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March 16, 2015

Via U.S. and Electronic Mail
Mr. Tyler Crumbley
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Re: Comments on Draft Environmental Impact Statement (DEIS) for the Installation of a Terminal Groin Structure at the Eastern End of Ocean Isle Beach, Extending Into the Atlantic Ocean, West of Shallotte Inlet (Brunswick County, NC) (SAW2011-01241)

Mr. Crumbley:

Please accept these comments on the Draft Environmental Impact Statement ("DEIS") for the Ocean Isle Beach Shoreline Management Project. The Southern Environmental Law Center submits these comments on behalf of itself and the North Carolina Coastal Federation. As described below, the DEIS fails to meet the requirements of the National Environmental Policy Act ("NEPA"), 42 U.S.C. § 4321, *et seq*; the Clean Water Act ("CWA"), 33 U.S.C. § 1251, *et seq.*; and the Endangered Species Act ("ESA"), 16 U.S.C. § 1531, *et seq.* Therefore, we request that the U.S. Army Corps of Engineers ("Corps") re-evaluate each of the alternatives in a revised DEIS.

I. The DEIS Fails to Rigorously Explore and Objectively Evaluate Reasonable Alternatives.

The alternatives analysis "is the heart of the environmental impact statement." 40 C.F.R. § 1502.14. As such, it requires the Corps to "[r]igorously explore and *objectively evaluate* all reasonable alternatives." *Id.* § 1502.14(a) (emphasis added). The Corps failed to do so here, where it has published a DEIS with an alternatives analysis focused on justifying construction of Ocean Isle's preferred terminal groin alternative.

The DEIS description of the alternatives and analysis of the environmental impacts of the alternatives is taken from Appendix B, the Engineering Report prepared by Coastal Planning and Engineering of North Carolina, Inc. ("CPE"), and Appendix C, the Delft3D Numerical Modeling Study. Appendix B is the primary document cited in the DEIS to both explain alternatives and the effects of each alternative.[1] The central role of Appendix B in the DEIS cannot be overstated. Appendix C is also foundational, the Delft3D model is used throughout the DEIS to predict expected erosion rates and beach nourishment requirements,[2] each of which are critical factors in evaluating both the environmental and economic impacts of the alternatives.

The text of the Appendices makes clear that they are not the objective analysis required by NEPA. The Engineering Report states that it was "Prepared For" the "Town of Ocean Isle Beach."[3] Appendix C makes clear that "[t]he objective of the Engineering Report (Appendix B) and this numerical study *is to refine the terminal groin's design and develop a recommended plan which includes groin construction and strategic placement of beach fill*."[4] The plainly stated purpose of the documents is to determine how, not whether, to build a terminal groin. That goal is apparent in the analyses carried forward in the DEIS, which demonstrate a clear preference for the terminal groin alternative and an analysis biased in favor of that result. As such, the DEIS fails to "[r]igorously explore and *objectively evaluate* all reasonable alternatives." *Id.* § 1502.14(a) (emphasis added); *Nat'l Audubon Soc'y v. Dep't of Navy*, 422 F.3d 174, 183 (4th Cir. 2005) (rejecting Navy EIS as "a preordained decision . . . that the navy 'reverse engineered' . . . to justify" the outcome).

Moreover, recent history emphasizes the need for close scrutiny of CPE's analysis. The Corps is currently, and appropriately, re-analyzing the environmental impact statement prepared by CPE for Figure Eight Island because the Delft3D modeling predictions in the May 18, 2012 draft environmental impact statement for that proposed shoreline hardening project were entirely incorrect. At North Topsail, the town, Corps, and Division of Coastal Management are currently working to remove substantial quantities of rock from the beach nourishment project that was permitted based on CPE's assessment of the sand source.[5] These limited examples of CPE's recent errors, combined with their stated purpose of supporting a terminal groin alternative, further emphasize the need for thorough oversight of this EIS by the Corps. As discussed below, the lack of that oversight has resulted in a DEIS that does not meet the Corps' NEPA obligations or provide information necessary for the Corps' Clean Water Act and Endangered Species Act analyses.

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[1] *See* DEIS at 22 ("More details regarding the formulation of each alternative is provided in the Engineering Report (Appendix B)."), 28 ("Following the failure of the sandbag revetment, the shoreline would migrate at historic rates, measured for each profile on the east end of the island (Appendix B) for at least the next 30 years."), 33 ("Refer to Appendix B for a full discussion of the channel relocation alternative including the dredging associated with the Federal project."), 120 (citing Appendix B for comparison of alternatives).

[2] *See, e.g. id.* at 29.

[3] Appendix B cover.

[4] Appendix C at 2 (emphasis added).

[5] Trista Talton, *Pumping Project Dumps Tons of Rocks at N. Topsail*, Mar. 13.2015, http://www.coastalreview.org/2015/03/pumping-project-litters-beach-with-rocks/.

II. The Delft3D Model Does Not Provide Any Basis for Evaluating Alternatives.

The very purpose of NEPA is "to help public officials make decisions that are based on understanding of environmental consequences, and that take actions that protect, restore, and enhance the environment." 40 C.F.R. § 1500.1(c). Predicting the future environmental impacts of a proposed project and alternatives to it are the "heart of the environmental impact statement." 40 C.F.R. § 1502.14. The Corps is obligated to estimate future impacts that will occur in Shallotte Inlet. Here, despite admitting that the Delft3D model is incapable of accurately predicting shoreline changes on Ocean Isle, the Corps has extensively relied on that model to evaluate future shoreline changes under each alternative.

A. The DEIS description of Delft3D model fails to reveal its fatal flaws.

The DEIS glosses over the extraordinary limitations of the Delft3D model it relies on extensively. The limited discussion of the model's deficiencies states that "the model results are by no means intended to represent predictions of what changes to expect in the future with certainty, as this would require an ability to predict future weather and oceanic conditions."[6] Appendix C expands on that description slightly, stating that "the Delft3D-FLOW model as calibrated is best suited to estimating general trends, rather than providing exact estimates of erosion rates into the future."[7] These descriptions vastly understate the shortcomings of the model. Review of Appendix C demonstrates that the model cannot predict the *direction* of sand transport or *past* erosion rates accurately, much less provide any indication of future erosion rates or shoreline change.

Shoreline change in inlets is the result of numerous factors as depicted in the following chart[8]:

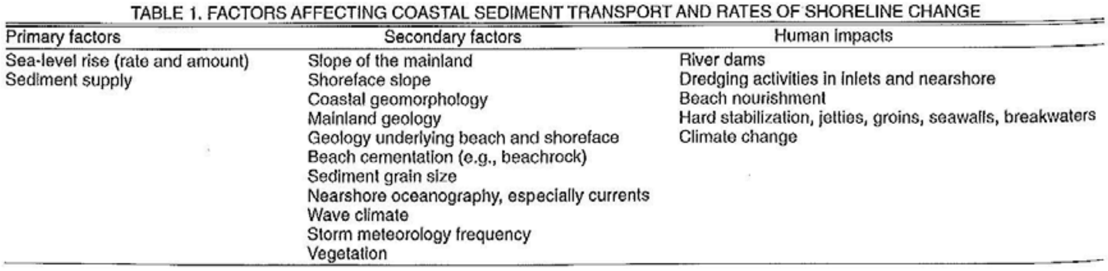

TABLE 1. FACTORS AFFECTING COASTAL SEDIMENT TRANSPORT AND RATES OF SHORELINE CHANGE

Primary factors	Secondary factors	Human impacts
Sea-level rise (rate and amount)	Slope of the mainland	River dams
Sediment supply	Shoreface slope	Dredging activities in inlets and nearshore
	Coastal geomorphology	Beach nourishment
	Mainland geology	Hard stabilization, jetties, groins, seawalls, breakwaters
	Geology underlying beach and shoreface	Climate change
	Beach cementation (e.g., beachrock)	
	Sediment grain size	
	Nearshore oceanography, especially currents	
	Wave climate	
	Storm meteorology frequency	
	Vegetation	

The Delft3D model is based on a limited set of these factors, including waves, tides, winds, density gradients, and sediment transport formulations.[9] It was calibrated based on past data in an effort to approximate *known* changes to the shoreline on Holden Beach and Ocean Isle.[10] The results of that calibration demonstrate that the Delft3D model has no valid use in the

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[6] DEIS at 113.

[7] Appendix C at 60.

[8] Orin Pilkey, et al, Quantitative modeling of coastal processes: A boom or a bust for society?, The Geological Society of America, Sp. Paper 502 at 136 (2013) (Attached as Ex. 1).

[9] DEIS at 113.

[10] *See* Appendix C at 53-55.

DEIS. Using known data from past observations, the Delft3D failed to predict past shoreline changes and therefore cannot be considered to represent the operation of "the inlet system and adjacent beaches"[11] under any set of conditions.

The first indication of that failure is that the model did not accurately predict the *direction* of longshore sand transport. As described in Appendix C, "most sources have estimated the net sediment transport direction to be from east to west along the majority of Ocean Isle Beach."[12] The model predicted the exact opposite; Appendix C states that "the net longshore transport based on the model results was from west to east, even along the midpoint of Ocean Isle Beach."[13] At the most basic level of analysis—which direction sand moves—the model was wrong. CPE later adjusted the model, but even the final calibration predicted that net sand transport would move in the wrong direction for more than a mile on Ocean Isle Beach.[14]

The second indication that the model cannot be used to evaluate future inlet processes and shoreline changes is that it failed to accurately predict whether Holden Beach would erode or accrete. Model Run 43A—the final calibration—predicted that Holden Beach would erode from HB300 to HB340; in reality, the beach accreted at each monitoring location.[15] The model predicted no change or slight erosion from HB340 to HB360; in reality, the beach accreted at each monitoring location. [16] The model only correctly predicted that erosion would occur at 6 monitoring locations; and at 3 of those sites, it predicted erosion was less than half the observed erosion. [17] The model was so inaccurate on Holden Beach that it predicted a loss of approximately 70 cy/ft at HB400 when in reality the beach accreted approximately 80 cy/ft.

Finally, the model failed to predict erosion on Ocean Isle Beach accurately. Appendix C states that "the model is able to reproduce the general erosion patterns along Ocean Isle Beach—high erosion rates from Shallotte Inlet to Profile OI_65 (Chadbourn Street) with stable beaches further to the west (see Figure 40)."[18] What it does not say—and cannot say—is that the erosion rate estimates approximated observed erosion rates. In the areas most critical to the EIS—between OI_15 and OI_45, modeled erosion rates were significantly different than observed rates.[19]

Despite the substantial failure of the Delft3D model to replicate past, known erosion rates and shoreline changes, the DEIS and Appendix B refers to the "inherent accuracy" of the model.[20] Notably lacking from either document is any discussion of the model's error rate or confidence intervals that could be used to support the assertion that the model has any "inherent

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[11] DEIS at 113.
[12] Appendix C at 58.
[13] *Id.*
[14] *See id.* (displaying graph showing model prediction of approximate location of longshore transport direction shift compared to location of observed shift).
[15] *Id.* at 55.
[16] *Id.*
[17] *Id.*
[18] *Id.* at 58.
[19] *Id.*at 53
[20] DEIS at 39, 158; Appendix B at 59.

accuracy." Without some clarification and definition, the term "inherent accuracy" as used to describe the model is misleading and must be removed.

The DEIS is correct that the Delft3D model cannot be used to predict the changes that can be expected in the future for any alternative. The reason is not, however, because the Corps lacks "an ability to predict future weather and oceanic conditions."[21] The Delft3D model cannot be used to evaluate the effect of any of the alternatives because it cannot accurately replicate *known* erosion rates and *known* shoreline change with *known* weather and oceanic conditions. The model cannot provide "an indication of how the inlet system and adjacent beaches would respond to a given set of forcing conditions (waves, tides, winds, etc.) and physical modification to the system"[22] because CPE's analysis demonstrates that the model does not accurately replicate basic aspects of the system—including which way sand will move and whether beaches will erode or accrete—when both the inputs and expected results are known. A model that cannot approximate past erosion rates and shoreline changes cannot provide meaningful information about future erosion rates or shoreline changes.

For the Corps' use of the Delft3D model to avoid being arbitrary and capricious, "[t]here must be a rational connection between the factual inputs, modeling assumptions, modeling results and conclusions drawn from these results." *Sierra Club v. Costle*, 657 F.2d 298, 334 (D.C. Cir. 1981). There is no rational connection between the Delft3D model and any assessment of erosion rates or shoreline changes for any of the alternatives. Based on the calibration prepared by CPE, the model fails at every level. It predicts that sand will travel the wrong direction for much of the beach. It predicts that beaches that have accreted eroded. Even when it correctly predicted past erosion, it does not begin to approach an accurate estimate of the erosion rate. There are no defensible conclusions that can be drawn from these results.

