (Holden Beach)	Low
Benefits (Relative to Status Quo)	
Reduction in future nourishment expense	High
Enhanced property value	High
Enhanced Recreation value	High
Environmental Improvement	
Public non-use value (nature)	Low
Public non-use value (Holden Beach)	High

predicted gains in beach width and shoreline stability, especially those in the vicinity of the structure, as well as the creation of rocky bottom area that may increase species diversity and enhance the quality of recreational fishing near the structure. Because dune and beach habitats in the project area will be subject to reduced losses from erosion, indirect and non-use values may also be created, enhanced, or preserved.

5.4.6 Alternative 6: Intermediate Terminal Groin and Beach Nourishment

Under Alternative 6, the Town would assume responsibility for East End shore protection through the construction of an ~1,000-ft-long intermediate terminal groin at the eastern end of the oceanfront beach between Stations 00+00 and 10+00 and the implementation of an independent 30-year beach nourishment plan. The main stem of the intermediate terminal groin would include a 700-ft-long segment extending seaward from the toe of the primary dune and a ~300-ft anchor segment extending landward from the toe of the primary dune. The groin would also include a 120-ft-long shore parallel T-Head segment centered on the seaward terminus of the main stem. As previously described for the short groin, the anchor segment is designed to prevent flanking of the groin in the event of shoreline migration landward of the primary dune. The anchor segment would be entirely buried at the completion of groin construction, and the majority of the anchor segment is designed to remain buried based on historical shoreline analyses back to 1938. Similar to the short groin, the intermediate groin is designed to be a relatively low profile structure, both to allow sand over-passing and to minimize impacts to beach recreation and aesthetics. In addition to the 300-ft anchor segment, a portion of the adjoining 700-ft segment across the upper dry beach would also be completely buried, thus maintaining recreational beach access across the groin. The relatively low profile of the groin would allow some sand over-passing even under eroded conditions at the end of the four-year nourishment cycle.

Similar to the short groin, the intermediate groin would be constructed of 4- to 5-ft-diameter granite armor stone; and unlike conventional groins and jetties; would not have a core component of smaller diameter stone. The use of only larger armor stone would allow for construction of the groin to the design 25 percent void ratio, thus providing the “leaky” characteristic that allows sand to pass through the structure. To prevent settlement of the stone, and if necessary to facilitate modification or removal of the groin, a base layer of geo-textile matting (1-ft thick) would be installed below grade prior to armor stone placement. The rubble mound (i.e., armor stone) component of the groin would have a crest width of ~5 ft and a base width of ~40 ft, whereas the underlying geo-textile base layer would have a slightly greater width of ~45 ft. The relatively short length of the intermediate groin along with the large tidal range at Holden Beach would allow for construction of the groin entirely from shore. It is anticipated that the public access parking lot would provide the necessary beach access, staging, and storage areas for construction activities.

The projected beach nourishment regime would involve the placement of ~120,000 – 180,000 cy of sand on the East End beach every four years. Compared to the short groin, the intermediate groin would be located ~300 ft farther east, resulting in a corresponding 300-ft relative increase in the lengths of the berm, toe, and groin fillet components under Alternative 6. The greater length of the intermediate groin is designed to account for the landward shift in shoreline position as the east-west oriented oceanfront beach transitions to the north-south oriented inlet shoreline. Relative to the east-west oriented oceanfront shoreline at the proposed short groin location, the intermediate groin does not extend any farther seaward. The shore-perpendicular widths of the beach fill toe and groin fillet footprints in the vicinity of the intermediate groin structure would also increase slightly to account for the shift in shoreline position. Otherwise, the beach fill profile design would be similar to that of Alternatives 3, 4, and 5; including a +9 ft NAVD high dune with a 50-ft-wide crest, a +7 ft NAVD high, ~200-ft-wide berm, and a 90- to 200-ft-wide transition with a 15 percent slope. The anticipated borrow sites and dredging regimes would be the same as those described above under Alternative 5.

5.4.6.1 Marine Benthic Resources

Soft Bottom Communities

Dredging

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; the direct, indirect, and cumulative impacts of dredging operations on soft bottom communities would be the same as those described under Alternative 5.

Intermediate Terminal Groin and Nourishment

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; the direct, indirect, and cumulative impacts of the intermediate groin and periodic East End nourishment on soft bottom communities would be essentially the same as those described under Alternative 5. The relatively long intermediate groin requires a slightly larger beach fill footprint, resulting in a minor increase in the extent of direct beach fill placement impacts on soft bottom habitats.