B. The information provided in the DEIS regarding the Delft3D model is incomplete and inadequate.

The incomplete and inadequate information presented in the DEIS is further evidence of the Delft3D model's limitations in this context. NEPA demands clarity. "Environmental impact statements shall be concise, clear, and to the point, and shall be supported by evidence that agencies have made the necessary environmental analyses." 40 C.F.R. § 1500.2(b). The EIS "shall provide full and fair discussion of significant environmental impacts and shall inform decisionmakers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the human environment." 40 C.F.R. § 1502.1. The description of the Delft3D model in the DEIS fails to provide that clear analysis of impacts, further revealing its inappropriate use in this context.

Given the model's central role in analyzing "changes in hydrodynamics, sediment transport, and the morphology of the inlet and nearshore environments in response to changes imposed by project alternatives over a 3-year period,"[23] such an omission is inexplicable. As discussed below, the DEIS fails to present clearly the model results, fails to provide any rationale

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[21] DEIS at 113.
[22] *Id.*
[23] *Id.* at 115.

supporting application of the model results to the analysis of future erosion rates, and fails to apply the model consistently across alternatives, precluding meaningful analysis.

The DEIS does describe modeled shoreline changes for Alternatives 1 and 2. The document states that between stations 0+00 and 0+30, the focal point of the DEIS's analysis, erosion is expected to be 24,000 cubic yards per year.[24] The model results are succinctly and clearly depicted in a chart.

No such chart is provided to describe model results for Alternatives 3 or 4. In the DEIS's analysis of Alternative 3, the document refers to "a Delft3D model assessment of beach fill performance," but does not include a description of model results.[25] Appendix B similarly omits the model results for Alternative 3.[26] Appendix C lacks any description of model results for individual alternatives.

While the DEIS lacks model results for Alternative 3, it appears that Alternative 4 was not modeled at all. The DEIS states that the "models were employed to determine impacts for Alternatives 1, 2, 3, 4, and 5."[27] It clarifies that "the model results for Alternative 1 are also applicable to Alternative 2," explaining the lack of separate modeling analysis for Alternative 2 and indicating that the remaining alternatives, including Alternative 4, were independently modeled.[28] But the description of environmental consequences for Alternative 4 does not include any description of that modeling.[29] Instead, it refers to modeling of Alternative 1, which differs significantly from Alternative 4, under which "the Federal project dredging scheme employed by the USACE would be modified to concentrate sediment removal for periodic nourishment along a channel close, and generally parallel to, the west boundary of the USACE borrow area in Shallotte Inlet."[30] This type of concentrated dredging is not done under the current dredging scheme continued by Alternative 1 and differentiates Alternative 4 from every other alternative.[31]

The DEIS's omission of any modeling information regarding Alternative 4 is not salvaged by Appendix B. The description of Alternative 4 in that Appendix does not include any modeling description.[32] It is noteworthy that Appendix B includes figures representing the model results for Alternatives 1, 3, and 5, but lacks any figures depicting the effects of Alternative 4.

The descriptions of modeling results for the terminal groin alternatives fare little better. The DEIS states that "[t]he model results of volume changes above the -6-foot NAVD depth contour measured between the terminal groins and station 30+00 indicate the volumetric erosion rates and hence periodic nourishment requirements in this area would be reduced by 29.2% for

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[24] *Id.* at 117.
[25] *Id.* at 120.
[26] *See* Appendix B at 39.
[27] DEIS at 113.
[28] *Id.*
[29] *See* DEIS at 123.
[30] *Id.* at 31.
[31] *See id.* at 32.
[32] *See* Appendix B at 41-50 (omitting any reference to modeling results).

the 250-foot terminal groin and by 75.0% and 95.8% for the 500-foot and 750-foot terminal groins respectively."[33] The only citation provided is a general citation to Section 4 of Appendix B. This citation is woefully inadequate and fails to provide the explanation necessary to comply with NEPA.

This presentation of the modeling results is unnecessarily complex. The results can be presented in a simple chart, allowing meaningful analysis of the model results and comparison of the alternatives. Appendix B provides such a chart for Alternatives 1 and 5, which has been reproduced below.

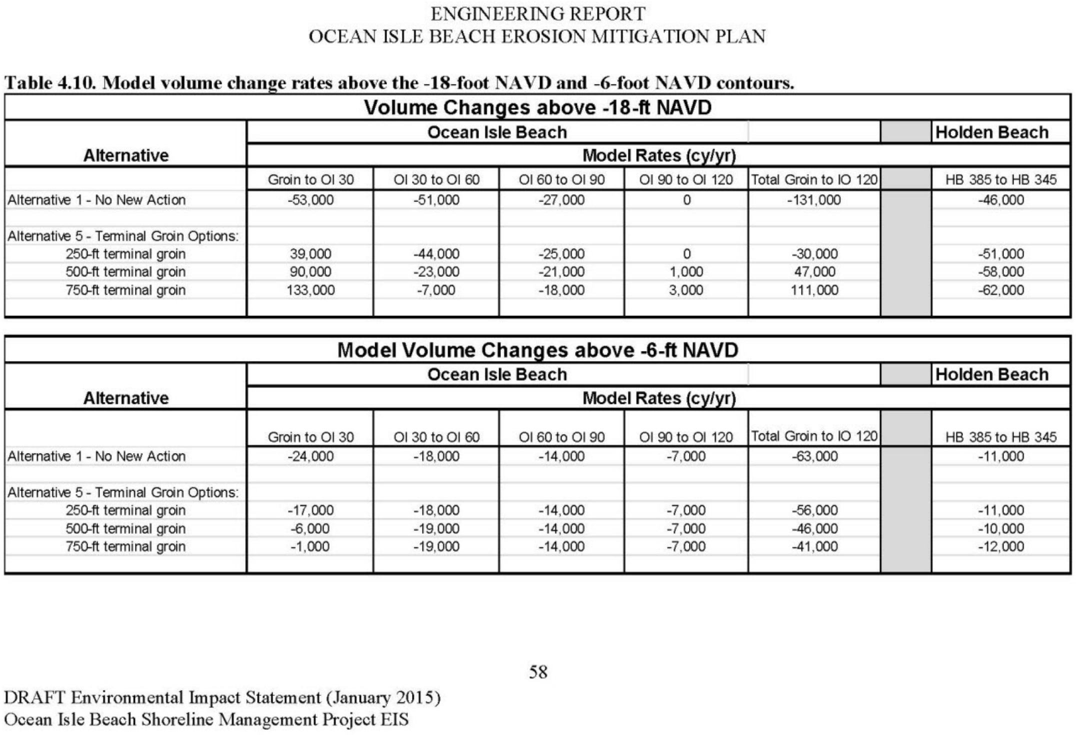

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Table 4.10. Model volume change rates above the -18-foot NAVD and -6-foot NAVD contours.

Volume Changes above -18-ft NAVD							
Alternative	Ocean Isle Beach						Holden Beach
	Model Rates (cy/yr)						
	Groin to OI 30	OI 30 to OI 60	OI 60 to OI 90	OI 90 to OI 120	Total Groin to IO 120		HB 385 to HB 345
Alternative 1 - No New Action	-53,000	-51,000	-27,000	0	-131,000		-46,000
Alternative 5 - Terminal Groin Options:							
250-ft terminal groin	39,000	-44,000	-25,000	0	-30,000		-51,000
500-ft terminal groin	90,000	-23,000	-21,000	1,000	47,000		-58,000
750-ft terminal groin	133,000	-7,000	-18,000	3,000	111,000		-62,000

Model Volume Changes above -6-ft NAVD							
Alternative	Ocean Isle Beach						Holden Beach
	Model Rates (cy/yr)						
	Groin to OI 30	OI 30 to OI 60	OI 60 to OI 90	OI 90 to OI 120	Total Groin to IO 120		HB 385 to HB 345
Alternative 1 - No New Action	-24,000	-18,000	-14,000	-7,000	-63,000		-11,000
Alternative 5 - Terminal Groin Options:							
250-ft terminal groin	-17,000	-18,000	-14,000	-7,000	-56,000		-11,000
500-ft terminal groin	-6,000	-19,000	-14,000	-7,000	-46,000		-10,000
750-ft terminal groin	-1,000	-19,000	-14,000	-7,000	-41,000		-12,000

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The DEIS must be revised to include a similar analysis for each of the alternatives as well as a reasoned explanation for the varied manipulations of the model results described in the DEIS and addressed below.

C. The DEIS does not demonstrate that the Delft3D model is an appropriate surrogate for expected erosion rates.

The DEIS's disjointed and incomplete presentation of the model results cannot conceal the error in relying on the fictional scenarios created by the Delft3D model. As discussed above, the model failed to accurately predict past erosion rates and shoreline changes (failing to even predict the direction of sand transport for a large portion of Ocean Isle Beach). Similarly, the

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[33] DEIS at 124.

DEIS concedes that the model cannot predict erosion rates or shoreline changes for Alternative 1 or any other alternative.[34]

Because the model cannot and does not predict accurate erosion rates or shoreline changes, the Corps attempts to use the model as a surrogate, inferring changes to observed erosion rates based on changes to the modeled erosion rate. The DEIS defines baseline conditions under Alternative 1 to mean two different sets of conditions.[35] The document describes the baseline, or existing, conditions both in terms of observed erosion rates[36] and modeled erosion rates.[37] On page 29, the DEIS assumes that erosion will continue at previous rates under Alternative 1 east of station 30+00, which are estimated to "average 91,000 cubic yards/year."[38] On page 117, the DEIS reports that the model for Alternative 1 predicts that the same stretch of beach will erode at a rate of 24,000 cy/yr.

The DEIS assumes, without explanation, that the model results provide meaningful information notwithstanding this substantial discrepancy in baseline conditions.[39] To do so, the Corps adopts the untenable position that any modeled increase in erosion greater than 24,000 cy/yr will correspond to a proportional increase in the observed erosion rate. For example, a modeled erosion rate of approximately 37,000 cy/yr under Alternative 3 was assumed in the DEIS to mean that the observed erosion rate would increase by 54% to 140,000 cy/yr.[40] Likewise, according to the Corps' unsupported analysis, any modeled decrease in erosion rate from 24,000 cy/yr would correspond to a proportional decrease in observed erosion rate. For example, a modeled decrease in erosion rate to 1,000 cy/yr with a 750-foot terminal groin was assumed to decrease observed erosion by 95.8%.[41]

Yet, the Corps has not provided any analysis to support the assumption that modeled erosion rates under Alternative 1 are proportional to the observed erosion rates (and that, therefore, changes in the erosion rate predicted by the model are proportional to changes in the observed erosion rates). As the Fourth Circuit has held, "[a]n unjustified leap of logic or unwarranted assumption, however, can erode any pillar underpinning an agency action, whether constructed from the what-is or the what-may-be." *Friends of Back Bay v. U.S. Army Corps of Engineers*, 681 F.3d 581, 588 (4th Cir. 2012). That is particularly so when the assumption goes directly to the assessment of baseline conditions, as it does here. "A material misapprehension of the baseline conditions in advance of an agency decision can lay the groundwork for an arbitrary and capricious decision." *Id.* "Without [accurate baseline] data, an agency cannot carefully consider information about significant environment impacts . . . resulting in an arbitrary and capricious decision." *N.C. Wildlife Fed'n v. N.C. DOT*, 677 F.3d 596, 603 (4th Cir. 2012)

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[34] DEIS at 113.

[35] *See id.* at 29 (comparing Alt. 3 to existing conditions without defining the term), 39 (same, with Alt. 5), *but see* 115 (suggesting that "existing conditions" are different than "implied changes deduced from the model results for all of the alternatives"), 120 (describing existing conditions in terms of observed past erosion).

[36] *Id.* at 120 .

[37] *Id.* at 29, 158 (comparing modeling of Alternative 3 to modeled existing conditions in Alternative 1).

[38] *See* Appendix B at 36.

[39] *See* DEIS at 113 (stating that result "forms a basis for comparing relative changes in Shallotte Inlet and the adjacent shorelines").

[40] *See id.*at 29.

[41] *Id.* at 39.

(citing *See N. Plains Res. Council v. Surface Transp. Bd.*, 668 F.3d 1067, 1085 (9th Cir. 2011). Reliance on data that has no credible predictive value "does not constitute the 'hard look' required under NEPA." *N. Plains Res. Council*, 668 F.3d at 1087 (9th Cir. 2011). As the U.S. District Court for the Eastern District of North Carolina held last week, a "fundamental assumption . . . unsupported by any evidence . . . constitute[s] clear error and violates NEPA and the APA." *Catawba Riverkeeper Found., et al. v. N.C. DOT, et al.*, No. 5:15-CV-29-D at 13 (E.D.N.C. Mar. 13, 2015).

The information in the DEIS does not support the Corps' use of the Delft3D model as a surrogate for future erosion rates. It has not accurately predicted past erosion rates or shoreline changes. The Corps concedes that it cannot predict future erosion rates and rejects the erosion rates predicted for the alternatives evaluated. The DEIS rejects the difference in erosion rates as unreliable. Given these shortcomings of the model, it is far from self-evident how the relative difference between unreliable model results could ever form the basis for the analysis presented in the DEIS. The Corps has not offered any explanation of that foundational assumption and has, therefore, violated NEPA.

D. The three-year Delft3D modeling run is uninformative.

Even if the Delft3D model could reliably estimate future erosion rates and shoreline changes, it cannot do so as prepared. The model was run for three years, a time period so short that it fails to account for the regular beach renourishment events that are part of each alternative. By doing so, the analysis presumes that after each three-year cycle, the shoreline will return to the shoreline assumed in year 0. That plainly is not so. There is no indication that any alternative would result in complete erosion of the exact preceding beach nourishment, leaving the same shoreline as assumed in year 0. By truncating the model at three years, the analysis entirely ignores a fundamental aspect of each alternative—regular renourishment—and unreasonably assumes that foreseeable effects of each alternative will be revealed in that short timeframe. That oversight is critical. If the model for Alternative 1 were run for just one more year, it would show significant beach growth because the volume of beach nourishment significantly outpaces the modeled erosion rates. The model, therefore, cannot "provide full and fair discussion of significant environmental impacts and shall inform decisionmakers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the human environment." 40 C.F.R. § 1502.1.

E. The Corps must accept the Delft3D model in its entirety or reject it outright.

The Corps must decide if the Delft3D model is reliable or not. The Agency cannot, as the DEIS does, pick and choose those results from the model that serve the Town's purpose of building a terminal groins. It certainly cannot distort the results of the model as it has done in this DEIS. If the Corps relies on the Delft3D model to predict erosion rates, it must do so throughout the modeled area—without manipulation. It cannot, for example, reject the model's predicted erosion rates for Alternative 1 between station 0+00 and station 0+30[42] and then accept

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[42] *Id.* at 25-26 (assuming significantly greater erosion rates than those predicted by the model to predict shoreline migration).

the model's predicted erosion rates in Shallotte Inlet and on Holden Beach.[43] The modeled erosion rates are part and parcel of the modeling analysis. If the Corps cannot accept them as produced by the model—and the shoreline changes based on those modeled erosion rates—it must discard the model. We encourage the Corps to do just that. Require CPE to start over, reevaluate the proposed alternatives without modeling that has no predictive value, and issue a new DEIS. NEPA requires the Corps to do so. *See* 40 C.F.R. 1502.9(a) ("If a draft statement is so inadequate as to preclude meaningful analysis, the agency shall prepare and circulate a revised draft of the appropriate portion.").

III. The DEIS's Analysis of Non-Groin Alternatives is Fundamentally Flawed.

Ocean Isle and CPE's preference for a terminal groin and the focus of Appendix B and Appendix C on supporting the construction of a terminal groin are evident in the alternatives analysis presented in the DEIS. In sum, the analysis presents limited information intended to support Ocean Isle and CPE's shared goal of having the terminal groin emerge as the least environmentally damaging practicable alternative. That analysis does not meet NEPA's requirement that the Corps take a "hard look" at each alternative, prepare an objective analysis, and "[d]evote substantial treatment to each alternative considered in detail including the proposed action so that reviewers may evaluate their comparative merits." 40 C.F.R. § 1502.14(b). The DEIS must, but does not, explain key assumptions that underlie the Corps' analysis of each alternative.

First, it must be noted that although the DEIS states that "A complete description of the measured and modeled shoreline and volumetric changes is provided in Appendix C,"[44] no such description is included in Appendix C.[45] As discussed above, while Appendix B has some modeling information, it does not provide a "complete description of measured and modeled shoreline and volumetric changes."

A. Alternative 1 relies on unsupported assumptions regarding shoreline change that conflict with modeled erosion rate predictions.

At the center of the DEIS's analysis of Alternatives 1 and 2 is the unsupported assumption that future erosion is adequately predicted by measured erosion rates from September 1999 to May 2010.[46] As described in Appendix B, CPE concluded that "[t]he average rates of movement of the scarp line during this period . . . appeared to provide a reasonable representation of recent changes on the east end of Ocean Isle Beach."[47] Impacts of Alternatives 1 and 2 were premised on continuation of these erosion rates for the next 30 years.[48]

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[43] *Id.* at 136 (relying on modeled erosion rates to assess indirect and cumulative impacts in Shallotte Inlet and on Holden Beach).

[44] *Id.* at 115.

[45] *See* Appendix C at 60 (stating that evaluation of alternatives will be provided "in the next section" but omitting that section).

[46] Appendix B at 26.

[47] *Id.* at 25.

[48] *See id.* at 26 (describing calculation of scarp line for evaluating Alternative 1 economic impacts); DEIS at 28 (describing erosion under Alternative 2 as occurring "uniformly" from 2015 to 2045 at 1999-2010 rates).

This assumption has two critical flaws. First, it appears to be based on a subset of LiDAR data that excludes relevant time periods with lower erosion rates. Second, the DEIS does not offer any rationale as to why the erosion rates observed during the isolated 10-year period selected can be expected to occur "uniformly" for the next 30 years—particularly in light of modeling that predicts much lower erosion rates.

In its "Assessment of Terminal Groin Feasibility" report, CPE collected eight sets of LiDAR data ranging from 1997 to 2010.[49] Figure 3 of that report, which is reproduced below, mapped the eight LiDAR data sets.

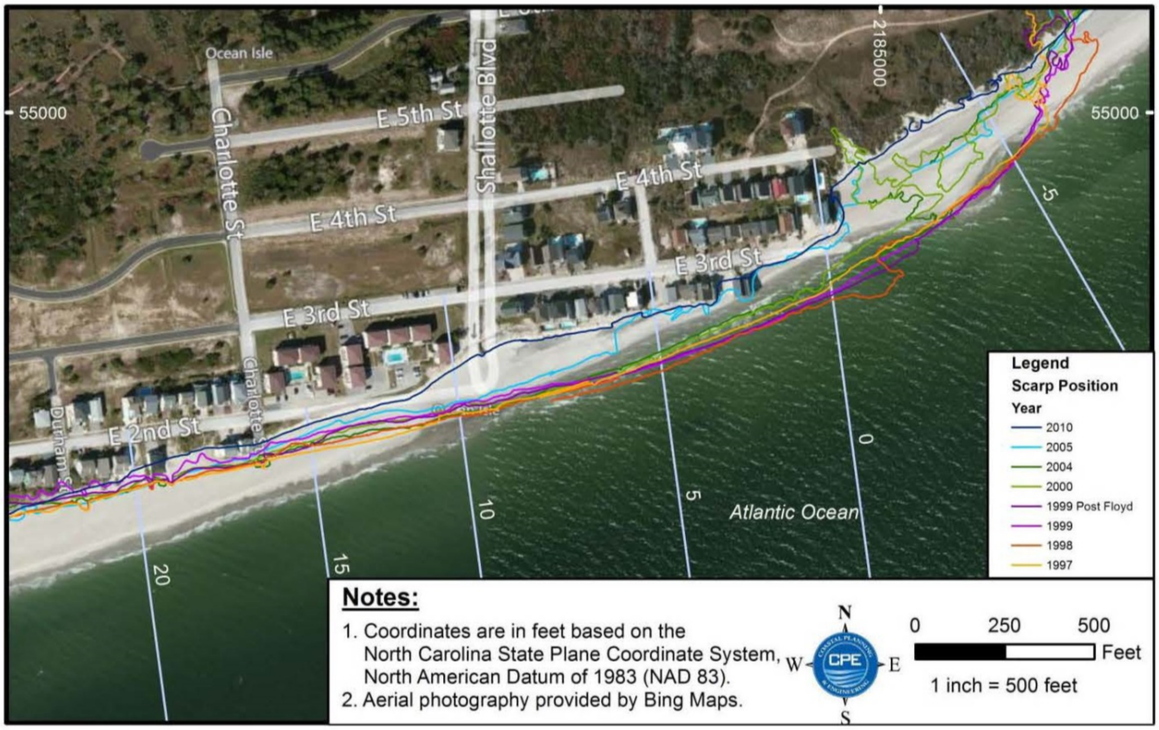

Figure 3. Position of the erosion scarp line obtained from LiDAR data between 1999 and 2010. The station numbers are in 100's feet and correspond to USACE stations, with the addition of Station -5.

When calculating erosion rates, however, CPE limited its analysis to LiDAR data from 1999 to 2010.[50] The Feasibility Report does not provide any explanation for excluding the 1997 and 1998 LiDAR data. That analysis was carried forward in Appendix B[51] and the DEIS,[52] still without any explanation for the exclusion of the available data.

The exclusion of this data must be explained. The mapped data appears to show accretion on Ocean Isle Beach between 1997 and 1999 and would undermine the DEIS's assumption that "the average rates of movement of the scarp line [between 1999 and 2010]

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[49] Coastal Planning & Engineering of North Carolina, Town of Ocean Isle Beach: Assessment of Terminal Groin Feasibility at 5 (May 2012) (attached as Ex. 2).

[50] *Id.* at 6-7.

[51] Appendix B at 25.

[52] DEIS at 28.

appeared to provide a reasonable representation of recent changes on the east end of Ocean Isle Beach."[53] It further undermines the assumption that erosion observed between 1999 to 2010 can be expected to continue "uniformly" for the next three decades.[54]

Even if the data from 1999 to 2010 accurately represented "recent changes on the east end of Ocean Isle Beach," the DEIS does not make any effort to support the assumption that those erosion rates can be expected to continue for the next 30 years. The Corps is well aware of recent, natural changes at Rich Inlet that have not only eliminated erosion at Figure Eight Island, but have resulted in substantial accretion of the northern end of the island in just a few years.[55] Inlets are dynamic systems and the Corps cannot simply assume that erosional forces at Shallotte Inlet will be static for the next 30 years.

Finally, the assumed erosion rates based on LiDAR data from 1999 to 2010 conflict with modeled erosion rates. According to the Delft3D model, very little erosion will occur after three years under Alternative 1. Figure 5.3 of the DEIS, which is reproduced below, shows little erosion between station 0+00 and 30+00.[56]

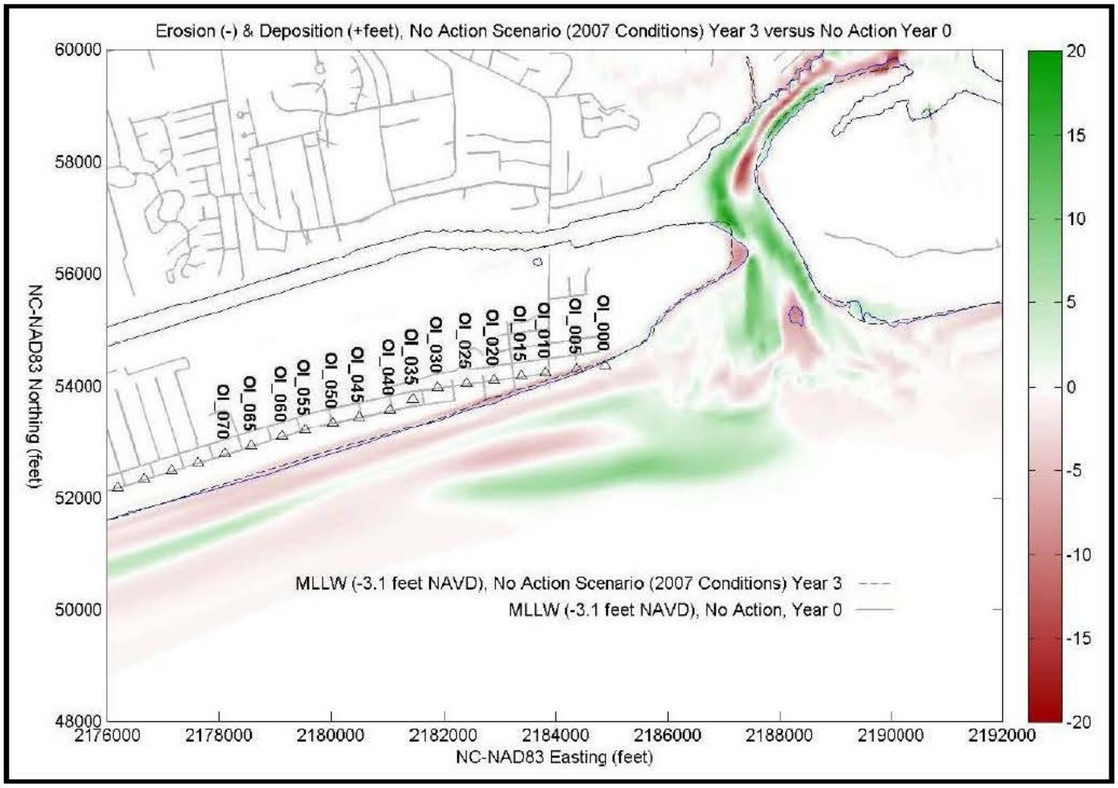

Figure 5.3. Alternative 1 erosion/deposition patterns after Year 3 of the Delft3D model simulation.