Hardbottom Communities

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; direct, indirect, and cumulative impacts on hardbottom communities would be the same as those described under Alternative 5.

5.4.6.2 Water Column

Hydrodynamics

Direct, Indirect, and Cumulative Impacts

Under Alternative 6, with the exception of the AIWW West channel, the CMS model-projected inlet and estuarine hydrodynamic responses are essentially the same as the projected future without project responses under Alternative 2. Simulated tidal prism volumes and current velocities for the inlet throat, AIWW East channel, and Eastern Channel are consistently within +/-10 percent of the corresponding Alternative 2 values during the four-year model simulation period (Table 5.16). The common pattern of hydrodynamic response under the two alternatives is generally one of steadily decreasing tidal prism volumes and current velocities across all three of these transects. In the case of the AIWW West channel, the hydrodynamic responses under Alternatives 2 and 6 are both characterized by rapid channel shoaling and rapidly declining tidal prism volumes, with the majority of the shoaling under both alternatives being related to the exclusion of navigation dredging in the model simulations. Also note that Alternatives 1, 3, 4, 5 and 6 include placement of sand on the beachfront and some of this material ends up in the AIWW West area after the four-year model runs, which also aids in slightly restricting the tidal prism. Under Alternative 6, the rate and extent of shoaling in the AIWW West channel is increased relative to Alternative 2, which is generally similar to the other modeled alternatives. As previously mentioned, existing flows within the AIWW West channel are significantly smaller than those to the AIWW East, therefore relative percentage changes can be expected to exhibit higher variation. As a result, the majority of the AIWW West simulated tidal prism volumes during Years 1, 2, and 3 of the model simulation period are reduced by 20 to 35 percent relative to Alternative 2. Alternatives 3, 4, and 5 exhibit some similar patterns of increased shoaling in the AIWW West channel; however, the pattern is most consistent and pronounced under Alternative 6. The Alternative 6 beach fill footprint extends farther east than any of the other alternative beach fills. Additionally, some proposed fill is placed to the east of the intermediate groin. This material travels into the AIWW West more quickly than the other alternative fills and influences the relative tidal prism decrease exhibited in the model. As indicated above, the projected hydrodynamic response throughout the majority of the inlet/estuarine system under Alternative 6 is essentially the same as the projected response under Alternative 2. The similarity of the responses under the two alternatives suggests that the majority of the model-projected inlet and estuarine hydrodynamic changes under Alternative 6 are primarily the result of natural background coastal processes; thus indicating that the intermediate groin and associated nourishment activities under Alternative 6 would have little effect on inlet and estuarine hydrodynamics outside of localized effects within the AIWW West channel. The intermediate groin would extend ~150 ft further seaward of the MHW line than the short groin; however, under Alternative 6, the model-projected nearshore ocean hydrodynamic response along Holden Beach and associated effects on longshore current dynamics (Figures 5.24 and 5.25) are the same as those described under Alternative 5. Similarly, the model-projected effects of Alternative 6 on larval transport (Figure 5.26) and rip current dynamics are the same as those described under Alternative 5. Under Alternative 6; the potential direct, indirect, and cumulative impacts of dredging operations on hydrodynamics would be comparable to those described under Alternative 5.

<u>Sediment Suspension and Turbidity</u>

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; direct, indirect, and cumulative sediment suspension effects would be the same as those described under Alternative 5.

Table 5.16. Alternative 6 relative tidal prism volumes (percentage of corresponding Alternative 2 volumes).

Year	Inlet		AIWW West		AIWW East		Eastern Channel	
	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb
Spring Tide								
0	97%	98%	97%	88%	100%	100%	99%	99%
1	92%	93%	81%	78%	100%	100%	99%	99%
2	91%	92%	79%	75%	101%	100%	99%	100%
3	96%	96%	82%	89%	101%	97%	95%	100%
4	101%	97%	80%	88%	99%	100%	139%	94%
Neap Tide								
0	98%	98%	97%	92%	100%	100%	100%	100%
1	90%	92%	69%	66%	100%	100%	97%	99%
2	92%	93%	73%	82%	101%	100%	101%	99%
3	95%	97%	72%	64%	98%	101%	96%	100%
4	102%	99%	104%	107%	107%	103%	110%	93%