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[53] *Id.* at 25.

[54] *Id.* at 28.

[55] *See* Letter from S. Weaver, SELC, to M. Sugg, Corps, at 2-3 (Oct. 13, 2014) (attached as Ex. 3).

[56] Importantly, it is this modeled shoreline, not the shoreline mapped in Figure 3.1 that the DEIS relies on for its analysis of environmental impacts. *See* DEIS at 113-14. Use of different erosion rates and different projected shorelines to evaluate the impacts of a single alternative is, on its face, arbitrary and capricious.

Therefore, even if the 1999 to 2010 data could be considered representative of past erosion rates, the Delft3D model—which was designed based on those past erosion rates—predicts that erosion will stabilize at a much lower rate, allowing the beach to build up when combined with the beach nourishment from the federal storm damage reduction project.

The conflict between the erosion rates relied on to develop the future scarp lines in Figure 3.1 of the DEIS and the modeled erosion rates and modeled shoreline changes cannot be overstated. The DEIS creates two Alternative 1 scenarios. Under the first, depicted in Figure 3.1, erosion continues uniformly and unabated for the next 30 years. Under the second, depicted in Figure 5.3, erosion stabilizes at a level that is more than replenished with beach nourishment. The DEIS relies on the first when evaluating economic impacts.[57] The DEIS relies on the second when evaluating environmental impacts.[58] Reliance on these dual forecasts could hardly be more arbitrary and capricious. Alternative 1 will result in one set of future erosion rates and a single shoreline. The Corps must choose one of the two scenarios offered by the DEIS and apply it consistently.

In conclusion, the fundamental assumption underlying the Corps' analysis of Alternatives 1 and 2, that future erosion will continue uniformly at rates observed between 1999 and 2010 is not only unsupported, but unwarranted based on data within CPE's possession and modeling relied on extensively in the DEIS's analysis of environmental impacts. The Corps must reevaluate the assumed erosion rate for Alternatives 1 and 2 in light of available evidence.

B. The DEIS analysis of Alternative 3 relies on dubious calculations of erosion rates.

The DEIS analysis of Alternative 3 suffers from similar unsupported and unsupportable assumptions. Like Alternative 1, the DEIS creates two scenarios for Alternative 3. One based on manipulations of observed erosion rates and one based on the modeled erosion rates and the modeled shoreline. Like Alternative 1, the DEIS uses the inflated observed erosion rate in its economic analysis—increasing beach nourishment costs substantially.[59] As with Alternative 1, the DEIS uses the modeled erosion rates and the modeled shoreline to evaluate environmental impacts.[60] As a result, the analysis of Alternative 3, on its face, is arbitrary and capricious—it predicts two fundamentally different outcomes.

Moreover, the DEIS assumed loss of 140,000 cy/yr between station 0+00 and 0+30 is not supported by the DEIS. The inflated erosion rate is primarily based on observations of 2006-07 beach fill deposited on the east end of Ocean Isle Beach *in addition to* the federal storm damage reduction project.[61] As reported in Appendix B, the *additional* fill of 155,000 cy eroded within approximately nine months.[62] The overall erosion rate between 0+00 and 0+30 during that the three years following the fill, however, was approximately 88,000 cy/yr,[63] indicating that while

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[57] *See id.* at 25-26.
[58] *See id.* at 113-14.
[59] *Id.* at 29.
[60] *Id.* at 113-114.
[61] Appendix B at 34-35.
[62] *Id.* at 35.
[63] *Id.* at 36.

the *additional* fill eroded quickly the overall erosion rate did not increase. Therefore, the assumption that overall erosion rates would increase with the additional beach fill does not appear to be supported by the data provided in the DEIS.

The assumption of increased erosion is further undermined by reliance on the Delft3D model. Appendix B explains that the modeled erosion rate was 54% higher than "existing conditions" or, more specifically, the modeled erosion rate under Alternative 1—24,000 cy/yr.[64] A 54% increase would result in a modeled erosion rate of approximately 37,000 cy/yr, though neither Appendix B nor the DEIS reveal the modeled erosion rate. Therefore, the model predicted that over the three years assessed, the 450,000 cy initial fill would be reduced to 339,000 cy, a 25% reduction. That result is evident in Figure 5.4, which depicts substantial accretion.

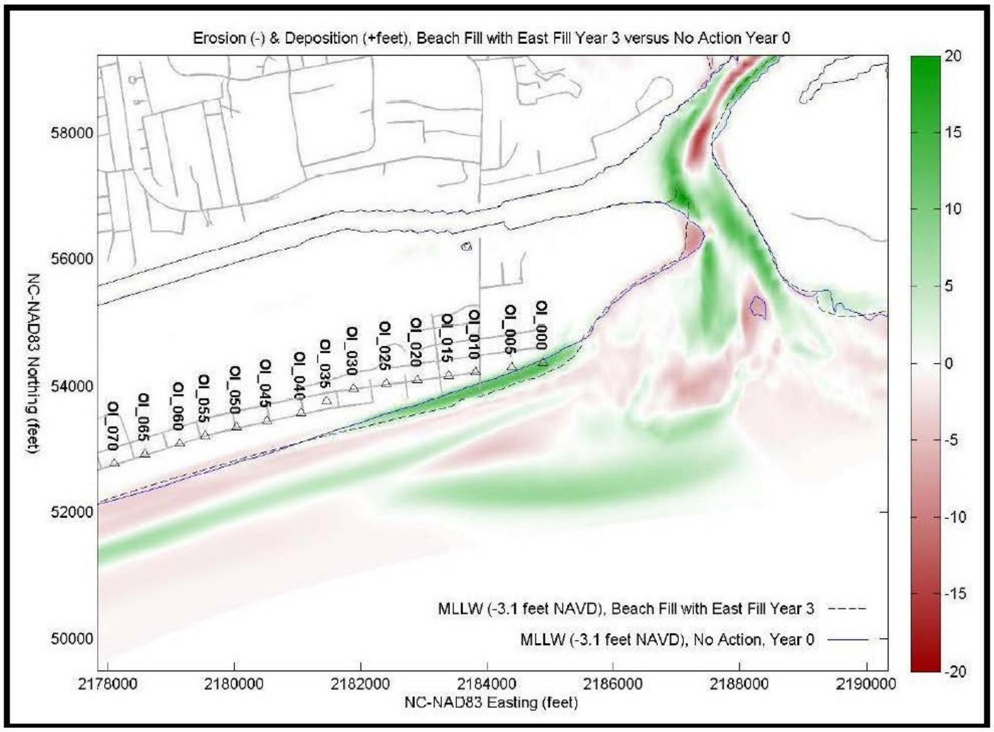

Figure 5.4. Alternative 3 – Erosion/deposition patterns after 3 years of the Delft3D simulation.

Based on the model results, it would take approximately 12 years for the initial beach fill (450,000 cy as modeled) under Alternative 3 to erode. As a result, beach nourishment costs would be dramatically reduced. That conclusion stands in stark contrast to the assumption made in the DEIS—that the Alternative 3 beach fill of 557,000 cy[65] would be entirely eroded in less than four years. The DEIS's assumption that "volumetric losses from a beach fill placed east of baseline station 30+00 would be expected to erode at a rate of 140,000 cubic yards/year"[66] is refuted by the very analysis it cites.

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[64] *Id.* at 36-39.

[65] DEIS at 30 (showing initial Alternative 3 beach fill), 24 (federal storm damage reduction project fill)

[66] *Id.* at 120.

Even if the model results did not refute the assumed inflated erosion rate, it cannot be accepted. As discussed above, the DEIS does not provide any rationale for the conclusion that variations in the modeled erosion rate are proportional to future variations of previously observed erosion rates. The Corps cannot rationally conclude that the modeled erosion rate for Alternative 1 is inaccurate, that the modeled erosion rate for Alternative 3 is inaccurate, that the increased volume lost (13,000 cy/yr) is inaccurate, *and* that the proportional increase (54%) is accurate. The DEIS does not attempt to explain, and cannot justify, this assumption.

C. The DEIS's analysis of Alternative 4 relies on unsupported assumptions and unsupportable erosion rates.

Alternative 4 is distinct from each of the other alternatives in two important ways. First, it dictates a narrower, more specific dredging pattern that is designed to realign the inlet.[67] While other alternatives rely on dredging from Shallotte Inlet, none propose to do so with the specificity of Alternative 4. Second, Alternative 4 is the only alternative that was not modeled.

Given the role that modeling played in the DEIS analysis, the decision not to model Alternative 4 is puzzling.[68] The DEIS refers to modeling of Alternative 1 in the discussion of Alternative 4,[69] but Alternative 1 modeling cannot substitute for an analysis of Alternative 4 as is evident by the projection that Alternative 1 would require continued beach renourishment for 30 years[70] as compared to the more specific dredging in Alternative 4 that CPE projects would eventually eliminate the need for beach nourishment between stations -5+00 and 30+00.[71] Similarly, the DEIS refers to erosion rates under Alternative 3, but even if those erosion rates were reliable (they are not), they do not reflect the specific channel dredging included in Alternative 4.[72]

If the Corps is to rely on the Delft3D model, it must run the model for Alternative 4 and disclose those results to the public. Neither the DEIS nor Appendix B do so.

Beyond the failure to evaluate Alternative 4 through the Delft3D model, the DEIS errs by assuming that the inlet relocation will take 20 years without explanation. The historic shorelines mapped on Figure 4.13 of Appendix B do not support that assumption. The inlet position is not indicated in relation to the shorelines. Therefore it is not possible to draw any conclusions from the information included.

Moreover, the natural migration of the inlet was almost certainly a more gradual process than the proposed realignment. The realignment proposed in Alternative 4 should result in changing sand transport patterns much more quickly than a natural migration. The DEIS

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[67] *Id.* at 32.

[68] To be clear, the Delft3D model should be rejected outright. But given the central role assigned to it in the DEIS the Corps can hardly "rigorously explore and objectively evaluate" Alternative 4 compared to other alternatives in the absence of modeling. 40 C.F.R. § 1502.14(a).

[69] DEIS at 123.

[70] *Id.* at 27, 122 (explaining the difference between continuing past general dredging as compared to more specific dredging proposed by Alternative 4).

[71] Appendix B at 49.

[72] DEIS at 123.

recognizes that a similar realignment at Emerald Isle achieved that modified sand transport after just 6 years.[73] As the Corps is aware, a relatively rapid natural shift in the channel alignment at Rich Inlet also resulted in rather rapid changes in sand transport on Figure Eight Island. As a result, the assumption that it will take 20 years to achieve the results of the inlet realignment is not warranted.

IV. The Analyses of the Terminal Groin Alternatives Are Arbitrary and Capricious.

The DEIS analyses of the terminal groin alternatives is based entirely on the Delft3D model results. For the reasons stated above, that reliance renders the DEIS analysis arbitrary and capricious.

In addition, the DEIS is decidedly one-sided, omitting any discussion of the disadvantages of terminal groins experienced elsewhere, only briefly addressing the groin at Oregon Inlet. The Corps' Coastal Engineering Manual describes groins as: "…probably the most misused and improperly designed of all coastal structures."[74] It recognizes that "[o]ver the course of some time interval, accretion causes a positive increase in beach width updrift of the groin. Conservation of sand mass therefore produces erosion and a decrease in beach width on the downdrift side of the groin." A Division of Coastal Management Report that preceded the CRC's terminal groin study found that, at Oregon Inlet, "[t]he six miles of [Pea Island] shoreline south of the terminal groin fillet that was monitored continues to erode at rates that range from slightly more to slightly less than the pre-terminal groin shoreline erosion rates, in spite of frequent dredging and beach nourishment efforts."[75] With respect to Fort Macon, the report concluded that "[w]ithout constant beach nourishment, the terminal groin would no longer perform as observed historically and, potentially fail altogether."[76] Similarly, the CRC's terminal groin study suggests that substantial beach nourishment is required even when terminal groins are constructed.[77]

Even the limited analysis of Oregon Inlet's terminal groin in the DEIS is flawed. The DEIS states that "[r]esults have shown that the project erosion rates are much less than historical rates in the first four miles of the study area."[78] The CRC's study found that when the effect of beach nourishment was removed, the 1998-2004 erosion rate on Pea Island exceeded the 1949-1980 erosion rate at intervals 1-2 miles from the inlet, 2-3 miles from the inlet, 4-5 miles from the inlet, and 5-6 miles from the inlet.[79] On Bodie Island, the effect was more severe—erosion increased substantially at five of the six intervals evaluated.[80]

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[73] *Id.* at 129.
[74] U.S. Army Corps of Engineers, Coastal Engineering Manual at 3-59 (Aug. 1, 2008).
[75] N.C. Division of Coastal Management, North Carolina's Terminal Groins at Oregon Inlet and Fort Macon: Descriptions and Discussions at 7 (2008) (attached as Ex. 4).
[76] *Id.* at 17.
[77] N.C. Coastal Resources Commission, Final Report: Terminal Groin Study at II-58 (Mar. 1, 2010) (describing volume changes at Fort Macon) ("CRC Report").
[78] DEIS at 172 (citing an "Overton, 2011" study not listed in the DEIS references).
[79] CRC Report at II-32.
[80] *Id.*

Neither the modeling nor experience at other North Carolina inlets support the DEIS assumptions of significant reductions in nourishment requirements as a result of the evaluated terminal groin alternatives.