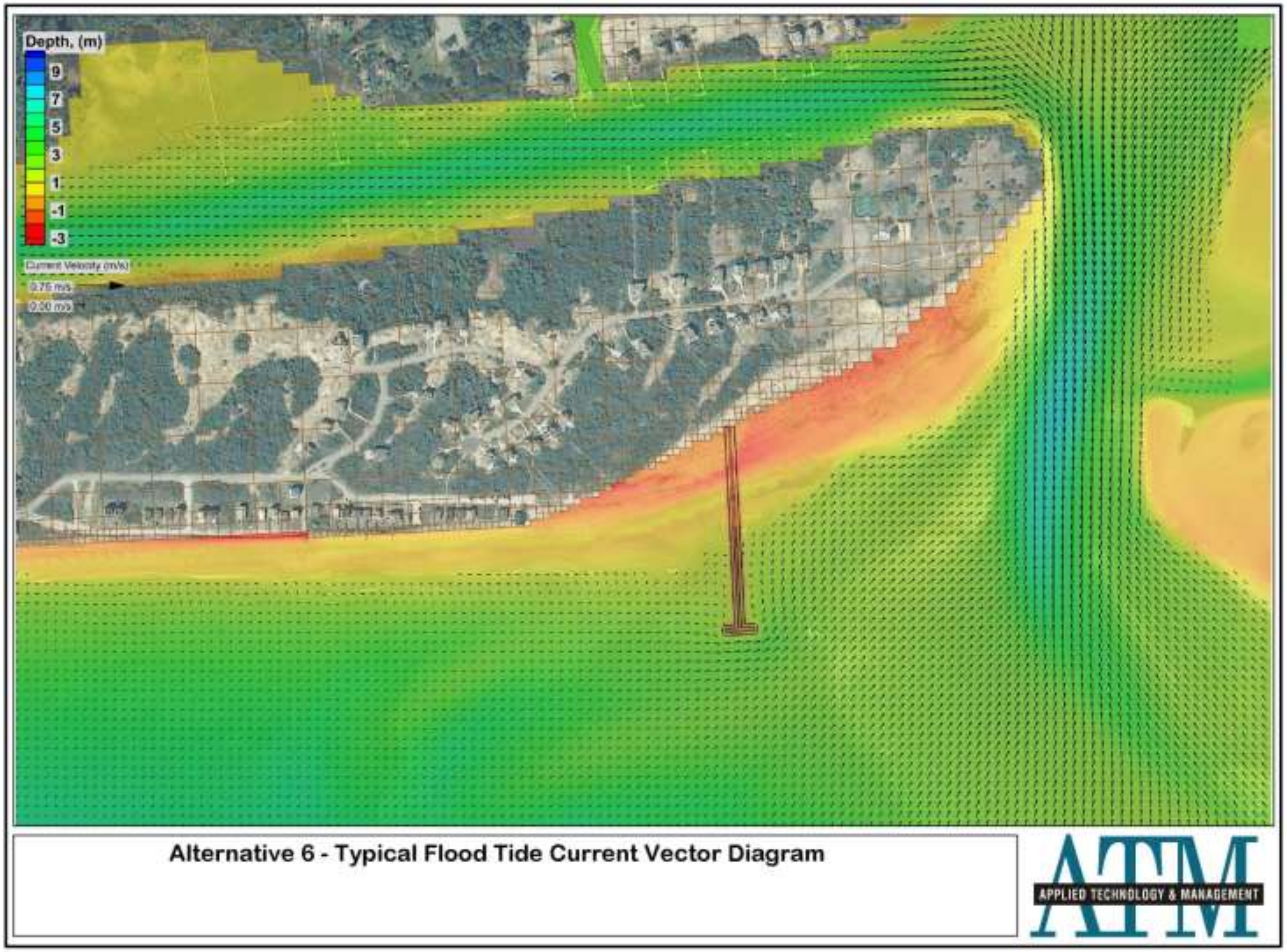

Figure 5.24. Alternative 6 - Typical Flood Tide Current Vector Diagram

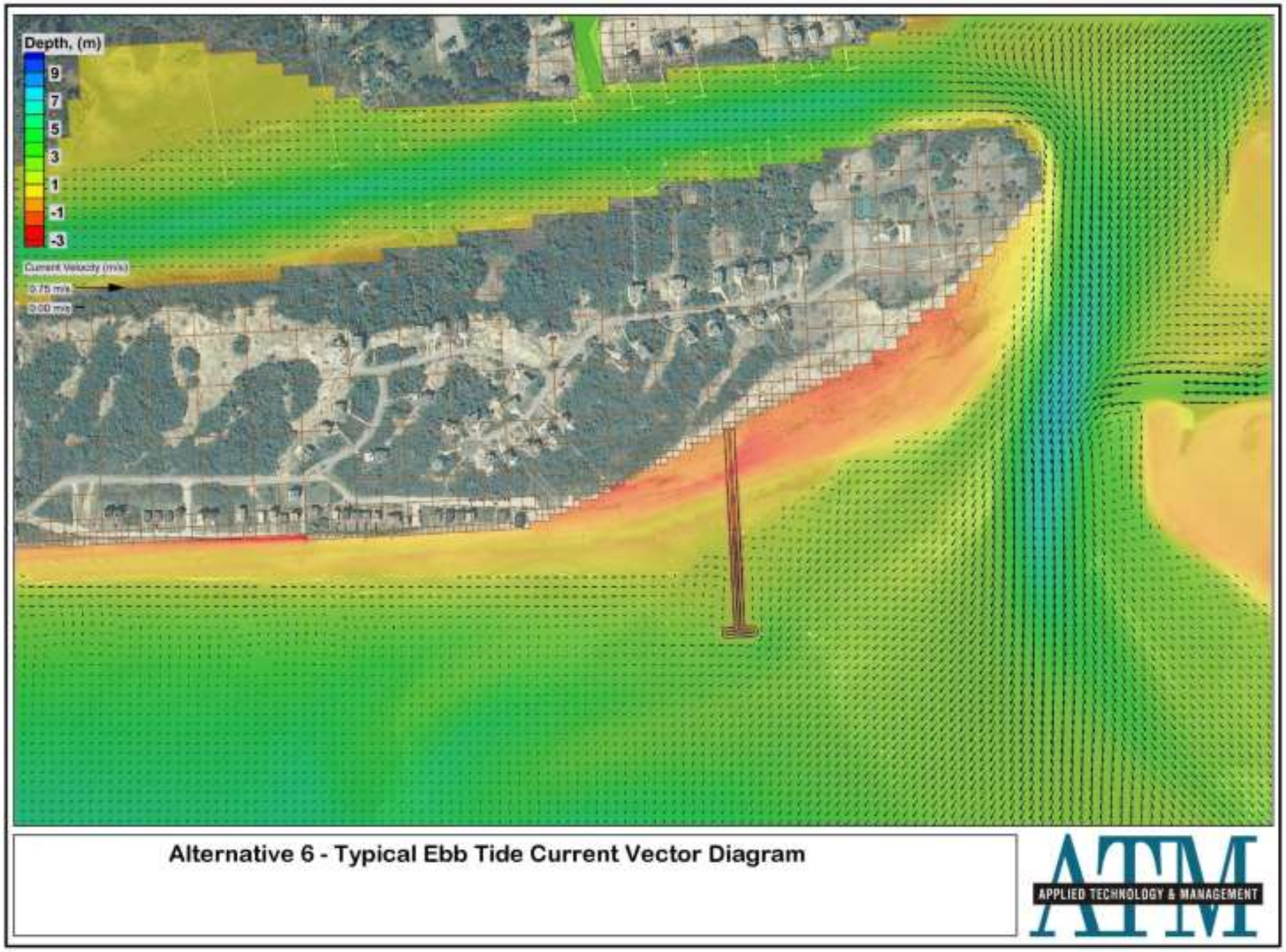

Figure 5.25. Alternative 6 – Typical Ebb Tide Current Vector Diagram

Figure 5.26. Alternative 6 - Relative Particle Concentration

Underwater Noise

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; direct, indirect, and cumulative underwater noise effects would be the same as those described under Alternative 5.

Entrainment

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; direct, indirect, and cumulative impacts related to entrainment would be the same as those described under Alternative 5.

5.4.6.3 Oceanfront Beach and Dune Communities

Intertidal Beach Communities

Direct Impacts

Under Alternative 6, direct impacts on intertidal beach habitats and communities would be the same as those described under Alternative 5.

Indirect Impacts

Indirect impacts on intertidal beach communities under Alternative 6 would be the same as those described under Alternative 5.

Under Alternative 6, the CMS model-projected response of the Oak Island west-end oceanfront shoreline (Figure 5.27) is essentially the same as the projected future without project shoreline response under Alternative 2 (Figure 5.13). Under Alternative 6, a minor reduction in shoreline erosion over the course of the four-year model simulation period slightly reduces intertidal beach habitat loss by ~1 ac in relation to Alternative 2 (Table 5.3). The similarity of the Oak Island responses indicates that the projected shoreline and intertidal beach habitat changes under Alternative 6 are primarily the result of natural background coastal processes; thus suggesting that Alternative 6 would have little effect on intertidal beach habitat on Oak Island.

The projected response of the Holden Beach East End oceanfront shoreline under Alternative 6 is similar in pattern to that of Alternative 2; however, there are differences between the responses that are related to the performance of the beach fill and the sand trapping function of the groin under Alternative 6. The entire East End beach to the west of the groin fillet is erosional under both alternatives; however, under Alternative 6, the performance of the beach fill is reflected in a relative increase in beach width at the end of Year 4.

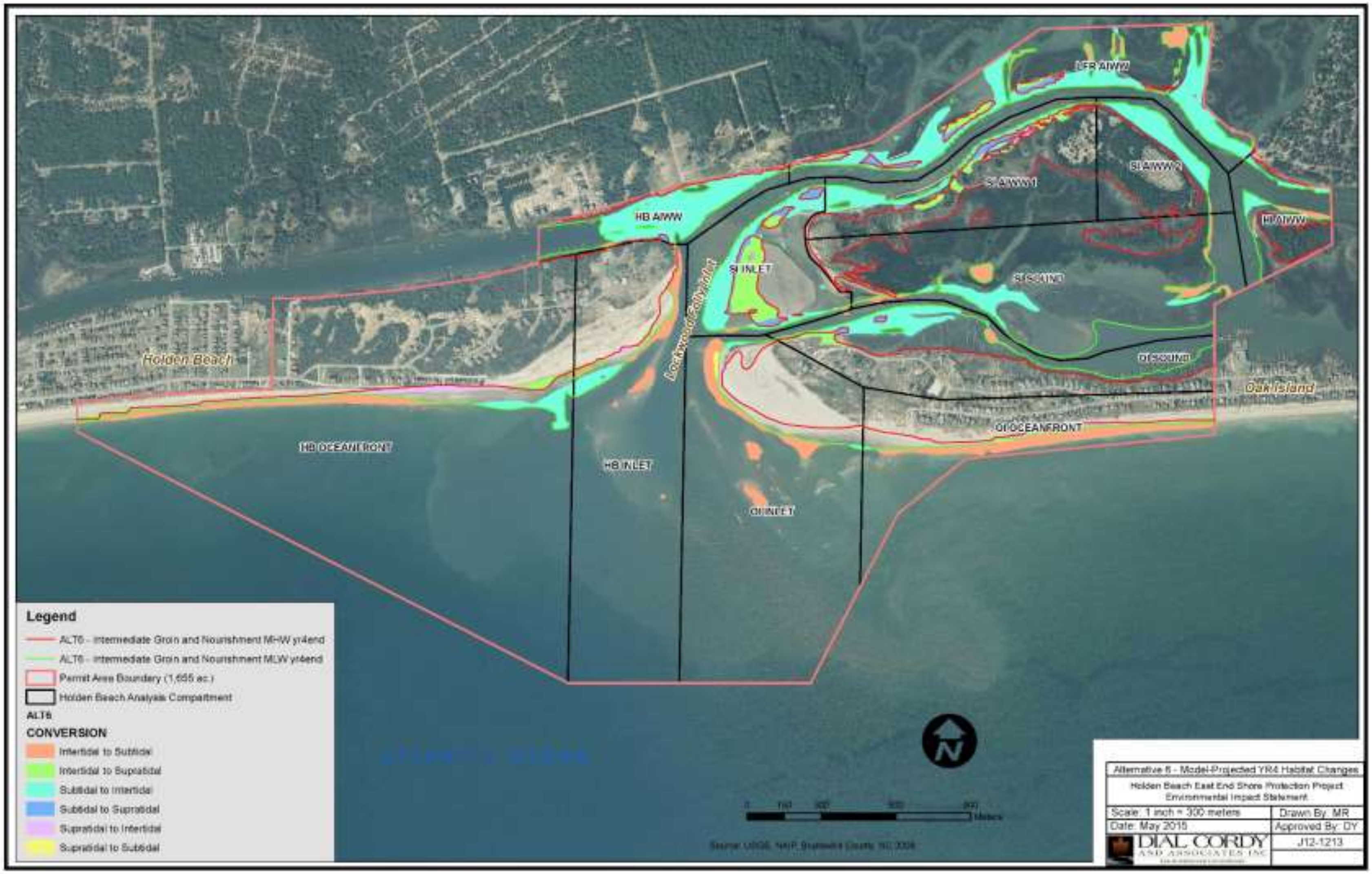

Figure 5.27. Alternative 6 – Model-Projected YR4 Habitat Change

Under both alternatives, the response of the remaining East End beach to the east of the groin is characterized by shoal attachment and corresponding net accretion at the end of Year 4; however, under Alternative 6, a larger quantity of the shoal sediment volume is retained by the groin, resulting in a relative increase in accretion at the end of Year 4. As a result of beach fill performance and groin effects, the nourished East End beach under Alternative 6 is on average ~63 ft wider than the corresponding East End beach under Alternative 2 at the end of Year 4 (Table 5.4). The corresponding effect of the wider beach on the quantity of intertidal beach habitat under Alternative 6 is an increase of ~4 ac relative to Alternative 2 (Table 5.3).

Cumulative Impacts

Under Alternative 6, cumulative impacts on intertidal beach communities would be the same as those described under Alternative 5.

<u>Dry Beach and Dune Communities</u>

Direct Impacts

Under Alternative 6, direct impacts on dry beach and dune habitats and communities would be the same as those described under Alternative 5.

Indirect Impacts

Initial Beach Fill Placement, Dredging, and Groin Construction