V. The DEIS's Environmental Analysis Fails to Analyze Relevant Impacts.

NEPA requires a robust analysis of environmental impacts. The Corps must not only consider direct impacts from each alternative, but must also take into account indirect and cumulative impacts. That analysis then forms the basis for the evaluation of the alternatives under the 404(b)(1) guidelines and the Endangered Species Act. The DEIS fails at the first step, defining the impacts, eliminating the document's utility.

A. The DEIS fails to properly evaluate direct, indirect, and cumulative impacts.

Direct effects are those "which are caused by the action and occur at the same time and place." 40 C.F.R. § 1508.8(a). The direct effects were determined here "by identifying the footprints of project-related activities (i.e. proposed areas to be dredged, beach fill locations, staging area, etc.)."[81] Because the footprint of each alternative depends on nourishment values derived from the inflated erosion rates based on the Delft3D model, the estimate of habitat directly affected by the alternatives is unreliable.

More importantly, the analysis of indirect effects is indefensible. Because the purpose of this project is to modify natural sand transport processes, the analysis of indirect effects is a crucial part of the DEIS. The importance of the indirect effects analysis is heightened for the terminal groin alternatives because they would permanently disrupt natural inlet dynamics. Indirect effects are those that "are caused by the action and later in time or farther removed in distance, but are still reasonably foreseeable." 40 C.F.R. § 1508.8(b). In the DEIS, "[i]ndirect impacts were determined by the changes to the shoreline at *Year 1 Post-construction* as interpreted from the Delft3D modeling results."[82] Two aspects of this analysis are critical. First, the impacts are based solely on the shoreline predicted by the Delft3D model. The DEIS itself says that such a use is improper.[83] Second, the analysis was limited to one year following construction. There is no conceivable argument that indirect effects will cease one year post construction. In its assessment of Alternative 4, for example, the DEIS predicts that the full effect of the alternative will not be felt for 20 years.

Finally, the DEIS's cumulative impacts analysis fails to meet basic requirements. A "[c]umulative impact is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions." 40 C.F.R. § 1508.7. As discussed in more detail below, the proposed project threatens to degrade habitat for birds, turtles, and fish that use inlets like Shallotte Inlet for key portions of their life cycles. There are a limited number of inlets in North Carolina and several are

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[81] DEIS at 113.

[82] *Id.* (emphasis added).

[83] *Id.* ("The model results are by no means intended to represent predictions of what changes to expect in the future . . . .").

intensively managed,[84] hardened,[85] or have proposed terminal groin projects.[86] The Corps is a permitting agency for each of these inlet management projects. Yet the DEIS provides no analysis of the cumulative impact of these numerous projects on species that depend on functioning inlet systems. That failure violates NEPA. *See Nat'l Audubon Soc'y*, 422 F.3d at 187 ("The hallmarks of a 'hard look' are thorough investigation into environmental impacts and forthright acknowledgment of potential environmental harms.").

B. The DEIS does not provide information required to satisfy the 404(b)(1) Guidelines.

The purpose of the DEIS in this context is to provide information for the Corps to conduct its required analysis under Section 404 of the Clean Water Act. Because of its failure to adequately evaluate direct, indirect, and cumulative impacts, this DEIS fails to meet that goal. For the reasons described above, the analysis of environmental impacts based on a terminal-groin-oriented analysis does not provide the objective evaluation necessary to complete that analysis. The DEIS does not "consider[] the alternatives in sufficient detail to respond to the requirements of these Guidelines" discussed below and it is "necessary to supplement these NEPA documents with this additional information." 40 C.F.R. § 230.10(4).

Under the Clean Water Act, the Corps is only able to permit the least environmentally damaging practicable alternative ("LEDPA"). Practicable means "available and capable of being done after taking into consideration cost, existing technology, and logistics." 40 C.F.R. § 230.3(q). Although the Corps has not defined practicability in the DEIS—thereby unlawfully denying the opportunity for public comment on that essential element of the analysis—it is apparent that each alternative is practicable.

Nonetheless, based on the modeled erosion rates, which must be accepted if the Delft3D model is to be relied upon, no structures will be lost under any alternative and each alternative would provide protection to the imminently threatened properties with significantly reduced beach nourishment requirements. On that basis, each alternative is practicable and Alternative 4 appears to be the LEDPA. Therefore, it is the only alternative that can be permitted.

The alternatives fall into two categories. The first includes the non-structural alternatives, whose environmental impacts – dredging, smothering benthic organisms, altered beach profile, etc. – vary by degree. The second category includes the terminal groin alternatives, whose unique environmental impacts – hardening of the shoreline, loss of overwash areas, etc. – are permanent.

In its application of the 404(b)(1) Guidelines, the Corps must evaluate "the nature and degree of effect that the proposed discharge will have, individually and cumulatively, on the characteristics at the proposed disposal sites." 40 C.F.R. § 230.11(a). That effect is measured by

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[84] Oregon Inlet, Beaufort Inlet, Mason Inlet, Rich Inlet, Shallotte Inlet, and New River inlet, among others, are managed through dredging.

[85] Oregon Inlet, Beaufort Inlet, Masonboro Inlet, and Bald Head Island each have some type of hardened structure.

[86] The Wilmington District's web page lists terminal groin projects proposed for Holden Beach and Figure 8 Island in addition to Ocean Isle Beach and Bald Head Island.

how the discharges change the “physical, chemical, and biological characteristics of the substrate” and affect “bottom-dwelling organisms at the site by smothering immobile forms or forcing mobile forms to migrate.” 40 C.F.R. § 230.20(b).

The analysis of these factors reveals a clear divide. The non-structural alternatives will have varying degrees of impact on infaunal communities in both the dredged areas and the nourished areas. Because it would require decreasing dredging and nourishment, Alternative 4 would have the least impact on substrate and benthic organisms. Unlike any of the non-structural alternatives, however, the terminal groin alternatives will permanently alter the characteristics of the inlet. The intertidal areas lost in the area that would be impacted by the terminal groin will not redevelop, eliminating the possibility that the benthic organisms buried or displaced could repopulate the area. The groin alternatives will fundamentally change the nature of the eastern end of the island, eliminating overwash areas and permanently altering substrate and eliminating habit for benthic organisms. Alternatives 5a, 5b, and 5c are the most environmentally damaging alternatives when evaluated under the factors in 40 C.F.R. § 230.20.

The Corps must also evaluate “the nature and degree of effect that the proposed discharge will have individually and cumulatively on water, current patterns, circulation including downstream flows, and normal water fluctuation.” 40 C.F.R. § 230.11(b). These effects are measured by the “adverse changes” that occur in “[l]ocation, structure, and dynamics of aquatic communities; shoreline and substrate erosion and deposition rates; [and] the deposition of suspended particulates.” 40 C.F.R. § 230.23(b).

As with impacts to substrate, Alternative 4 clearly has the least environmental impact on the aquatic communities and deposition of suspended particles. It would less adversely affect aquatic communities and would continue to allow deposition of suspended particles on the overwash areas at the eastern end of the island (as would the other non-structural alternatives). By comparison, the terminal groin alternatives would permanently displace aquatic communities at the eastern end of the island and eliminate overwash, cementing the accompanying adverse environmental impacts.

The Corps’ consideration of the fluctuation of normal water level must include consideration of “modifications [that] can alter or destroy communities and populations of aquatic animals and vegetation, . . . modify habitat, reduce food supply, restrict movement of aquatic fauna, destroy spawning areas, and change adjacent, upstream, and downstream areas.” 40 C.F.R. § 230.24.

For the reasons described above and the impacts on the benthic communities, Alternative 4 appears to have the least environmental impact. Alternative 4 would also appear to have the least adverse environmental effect on wet beach habitat, adjacent dry beach habitat, and back beach habitat. Other non-structural alternatives would similarly have temporally limited environmental impacts to these habitats. Alternatives 5a, 5b, and 5c would have significant, permanent impacts to these areas. They would eliminate wet beach habitats and the associated benthic organisms, significantly modify dry beach habitats, and result in dense vegetation of what are now sparsely vegetated back beach habitats. They would therefore have the greatest adverse impacts of any of the alternatives.

In addition to the Corps' endangered and threatened species analysis under the ESA, it must also consider listed species under the 404(b)(1) Guidelines. The Corps must compare alternatives based on their potential impact on "nesting areas, protective cover, adequate and reliable food supply and resting areas for migratory species." 40 C.F.R. § 230.30(b)(2).

Alternative 4 and the other non-structural alternatives would maintain habitat for piping plover on Ocean Isle Beach and allow critical habitat for piping plover to remain in Shallotte Inlet and on Holden Beach.

Finally, the Corps must consider "the loss or change of breeding and nesting areas, escape cover, travel corridors, and preferred food sources for resident and transient wildlife species associated with the aquatic system." 40 C.F.R. § 230.32(b).

Construction of Alternative 5a, 5b, or 5c would eliminate habitat for all shorebirds that rely on relatively unvegetated back beach, wet beach, and intertidal habitats. Therefore, the adverse effects described above for piping plover are likely to be felt by red knots and other shorebirds.

It is clear from the DEIS that under the 404(b)(1) Guidelines, the Corps cannot permit either Alternative 5a, 5b, or 5c. All would have significantly greater environmental impact than Alternative 4. Based on the available information, it appears that Alternative 4 is the LEDPA and is the only alternative that can be permitted by the Corps.

C. The DEIS fails to meaningfully analyze impacts to critical habitat.

Shallotte Inlet provides habitat for threatened and endangered species including piping plovers, red knots, Atlantic sturgeon, short-nosed sturgeon, and sea turtles. Because this project "may affect" these listed species and designated critical habitat, the Corps must consult with the expert wildlife agencies – U.S. Fish and Wildlife and the National Marine Fisheries Service – to determine the effects of the project on these resources. 16 U.S.C. § 1536(a)(2). Production of such a "biological opinion" is required by the ESA and its implementing regulations unless the Corps determines, with the written concurrence of the expert wildlife agencies, "that the proposed action is not likely to adversely affect any listed species or critical habitat." 50 C.F.R. § 402.14.

The FWS has previously made its view of this project known. In an email sent during the scoping process for this proposal, Pete Benjamin wrote as follows:

> The issues are clear. A project of this nature will destroy the ecological functioning of this inlet and the surrounding areas. The science is unequivocal. I see no unique issues or areas of significant uncertainty. We oppose this project. There is nothing more to discuss.[87]

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[87] Email from W. Laney, FWS, to C. Weaver, NCDENR, (Dec. 19, 2011) (attached as Ex. 5).

The project area in Shallotte Inlet includes designated critical habitat for wintering populations of piping plover. The area is a key wintering site for piping plovers. Despite the DEIS's failure to provide information required to conduct a full analysis of environmental impacts, based on the well-known and intended effects of terminal groins, it is unavoidable that the terminal groin as proposed in Alternative 5 will destroy and adversely modify both habitats and inlet processes that constitute primary constituent elements of critical habitat and the Endangered Species Act ("ESA") prohibits issuance of a permit that would authorize these activities.