Indirect impacts on dry beach and dune communities under Alternative 6 would be the same as those described under Alternative 5.

Long-Term Model-Projected Effects

As described above, the CMS model-projected response of the Oak Island oceanfront shoreline under Alternative 5 (Figure 5.27) is the same as the projected future without project response under Alternative 2 (Figure 5.13). Corresponding dry beach and dune habitat changes on Oak Island are also the same, with both alternatives resulting in projected losses of ~3 ac at the end of Year 4 (Table 5.3). The similarity of the Oak Island responses suggests that Alternative 6 would not affect dry beach and dune communities on Oak Island.

As described above, the model-projected response of the Holden Beach East End oceanfront shoreline under Alternative 6 indicates an average increase in beach width of ~63 ft relative to Alternative 2. The corresponding effect of a wider beach on dry beach habitat is an increase of ~4 ac relative to Alternative 2 (Table 5.3).

Cumulative Impacts

Under Alternative 6, potential cumulative impacts on dry beach and dune communities would be the same as those described under Alternative 5.

5.4.6.4 Inlet Complex

Intertidal Flats and Shoals

Direct Impacts

Under Alternative 6, direct impacts on intertidal flats and shoals would be similar to those described under Alternative 5.

Indirect Impacts

The CMS model-projected inlet response under Alternative 6 (Figure 5.27) is essentially the same as the projected future without project inlet response under Alternative 2 (Figure 5.13). The only dissimilarity between the projected inlet responses under the two alternatives is a minor relative decrease in the extent of westward flood shoal accretion under Alternative 6. The corresponding effect on intertidal shoal habitat under Alternative 6 is an increase of ~2 ac relative to Alternative 2 (Table 5.3). Otherwise, the projected inlet response under Alternative 6 and the associated losses and gains of intertidal habitat are essentially the same as those described under Alternative 2. The similarity of the inlet responses under the two alternatives indicates that the projected inlet habitat changes under Alternative 6 are primarily the result of natural background coastal processes; thus suggesting that Alternative 6 would have little effect on inlet intertidal habitats.

Cumulative Impacts

Under Alternative 6, cumulative impacts on intertidal flats and shoals would be the same as those described under Alternative 5.

Inlet Dry Beach and Dune Communities

Direct Impacts

Under Alternative 6, direct impacts on dry inlet beach and dune communities would be similar to those described under Alternative 5.

Indirect Impacts

The CMS model-projected inlet response and corresponding changes in the distribution and quantity of inlet dry beach and dune habitats under Alternative 6 (Figure 5.27) are essentially the same as the projected future without project changes under Alternative 2 (Figure 5.13). Projected inlet dry beach/dune and supratidal flood shoal habitat changes at the end of Year 4 are essentially the same under both alternatives (Table 5.3). The similarity of the responses indicates that the projected inlet dry beach and dune habitat changes under Alternative 6 are primarily the result of natural background coastal processes; thus suggesting that Alternative 6 would have little effect on inlet dry beach and dune habitats.

Cumulative Impacts

Under Alternative 6, cumulative impacts on dry inlet beach and dune communities would be the same as those described under Alternative 5.

5.4.6.5 Estuarine Resources

Shellfish

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 6 on shellfish would be the same as those described under Alternative 5.

SAV

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 6 on SAV would be the same as those described under Alternative 5.

Tidal Marsh Communities

Direct, Indirect, and Cumulative Impacts

The direct, indirect, and cumulative impacts of Alternative 6 on tidal marshes would be the same as those described under Alternative 5.

5.4.6.6 Threatened and Endangered Species

North Atlantic Right Whale and Humpback Whale

Direct, Indirect, and Cumulative Impacts

The potential direct, indirect, and cumulative impacts on right and humpback whales and proposed right whale critical habitat under Alternative 6 would be the same as those described under Alternative 5.

West Indian Manatee

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; potential direct, indirect, and cumulative impacts on the West Indian manatee would be the same as those described under Alternative 5.

Piping Plover

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; potential direct, indirect, and cumulative impacts on piping plovers would be comparable to those described under Alternative 5.

Red Knot

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; potential direct, indirect, and cumulative impacts on red knots would be comparable to those described under Alternative 5.

Wood Stork

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; potential direct, indirect, and cumulative impacts on wood storks would be comparable to those described under Alternative 5.

Sea Turtles

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; direct, indirect, and cumulative impacts on sea turtles would be the same as those described under Alternative 5.

Atlantic and Shortnose Sturgeons

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; direct, indirect, and cumulative impacts on Atlantic and shortnose sturgeons would be the same as those described under Alternative 5.

Seabeach Amaranth

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; direct, indirect, and cumulative impacts on seabeach amaranth would be the same as those described under Alternative 5.

5.4.6.7 Cultural Resources

Direct, Indirect, and Cumulative Impacts

Under Alternative 6, potential direct, indirect, and cumulative impacts on cultural resources would be the same as those described under Alternative 5.

5.4.6.8 Public Interest Factors

Public Safety

Direct, Indirect, and Cumulative Impacts

Under Alternative 6, potential direct, indirect, and cumulative impacts on public safety would be the same as those described under Alternative 5.

Aesthetics and Recreation

Direct, Indirect, and Cumulative Impacts

Under Alternative 6; direct, indirect, and cumulative impacts on aesthetics and recreation would be the same as those described under Alternative 5.

Navigation

Direct, Indirect, and Cumulative Impacts

Under Alternative 6, potential direct, indirect, and cumulative impacts on navigation would be similar to those described under Alternative 5.

Infrastructure

Direct, Indirect, and Cumulative Impacts

Under Alternative 6, the CMS model-projected response of the developed East End oceanfront beach is one of recession throughout the four-year simulation period. By the end of Year 4, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~1,100 linear ft) has migrated landward of the existing primary dune, resulting in impacts to 16 oceanfront properties and ~130 ft of roads and associated linear utilities (Figure 5.28). In comparison, the projected future without project East End beach response under Alternative 2 follows a similar erosional pattern; however, the landward extent of shoreline recession at the end of Year 4 exceeds that of Alternative 6 by an average ~63 ft. Under Alternative 2, the MHW line between Avenue B and the eastern terminus of McCray Street (~1,700 linear ft) has migrated landward of the primary dune by the end of Year 4, resulting in impacts to 28 oceanfront properties and ~800 ft of roads and linear utilities (Figure 5.14). Thus, the modeling results suggest a relative reduction in property (12 fewer oceanfront properties impacted), road (impacts reduced by 670 linear ft), and utility (impacts reduced by 670 linear ft) impacts under Alternative 6.