1. *The Corps may not permit an action that adversely modifies critical habitat by diminishing the value of the habitat for either the survival or recovery of a species.*

Under the ESA, "[e]ach Federal agency shall, in consultation with and with the assistance of the Secretary, insure that any action authorized, funded or carried out by such agency is not likely to . . . result in the destruction or adverse modification of [critical] habitat." 16 U.S.C. § 1536(a)(2). Section 7 of the ESA "requires federal agencies to ensure that none of their activities, including the granting of licenses and permits, will … adversely modify a species' critical habitat." *Karuk Tribe of Cal. v. United States Forest Serv.*, 681 F.3d 1006, 1020 (9th Cir. June 1, 2012) (citing *Babbitt v. Sweet Home Chapter,* 515 U.S. 687, 692 (1995)). The Corps also has "an independent duty under section 7(a)(2) to ensure that its [action] … [is] not likely … to adversely modify [critical] habitat." *Defenders of Wildlife v. United States EPA*, 420 F.3d 946, 976 (9th Cir. 2005). (Agency reliance on a faulty Biological Opinion violates its duty under Section 7(a)2) of the ESA).[88]

The regulatory definition of "adverse modification" is found in 50 C.F.R. § 402.02, and states that an "adverse modification" is a "direct or indirect alteration that appreciably diminishes the value of critical habitat for both the survival and recovery of a listed species." In *Gifford Pinchot Task Force v. U.S. Fish and Wildlife Service*, 378 F.3d 1059, 1070-70 (9th Cir.), the 9th Circuit ruled that "the regulatory definition of 'adverse modification' contradicts Congress's express command," and therefore violates the ESA. The court explained that Congress enacted the ESA "not merely to forestall the extinction of [a] species (i.e., promote a species['] survival), but to allow a species to recover to the point where it may be delisted." *Id.* at 1070. Because a species needs more critical habitat for its recovery than is necessary for survival, the court found

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[88] Further, "it is unlawful for any person subject to the jurisdiction of the United States to . . . take any species," which is defined to include "significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering." 50 C.F.R. § 17.3. The prohibition on take includes agencies authorizing activities carried out by others that result in take of a listed species. *Strahan v. Coxe*, 127 F.3d 155, 163 (1st Cir. 1997). (State of Massachusetts was found to have exacted a taking of endangered Northern Right Whales through its licensing and permitting of certain fishing practices that exacted a taking of the species); *Sierra Club v. Yuetter*, 926 F.2d 429, 438-39 (5th Cir. 1991)(finding Forest Service caused take of endangered red-cockaded woodpecker by permitting logging practices near nesting colonies); *Defenders of Wildlife v. Administrator, Envtl Protection Agency*, 882 F.2d 1294, 1300-01 (8th Cir.1989)(finding EPA caused take of endangered species through its registration of pesticides for use by others); *Loggerhead Turtle v. County Council of Volusia County*, 896 F. Supp.1170, 1180-1181 (M.D. Fla. 1995)(holding Volusia County caused take of endangered sea turtles through its authorization of vehicular beach access during turtle mating season).

that the regulation was invalid because "[w]here Congress in its statutory language required 'or,' the agency in its regulatory definition substituted 'and.'" *Id.*

In response to the *Gifford Pinchot* decision, the U.S. Fish & Wildlife Service ("FWS") issued a directive on the use of the invalidated regulatory definition of "adverse modification" in a Memorandum on December 9, 2004. *Minn. Ctr. for Envtl. Advocacy v. United States Forest Serv.*, 2012 U.S. Dist. LEXIS 51853, 44-46 (D. Minn. Apr. 12, 2012) (citing FWS0004205). The Memorandum directs FWS biologists "not cite to or use" the invalidated regulatory definition of adverse modification "at any point in the consultation process." *Id.* The Memorandum also directs FWS staff "to rely on an analytic framework based on the language of the ESA itself, which requires that critical habitat be designated to achieve the twin goals of survival and conservation (i.e., recovery) of listed species. Under current practice, the FWS "will find 'adverse modification' if the impacts of a proposed action on a species' designated critical habitat would appreciably diminish the value of the habitat for either the survival or the recovery of the species." *Id.*

The determination whether designated critical habitat would continue to serve its intended conservation role in recovery of a species is determined by whether the critical habitat retains its ability to provide and continue to establish the necessary primary constituent elements ("PCEs"). The FWS defines PCEs as "physical or biological feature[s] essential to the conservation of a species for which its designated or proposed critical habitat is based on."[89] The examples FWS give are "space for individual and population growth, and for normal behavior; … nutritional or physiological requirements; cover or shelter; sites for breeding, reproduction, rearing of offspring; … and habitats that are protected from disturbance or are representative of the species' historic geographic and ecological distribution."[90] In a recent revised designation of critical habitat for the Pacific coast population of the western snowy plover, FWS explains that activities that may constitute an "adverse modification" of critical habitat "are those that alter the physical and biological features to an extent that appreciably reduces the conservation value of critical habitat." 77 Fed. Reg. 36,728, 36,774 (June 19, 2012) (to be codified at 50 C.F.R. pt. 17). Agencies must use the "best scientific data" when conducting and relying on these Biological Opinions evaluating whether proposed actions result in adverse modification of critical habitat. *Conservation Cong. v. United States Forest Serv.*, 2012 U.S. Dist. LEXIS 84943, 36 (D. Cal. 2012)**.**

2. The Shallotte Inlet area includes designated critical habitat for the recovery of the piping plover.

FWS designated critical habitat for the wintering populations of piping plovers on July 10, 2001. 66 Fed. Reg. 36,038 (July 10, 2001). The habitat designated "is essential to the conservation of this species." 66 Fed. Reg. at 36,041. Areas containing primary constituent elements that constitute critical habitat were designated in eight states, including 18 units on the North Carolina coast. Unit NC-17: Shallotte Inlet is defined as follows:

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[89] FWS, Endangered Species Glossary, available at: www.fws.gov/nc-es/es/glossary.pdf.

[90] *Id.*

> This unit begins just west of Skimmer Court on the western end of Holden Beach. It includes land south of SR 1116 to where densely vegetated habitat, not used by the piping plover, begins and where the constituent elements no longer occur to the MLLW along the Atlantic Ocean. It includes the contiguous shoreline from MLLW to where densely vegetated habitat, not used by the piping plover, begins and where the constituent elements no longer occur along the Atlantic Ocean, Shallotte Inlet, and Intracoastal Waterway stopping north of Skimmer Court Road. The unnamed island and emergent sandbars to MLLW within the Shallotte Inlet are also included.

Id. at 36,088.

Designated critical habitat within critical habitat Unit NC-17 includes those primary constituent elements present in the area as described in the regulation:

> The primary constituent elements essential for the conservation of wintering piping plovers are those habitat components that support foraging, roosting, and sheltering and the physical features necessary for maintaining the natural processes that support these habitat components. The primary constituent elements include intertidal beaches and flats (between annual low tide and annual high tide) and associated dune systems and flats above annual high tide. Important components of intertidal flats include sand and/or mud flats with no or very sparse emergent vegetation. In some cases, these flats may be covered or partially covered by a mat of blue-green algae. Adjacent non-or sparsely vegetated sand, mud, or algal flats above high tide are also important, especially for roosting piping plovers, and are primary constituent elements of piping plover wintering habitat. Such sites may have debris, detritus (decaying organic matter), or micro-topographic relief (less than 50 cm above substrate surface) offering refuge from high winds and cold weather. Important components of the beach/dune ecosystem include surfcast algae, sparsely vegetated backbeach and salterns (beach area above mean high tide seaward of the permanent dune line, or in cases where no dunes exist, seaward of a delineating feature such as a vegetation line, structure, or road), spits, and washover areas. Washover areas are broad, unvegetated zones, with little or no topographic relief, that are formed and maintained by the action of hurricanes, storm surge, or other extreme wave action.

Id. at 36,086.

In designating critical habitat, FWS identified factors that may affect piping plover survival or use of the area:

> Overall winter habitat loss is difficult to document; however, a variety of human-caused disturbance factors have been noted that may affect plover survival or utilization of wintering habitat (Nicholls and Baldassarre 1990a, Haig and Plissner 1993). These factors include recreational activities (motorized and pedestrian), *inlet and shoreline stabilization, dredging of inlets that can affect spit (a small point of land, especially sand, running into water) formation, beach maintenance and renourishment (renourishing the*

> *beach with sand that has been lost to erosion),* and pollution (e.g., oil spills) (USFWS 1996). The peer-reviewed, revised recovery plan for the Atlantic piping plover population recognizes the need to protect wintering habitat from direct and indirect impacts of shoreline stabilization, navigation projects, and development. (emphasis added).

Id. at 36,039 (emphasis added).

The Recovery Plan for the critically endangered Great Lakes piping plover population states that "[i]nlet dredging and artificial structures, such as breakwalls and groins, can eliminate breeding and wintering areas and alter sedimentation patterns leading to the loss of nearby habitat."[91] The 5-year Status Review for Piping Plover states: "The three recovery plans state that shoreline development throughout the wintering range poses a threat to all populations of piping plovers. The plans further state that beach maintenance and nourishment, inlet dredging, and artificial structures, such as jetties and groins, can eliminate wintering areas and alter sedimentation patterns leading to the loss of nearby habitat."[92] The Status Review concludes: "Habitat loss and degradation on winter and migration grounds from shoreline and inlet stabilization efforts, both within and outside of designated critical habitat, remain a serious threat to all piping plover populations."[93]

As discussed in more detail below, Alternative 5's terminal groin options are specifically identified by FWS and other experts as factors leading to the decline of piping plovers. If authorized at Shallotte Inlet within critical habitat Unit NC-17, these alternatives would destroy and adversely modify primary constituent elements of plover habitat, permanently alter natural processes that maintain these essential components of plover habitat, and undermine and appreciably reduce the likelihood of recovery of the species.

3. *Information in the DEIS is insufficient to fully evaluate impact on critical habitat as required by NEPA, the ESA, and the CWA.*

Although it is not possible to reasonably predict the specific effects of the terminal groin alternatives based on the information provided in the DEIS, experience with terminal groins in other contexts makes clear that any of the terminal groin alternatives will result in the adverse modification of critical habitat. Primary constituent elements of critical habitat include intertidal flats, spits, sparsely vegetated flats above high tide, sparsely vegetated back beach, and inlet processes.

The piping plover status report discusses the impacts of groins and inlet stabilization on these key elements:

> Inlet stabilization with rock jetties and associated channel dredging for navigation alter the dynamics of longshore sediment transport and affect the location and

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[91] U.S. Fish & Wildlife Service, Recovery Plan for the Great Lakes Piping Plover (Charadrius melodus) (September 2003) at 23.

[92] U.S. Fish & Wildlife Service, Piping Plover (Charadrius melodus) 5-Year Status Review: Summary and Evaluation (2009) at 31.

[93] *Id.* at 39.

> movement rate of barrier islands (Camfield and Holmes 1995), typically causing downdrift erosion. Sediment is then dredged and added back to islands which subsequently widen. Once the island becomes stabilized, vegetation encroaches on the bayside habitat, thereby diminishing and eventually destroying its value to piping plovers. Accelerated erosion may compound future habitat loss, depending on the degree of sea-level rise. Unstabilized inlets naturally migrate, re-forming important habitat components, whereas jetties often trap sand and cause significant erosion of the downdrift shoreline. These combined actions affect the availability of piping plover habitat (Cohen et al. 2008).[94]

Indeed, the very purpose of the terminal groin is to fundamentally alter the natural inlet processes at Shallotte Inlet that form and maintain the other primary constituent elements.

The failure of the DEIS to conduct a valid environmental effects analysis notwithstanding, construction of a terminal groin as proposed in Alternative 5 will destroy and adversely modify primary constituent elements of critical habitat for the piping plover and cannot be permitted.

Because of these substantial environmental impacts, the terminal groin alternatives fail to meet the purpose and need. As described in the EIS, the purpose and need of this project is to "[b]alance the needs of the human environment with the protection of existing natural resources."[95] The terminal groin alternatives will substantially and permanently degrade existing natural resources and cannot be permitted.

VI. The DEIS's Economic Assumptions Are Fundamentally Flawed.

The DEIS's economic analysis is erroneous for several reasons. First, as modeled, each alternative will require significantly less dredging and beach nourishment than estimated in the economic analysis and no buildings or infrastructure will be lost. Second, even if buildings and infrastructure is lost, the DEIS substantially overestimates the "cost" to Ocean Isle Beach.

As discussed above, the modeled erosion rates and modeled shorelines show dramatically reduced erosion without constructing a terminal groin. Under Alternative 1 and 2, the beach between 0+00 and 0+30 would grow larger each year. Under Alternative 3 the initial fill would last 12 years at the erosion rates predicted by the model. Because Alternative 4 more narrowly focuses the channel to reduce erosion, the initial beach fill should last even longer than that under Alternative 3. Therefore, the estimated dredging, beach nourishment, and property-loss related costs are over estimated for each of these alternatives and must be revised.

Even if Alternatives 1 and 2 were to result in the loss of houses and infrastructure as projected in the DEIS, the "cost" to Ocean Isle Beach is dramatically overstated. Ocean Isle Beach does not own the properties at issue; its only loss is future profit from tax revenue. Given the current tax rate of 0.155/$100,[96] the lost future revenue would be miniscule compared to the

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[94] *Id.*
[95] DEIS at 16.
[96] Ocean Isle Beach web page, Residents FAQs, http://www.oibgov.com/faqs.cfm.

cost of constructing a terminal groin.[97] Moreover, the DEIS errs in assessing the value of lost infrastructure at the "replacement cost."[98] The infrastructure would not be replaced and, therefore, the cost would not be incurred.

VII. Conclusion

For the reasons described above, the DEIS fails to meet the minimum requirements of NEPA and fails to provide the analysis of shoreline changes and environmental impacts necessary to meet the Corps' obligations under the CWA or ESA. Therefore, we respectfully request that the Corps issue a revised DEIS addressing the issues raised in these comments.

Thank you for considering these comments. Please contact me at (919) 967-1450 or ggisler@selcnc.org if you have any questions regarding their content.

Sincerely,

Geoffrey R. Gisler
Senior Attorney

GRG/ao

Enclosures

cc (via email):
Todd Miller, N.C. Coastal Federation
Mike Giles, N.C. Coastal Federation
Ana Zivanovic-Nenadovic, N.C. Coastal Federation

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[97] *See* Andrew S. Coburn, A Fiscal Analysis of Shifting Inlets and Terminal Groins in North Carolina at 8, http://www.wcu.edu/WebFiles/PDFs/TG_White_paper.pdf (calculating tax revenue of properties within 30-year risk area identified by Coastal Resources Commission) (attached as Ex. 6).

[98] DEIS at 26.

EXHIBIT 1

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Quantitative modeling of coastal processes: A boom or a bust for society?

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ABSTRACT

The enormous and growing scale of human intervention in coastal processes is driven by a short-sighted societal desire to protect property in the face of shoreline recession. Underpinning this effort in both the design of engineering interventions and the amelioration of their impacts is the application of numerical models that purport to simulate and predict coastal processes. Coasts are complex systems in which (1) waves, currents, tides, and wind operate on a (2) finite or changing volume of sediment of specific character (3) within a particular geological context. Feedbacks exist within and between these three domains, and all are temporally and spatially variable. The simplifications and assumptions involved in reducing this complexity to equations and numerical models cause a deviation from reality such that models are unable to provide realistic predictions of coastal behavior. Nonetheless (and despite criticism from geologists), models have become entrenched in coastal engineering practice and are now a standard weapon in society's assault on the world's coasts. In this paper, we chart the development of several widely used models, highlight their shortcomings, and speculate on why they remain in use. The disconnect between reality and the mathematics of coastal process models is extreme, and a fundamental reassessment is required.

INTRODUCTION

An increase in the long-term rate of sea-level rise is driving an increase in the rate of shoreline retreat along most of the world's beaches. Despite this reality, the last three decades have seen a global rush to develop the beach front for tourism and investment. This collision of eroding shorelines with very expensive coastal development is fueling an ever-growing desire among coastal communities to protect their property using a wide variety of coastal engineering techniques. These stabilization efforts typically require project design and testing, the development of benefit-cost analyses, environmental impact assessments, and long-term predictions of project performance. All of these require a greater understanding of beach and coastal processes, along with a need to make some predictions about future shoreline positions and changes in beach geomorphology.

Pilkey, O., Young, R., and Cooper, A., 2013, Quantitative modeling of coastal processes: A boom or a bust for society?, *in* Baker, V.R., ed., Rethinking the Fabric of Geology: Geological Society of America Special Paper 502, p. 135–144, doi:10.1130/2013.2502(07). For permission to copy, contact editing@geosociety.org.

Unfortunately, this knowledge gap has too often been filled by the development of oversimplified, empirically derived "rules" of coastal evolution and generalized numerical models of shoreline dynamics that have dubious physical meaning and frequent misapplication in real-world design settings.

The use of mathematical models to predict and plan for the future began in the 1950s and 1960s. Robert McNamara, U.S. Secretary of Defense in the Kennedy and Johnson administrations, was a firm believer in the value of quantitative mathematical models. When confronted by a doubter who suggested that the Vietnam war was not going well, McNamara famously said, "Where is your data? Give me something I can put in a computer. Don't give me your poetry."

Pendulums swing, of course, and after the catastrophic economic downturn in 2009, Warren Buffett made another famous statement with regard to models: "Beware of geeks bearing formulas." He blamed much of the economic downturn on model failures, including especially the VaR (Value at Risk) models used to assess the risk of any particular financial portfolio. These models have been criticized because they give users a false sense of confidence and because they are unable to accurately characterize the risk of extraordinary events—two shortcomings they share with models of coastal processes.

Accurate modeling of the complex elements of nature is also difficult, especially the prediction of future behavior. A recent important example of a catastrophic failure of the modeling of natural processes was in the predictive modeling used to examine the vulnerability of coastal Japan to earthquake-induced tsunami hazard. As outlined in a news item in the journal *Nature* (Cyranowski, 2011), predictions of both potential earthquake magnitude and the resultant tsunami waves were far off, adding to the magnitude of the 2011 catastrophe.

There is a strong desire among coastal managers to be able to model the potential impacts of coastal hazards like long-term erosion from rising sea level, storm surge– and storm-induced erosion, and erosion caused by human activities (e.g., inlet dredging, jetty construction). Geologists understand that shoreline response to rising sea level and storms is a complex process controlled by the nonlinear interaction of the parameters listed in Table 1. Translating this complexity into mathematical equations for use in predictive modeling is problematic.

In this paper, we critically examine some of the widely used mathematical relationships and numerical models used for predicting shoreline change and beach behavior.

We believe that the problems with mathematical modeling of beaches, including the (un)reality of assumptions and model simplifications, are likely to apply in other predictive models of earth surface processes. The advantage of looking at coastal sediment transport models in this regard is that their use is geographically widespread and frequent (dozens of projects a year). In addition, the vast majority of model runs are performed for very practical purposes—predicting the life span of a beach nourishment project, for example. The questions that we seek to answer are not esoteric. They frequently guide the expenditure of public funds, and thus, we should expect a high degree of accuracy and a reasonable ability to assess the model's performance.

DISCUSSION

Oversimplified Mathematical Relationships

Bruun (1954, 1962) established the basis for much of today's shoreline change modeling. Schwartz (1967) coined the term "Bruun rule" for a very simple shoreline change relationship proposed in these papers. Many numerical models used for applied coastal engineering depend on the major assumptions of the Bruun rule. These models are used to predict future shoreline position, to examine the impact of coastal engineering structures, and to design and predict the performance of beach nourishment projects, as well as many other tasks.

At the time, Bruun's ideas were an important advance in our understanding of shoreline processes. No longer was shoreline erosion assumed to be a simple landward advance of mean high water. Shoreline retreat involved the whole shoreface. The assumptions made by Bruun were, however, made in the context of a relatively early understanding of nearshore processes. An understanding of the role of other important influences (Table 1), especially underlying geologic control and bottom currents, was missing. Similarly, the possibility that shorefaces and shorelines might respond to rising sea level at different rates (a fact since proven on the Dutch coast, for example) was not considered.

The Bruun rule is expressed as:

TABLE 1. FACTORS AFFECTING COASTAL SEDIMENT TRANSPORT AND RATES OF SHORELINE CHANGE

Primary factors	Secondary factors	Human impacts
Sea-level rise (rate and amount) Sediment supply	Slope of the mainland Shoreface slope Coastal geomorphology Mainland geology Geology underlying beach and shoreface Beach cementation (e.g., beachrock) Sediment grain size Nearshore oceanography, especially currents Wave climate Storm meteorology frequency Vegetation	River dams Dredging activities in inlets and nearshore Beach nourishment Hard stabilization, jetties, groins, seawalls, breakwaters Climate change

$$R = S(L/[B + h]) = S(1/\tan O), \qquad (1)$$

where L is the length of the cross-shore profile out to the "closure depth" h; O is the profile slope, and B is the berm height. For a sea-level rise S, the profile will shift landward by the amount R.

In addition, based on averages of nearshore profiles of the Danish North Sea, California, and Florida coasts, Bruun (1962) proposed that the nearshore zone or shoreface existed in an equilibrium profile, the shape of which could be determined by:

$$H = Ay^{2/3}, \qquad (2)$$

where H is water depth, y is the distance offshore, and A is a scaling parameter dependent on sediment characteristics. Dean (1977) argued that A was a function of grain size, where the coarser the grain size, the steeper the slope, and this relationship has been applied globally. Although, it is true that coarser grain size will result in steeper beaches (all other things being equal), Pilkey et al. (1993) and Thieler et al. (2000) demonstrated that a simple relationship between A and shoreface slope or shape is nonexistent.

In his 1962 paper, Bruun suggested that the profile shape would remain the same as the shoreface moves landward and seaward in response to changes in sea level. He suggested that sand is simply removed from the upper profile and redeposited on the lower shoreface profile as sea level rises (either quickly via a storm or slowly over time). The volumes removed and deposited are identical. Bruun also suggested that sand will not be transported offshore beyond the area of significant wave influence (a closure depth, h). Thus, sand never leaves the system in a cross-shore direction, and all alongshore transport is assumed to be in balance.

The Bruun rule has found global application in part because it is simple and easy to use, and there are no accepted modeling alternatives to the rule (Pilkey and Cooper, 2004; Cooper and Pilkey, 2004). For example, it is currently an important part of the development setback regulations in several Australian provinces. Typically, Bruun rule application on barrier island shorefaces predicts between 100 and 200 ft (30.5 and 61 m) of shoreline retreat per foot (0.3 m) of sea-level rise (e.g., Pilkey and Davis, 1988), leading to the widespread assumption that the 1 to ~100 rise to retreat ratio is a global rule (e.g., Anthony et al., 2012).

The Bruun rule may have been a nice way to conceptualize shoreline change 50 yr ago, but its continued application is problematic based on a modern understanding of coastal geology and oceanography.

Invalid Assumption 1. The Shoreface Maintains a Constant Shape While Moving Landward (or Seaward) (Typically Referred to as an Equilibrium Profile)

Problems with the equilibrium profile concept have been discussed by Pilkey et al. (1993), Thieler et al. (2000), and Cooper and Pilkey (2004), among others. In short, these critiques have pointed out that defining the shape of a shoreface profile based solely on the grain size of sandy profiles fails to consider the predominant role that underlying geology plays controlling the makeup and nature of the nearshore morphology. In particular, Pilkey et al. (1993) described how the predominant control on shoreface shape, slope, and width is underlying geologic control. This is something on which Per Bruun could not have had much perspective during the early 1960s.

There is no question that over short distances, the shoreface profile may be at least partially dependent upon grain size. However, grain size alone cannot explain the wide variability in shoreface widths and processes (Pilkey et al., 1993). Even some "ideal" shorefaces with thick blankets of sand overlying the antecedent geologic units never reach the equilibrium shape required by the Bruun rule. These profiles show considerable variation in shape related to seasonal changes and storm responses. On Gold Coast Australia beaches, the shoreface shows tremendous seasonal variability, as much as 4 m temporal variation in depth along its profile (Smith and Jackson, 1992). It is now widely recognized in the geologic community that shoreface shape may be affected by a number of parameters besides grain size, including sand supply, wave energy, storm size and frequency, underlying geology, and other factors (Backstrom et al., 2009). These complications are rarely discussed in the shoreline change modeling literature.

An example of the importance of the missing geologic context in the Bruun rule was pointed out by Curray (1969). He argued that today's shorefaces reflect a long-term Holocene stillstand of sea level during which the relatively stationary shorefaces steepened as sand moved landward and contributed to beaches, dunes, and barrier islands. Such a shoreface evolution was documented off Texel Island in the Netherlands (Beets et al., 1996).

Marine geophysical studies of the continental shelf reveal a number of features that could not have survived the passage of today's modern, oversteepened shoreface. The presence of submerged lithified carbonate barriers off the west coast of Florida (Hine and Locker, 2011), Australia, and South Africa provides spectacular evidence of a time when sea-level rise was so rapid, no shoreface (as we now conceive of it) existed. Such barrier remnants could not have survived passage of a shoreface. Thus, today's shorefaces, and the sea-level stillstand that formed them, are an anomaly in a geologic sense. The idea that we should expect a shoreface to maintain its current shape as it transgresses is particularly questionable in a time when the rate of sea-level rise may change dramatically.

Invalid Assumption 2. There Is a Closure Depth beyond Which Little Sediment Escapes in a Seaward Direction

Closure depth (discussed in the same papers listed under profile of equilibrium) is based on the assumption that sediment movement in the nearshore zone is caused exclusively by interaction of wave orbitals with the seafloor. The reasoning is that, as water depth increases, wave orbitals suspend less and less sediment until a point is reached where no more sediment is suspended. This concept ignores the common occurrence of various kinds of bottom currents including wind- and wave-induced upwelling and downwelling currents, and various gravity flows.

Two classic studies have indicated long-distance seaward transport of shoreface sand in the storm-surge ebb of hurricanes. Hayes (1967) made such observations on the Texas shelf after Hurricane Audrey (1957), and Gayes (1991) observed cross-shelf beach sand transport on the South Carolina shelf after Hurricane Hugo (1989).

Closure depth has become an important part of the design of replenished beaches. Since it is viewed as a fence preventing sand loss offshore, the shallower the closure depth, the less sand will be required for the new beach. Bruun (1962) originally suggested a depth of 18–20 m off the east Florida coast. Recently, that number has shoaled to as little as 4 m as far as replenished beach design is concerned. It is doubtful if closure depth exists under *any* circumstance, and certainly a 4 m closure depth is absurdly shallow.