<u>Economics</u>

Direct, Indirect, and Cumulative Impacts

Under Alternative 6, construction and maintenance costs would include those associated with construction and maintenance of the intermediate groin and periodic beach nourishment; including the costs of beach fill and groin materials, mobilization/demobilization, monitoring, surveying and permitting. Additional costs would be associated with risk to properties and infrastructure, loss of recreational opportunities, loss of habitat, and environmental impacts associated with the groin and periodic nourishment and dredging activities. Over a 30-year planning horizon, assuming $2.5 million for initial groin construction and nourishment of the East End Beach with approximately 150,000 cy of sand every four years, and an annual four percent increase in fill costs, Alternative 6 is expected to involve total construction costs of approximately $34.41 million. In present value terms, construction costs range from $15.24 million (6% discount rate) to approximately $23.43 million (2.5% discount rate). Potential erosional impacts to properties and infrastructure were projected based on the model-predicted shoreline changes. Specifically, properties and infrastructure that fall within 25 ft of the model-projected MHW at the end of the four-year simulation were considered to be impacted. Costs associated with these impacts were based on the assessed tax value of properties and the estimated cost of infrastructure replacement (see Appendix Q). Under Alternative 6, the MHW line between Dunescape Drive and the eastern terminus of McCray Street (~1,100 linear ft) has migrated landward of the primary dune at the end of Year 4, resulting in impacts to 16 properties (11 improved) and ~130 linear ft of roads and associated water, sewer, and power lines (Figure 5.28). Thus, relative to Alternative 2, the modeling results suggest a reduction in property (12 fewer oceanfront properties impacted), road (impacts reduced by 670 linear ft), and utility (impacts reduced by 670 linear ft) impacts under Alternative 6. The total assessed value of all properties protected to be newly impacted under Alternative 6 is roughly $2.1 million. The 131 linear feet of anticipated infrastructure replacement cost is valued at approximately $80,455, with a present value ranging from approximately $86,408 (6% discount rate) to $92,019 (2.5% discount rate).

Under Alternative 6, use and non-use values associated with recreation, aesthetics, and the natural environment are generally expected to be enhanced relative to Alternatives 1, 2, 3, and

Figure 5.28. Alternative 6 – Projected Properties at Risk and Infrastructure Impacts at YR4 End

4 and similar to those projected under Alternative 5 (Table 5.17). Public recreational values would be affected to the extent that the activities associated with nourishment physically impede and diminish the aesthetic appeal of the East End beach. These effects may result in economic losses associated with diminished use and non-use values and may have adverse effects on ecosystem service values in terms of provisioning and regulating services provided by the

The principle benefits of Alternative 6 would be associated with enhanced shoreline stability and increased beach width relative to baseline conditions. To the extent that the public views the terminal structure as reducing the risk of future erosion, this added stability would serve to enhance property values along the Holden Beach East End shoreline. Based on the literature (see Appendix O) it is reasonable to expect that properties up to 300 m inland of the shoreline would realize improvements in market value. Associated benefits would likely include increased rental revenues and higher municipal tax revenues. As noted in Parsons and Powell (2001), active mitigation efforts such as beach armoring may also serve to encourage additional use and/or development and generate additional economic impacts relative to the status quo in the form of increased municipal tax revenues as well as temporary construction employment and spending. The terminal groin may create enhanced recreation values as a result of the predicted gains in beach width and shoreline stability, especially those in the vicinity of the structure, as well as the creation of rocky bottom area that may increase species diversity and enhance the quality of recreational fishing near the structure. Because dune and beach habitats in the project area will be subject to reduced losses from erosion, indirect and non-use values may also be created, enhanced, or preserved.

Table 5.17. Alternative 6 scope of costs and benefits.

Costs (Relative to Status Quo)	
Construction and Maintenance	$34.41 M
Construction and Maintenance (Present Value)	$21.97 M – $36.32 M
Parcels affected	16
Assessed Tax Value of Affected Parcels	$2.10 M
Infrastructure Replacement Costs	$101,572
Infrastructure Replacement Costs (Present Value)	$92,019 - $80,455
Reduction in tax base	Low/None
Transition costs	Low
Diminished recreation value	Low
Diminished aesthetic value	Intermediate
Environmental Damage	
Public non-use value losses (nature)	Low
Public non-use value losses (Holden Beach)	High
Benefits (Relative to Status Quo)	
Reduction in future nourishment expense	High
Enhanced property value	High
Enhanced Recreation value	Moderate
Environmental Improvement	
Public non-use value (nature)	High
Public non-use value (Holden Beach)	Low