Despite the overwhelming geologic and oceanographic evidence that these two concepts greatly oversimplify the complexity of nearshore morphology and processes, they remain widely used in a variety of shoreline change models that are implemented in the design of coastal engineering projects. The main reason is that they provide an easy way to define the literal boundaries of any model grid, and they are easy to manipulate to provide the desired model outcome.

Shoreline Change Model Applications Using Invalid Concepts

The shoreface profile of equilibrium and the closure depth can be characterized as model simplifications or approximations, despite the fact that neither exists in nature. However, they continue to be used in the primary models utilized for applied coastal project design, including: the Bruun Rule, GENESIS (Hanson and Kraus, 1989), SBEACH (Larson and Kraus, 1989), the CERC equation (Shore Protection Manual, 1984), and a number of other beach models (Thieler et al., 2000).

The GENESIS model, used to simulate long-term shoreline changes resulting from gradients in longshore sediment transport at coastal engineering sites, was critically reviewed by Young et al. (1995). Those authors argued that the model's usefulness as a predictive tool is limited at best, due to poor assumptions and widespread use of smoothing averages, among other problems. The criticisms by Young et al. (1995) have never been responded to in any detail, and the model continues to find widespread application in the design of beach nourishment projects, groins, and other structures (e.g., Bocamazo et al., 2011).

The SBEACH model for simulating storm-induced beach changes also remains widely used, in spite of the same problems facing GENESIS with Bruun rule–founded weak assumptions. SBEACH was criticized by Thieler et al. (2000), but it remains in widespread use (e.g., Donnelly et al., 2006).

Although other predictive mathematical models of beach behavior have been formulated (see discussions by Cooper and Pilkey, 2007b, 2008), they are used much less frequently in the United States. The old "tried and true" models have strength in the consulting community because of their longevity. Interested parties challenging project design are told that a model has proven useful on dozens if not hundreds of beaches. Furthermore, these models are easy to acquire and relatively simple to run on a desktop computer, thereby allowing them to be applied by individuals with little expertise in the complexity of coastal systems.

Model Parameters and Ordering Complexity

A very large number of parameters may influence sedimentary processes in the surf zone. For example, Table 2 is a list of the factors that may control longshore sediment transport in the surf zone. Those parameters highlighted with asterisks in Table 2 are included in the CERC equation, which is used to predict the volume of longshore sediment movement on any given shoreline. However, virtually all the others are important to some degree under various circumstances. Table 2 illustrates not only the large number of parameters that may be involved in one aspect of nearshore sediment movement, but it is also an indication of the vast number of feedbacks that may be involved.

In addition to all of the complicated controls on longshore sediment movement listed in Table 2, the order in which things happen also matters. This is a phenomenon that we call ordering complexity. Because of ordering complexity, even in the unlikely event that, sometime in the future, we will recognize each of the parameters and feedbacks that go into a beach process, we can never accurately predict the future outcome of that natural process without knowing the exact timing and magnitude of the events that will drive that coastal evolution. For example, even if we understood all the processes of a storm that will impact on a given beach, we will never know when the storm will occur, where it will hit, the direction from which it will come, the order of occurrence of storm types, storm duration, tide stage, and storm intensity. This is particularly true for prediction on the scale (a few kilometers) necessary for engineering project design.

Hydrodynamic Model

It is worth noting here that a new generation of hydrodynamic models has been developed by many practitioners to address nearshore circulation, tides, and water-level fluctuations, along with many other applications related to the way in which water moves in the coastal ocean (as well as other areas). These models include the widely used ADCIRC (Luettich et al., 1992) and Delft3D developed by Deltares Systems (among others). The hydrodynamic models take a more sophisticated approach to numerical modeling in that they seek to apply the basic laws of physics to water movement. Underlying them are the set of Navier-Stokes equations that describe the basic motion of a fluid when a force is applied and resulting changes in flow. Hydro-

TABLE 2. LONGSHORE TRANSPORT PARAMETERS

Always important	Usually important	Sometimes important
Breaking wave depth*	Offshore bars	Bed liquefaction
Breaking wave height*	Groundwater pore pressure	Beach state
Wave period*	Wave current interactions	Storm surges
Angle of wave approach*	Wave setup	Tidal range
Storms	Wave energy loss, friction	Tidal currents
Shape of the shoreface*	Seaward sand transport	Offshore coastal currents
Shoreface bar feedback	Sand loss or gain from wind	Seawater infiltration
Grain size*	Sand loss, overwash	Wave types
Underlying geology	Type of coast	Wave breaking parameters*
Fluid density*	Sediment supply	Wave reflection
	Engineering structures	Infragravity waves
	Beach nourishment	Wave reformation, post-break
	Beachrock	Water temperature
	Nearshore wind currents	Sediment sorting
	Shell pavements	Beach stratigraphy
	Bed forms	Clast shape
	Bottom roughness	Sand specific gravity*
		Organic mats
		Offshore turbidity flows
		Burrowing organisms
		Rip currents
		Storm-surge ebb

dynamic models apply a continuity principle, where mass and energy are conserved.

Some of these models are also used to drive the movement of sediment in the nearshore and on the shoreface. However, they are not really designed to be shoreline change models or to model the impacts of engineering activities "on the beach." They focus on water movement, not sand movement. Occasionally, they are used to examine how an activity like removing sand from a nearshore borrow area may impact the hydrodynamics of the nearshore (e.g., changing tidal current flow through an inlet). They are also used to examine how various coastal morphologies or human-induced changes to the coast may impact storm surge, but they are not typically used to design a beach nourishment project or to examine the amount of sand a new groin may trap. Nor are they used to predict site-specific coastal erosion in response to long-term sea-level rise.

In fact, when it comes to predicting changes to the beach or shoreface over time periods useful for designing engineering projects (5–20 yr), all models suffer from the same major shortcoming: They cannot predict the weather. No matter how well a model can represent the physics of nearshore water movement, the best that one can hope for is that the model can provide a variety of possible scenarios based on what has happened in the past—using ADCIRC, for example, to recreate the storm surge from past hurricanes in an attempt to understand the nearshore controls on those water levels (Hagen et al., 2012).

The ultimate problem with utilizing a new hydrodynamic model or GENESIS to predict coastal change over the next 20 yr is that it is impossible to predict the wave climate and storm meteorology that any small stretch of coast will experience. Also, wind and waves are the necessary, fundamental drivers of all the models. Typically, "representative" wave climates are generated utilizing a variety of data sources. For project design and models like GENESIS, averages are often used, or a several-month record may be repeated multiple times as the model runs. Extreme events and periods of unusually low energy are typically unaccounted for. A conscientious modeler may use wave data from a "typical" storm, but that is the best one can do. What one can definitely *not* do is predict the actual wave climate that any particular project will experience, nor can one anticipate the actual storms that will occur. In addition, in the opinions of the authors of this paper, there is no such thing as a "typical" storm. In a return to the ordering of complexity, it is not simply what will happen, but also the order in which it happens that matters. Given these constraints, we find that, in applications of models utilizing the CERC equations and generalized models like GENESIS, it is absolutely impossible to predict with any confidence the changes that will occur along an ~5-km-long shoreline over a period of 5–20 yr. Even more troubling, it is also impossible to know *how wrong* the model prediction is.

Problem of Elastic Coefficients

One of the less visible problems in quantitative modeling is the use of calibration factors in the equations. These may be called constants, adjustments, tunings, or coefficients. Adjusting these corrections is often part of the "tweaking" process, i.e., the scheme by which models are adjusted during calibration to come up with correct answers for the nature of shoreline change over a given period utilizing historical data.

An early use of such coefficients stemmed from work on longshore transport. Komar and Inman (1970) carried out 14 four-hour, fair-weather experiments on Southern California and Gulf of California beaches during which they measured sand transport using fluorescent sand grains and also calculated sand transport using the CERC equation. Comparing the two results, the investigators concluded that the modeling results required adjustment of the original equations by a calibration coefficient (*k*). They assumed the following:

1. The fluorescent sand experiment in the swash zone gave correct sand volume transport. More recent field studies, partly summarized by Thieler et al. (2000), have shown that fluorescent sand grain studies of sand movement are of variable and generally poor accuracy in terms of long-term measurements of sand volume transport.
2. The CERC equation provides a wrong answer and must be corrected with a sediment transport coefficient *k* (0.77).
3. The corrected answer is obtained by multiplying 0.77 by the CERC equation volume figure.
4. The 0.77 (sediment transport coefficient) is applicable under all conditions, including storm conditions. No further experiments were carried out by these investigators under storm conditions, which is likely to be impossible anyway. Wright et al. (1987) argued that there are several *k* values for any ocean beach.
5. The 0.77 number is applicable to any beach in the world. For a number of years, 0.77 was used for *k* on a global scale, and it still finds wide use. More recently, values of *k* have been "adjusted" for different beaches. Bodge and Krause (1991) noted that *k* values in the literature ranged from 0.014 to 1.6, a two order of magnitude difference. Creed and Reilly (2008, p. 16) calibrated the SBEACH model on a Broward County beach and determined that *k* was "significantly lower than recommended values."

All of these major assumptions cannot be borne out. The concept that a few fair-weather experiments on California and Gulf of California beaches would provide a coefficient to be applied to beaches on a global scale clearly makes no sense, especially with the benefit of hindsight. In all likelihood, both the model and the field measurements in the original experiments are inaccurate, and a correction is meaningless (Cooper and Pilkey, 2004c).

Similar coefficients are applied in most models used to describe beach behavior. The *k* coefficient described here is used in the GENESIS and SBEACH models. Hsu et al. (2006, p. 14) noted that "models with different assumptions may yield similar predictions because each model has at least one parameter that can be tuned to compensate for neglected processes." Presumably the parameters he is referring to are coefficients or corrections in the equations.

In summary, we believe that such "corrections" are fudge factors designed to bring model results, such as longshore transport volumes, into the range of known or accepted values. Cooper and Pilkey (2004c, p. 599) concluded "that coastal scientists and engineers have been trapped in an expected universe of longshore-transport sand volumes without critical assessment of assumptions made in pioneering studies."

Myth of Calibration and Verification

Calibration-verification is standard practice for GENESIS and other models used to describe beach processes. Calibration is an attempt to predict the outcome of an event that has already happened using the model in question. This could be, for example, shoreline erosion during a time frame where aerial photographs or measured profiles provide the answer. Typically, the model does not accurately predict the shoreline change over the given period of time, so the model parameters are adjusted to reproduce the known changes as closely as possible. Iverson (2003) suggested that if calibration fails, the model should be examined for problems with assumptions, and the quality of the input data should be examined before tweaking takes place.

Once the model is calibrated, a second step, known as a verification, is carried out as a means to check the validity of the now-calibrated model. This is accomplished by attempting to predict the outcome of a second set of events such as known erosion rates or sand transport volumes during a different time frame than that used for the original calibration. If the verification comes up with the correct answer, the model is deemed to be verified. No further adjustment should occur during the verification run.

With models like GENESIS, verification runs are rarely successful. Technical reports and environmental impact statements are full of verification runs that produce "reasonable" results. Then, the model is used to predict changes along that shoreline 10 yr into the future. One major shortcoming of this process is that calibration and verification runs are often performed over time periods that are far shorter than the final predictive runs.

Frequently, a model will be calibrated and then produce a subpar verification run; yet, the model will be applied as calibrated anyway. In 2009, an administrative law judge threw out a permit for a beach nourishment project after he found that the calibration and verification of the GENESIS model had failed, but the model had been used for project design anyway. The judge (Meale, 2009, p. 124, #246) wrote:

> This verification effort was an irredeemable failure. But [the consultant] proceeded with the calibrated model as though the verification process had been successfully completed. The most likely explanation was that Palm Beach wanted to commence construction within five months of filing the Application, and there was not time to fix the model verification or find a new model and run it.

The real problem, as pointed out by Oreskes (1998), Oreskes et al. (1994), and Pilkey and Pilkey-Jarvis (2007), is that even successful calibration and verification of a deterministic model in a complex natural environment are no guarantee that the model will accurately predict future events. In fact, it is unlikely that verification could ever work. For it to work, it would require the assumption that the seasonal schedule, and the intensity, duration, and direction of storms, as well as many other parameters, would have to be essentially the same in both the calibration and verification time frames.

Ultimately, calibration and verification become an exercise where the modeler "turns the knobs" in order to produce results that, in their own professional judgment, look reasonable. The process sheds no light on the ability of the model to predict future shoreline behavior or the way in which a modification like a terminal groin will impact that future behavior.

Recent Attempts to Improve Sea-Level Rise and Shoreline Retreat Modeling

Despite the clear shortcomings of modeling beaches, they are so widely accepted that criticism is regarded as heretical. Most of our work demonstrating the failings of models has gone unanswered. It is even difficult to penetrate the editorial regime of many journals where modeling is accepted without question. For example, a paper by Ranasinghe et al. (2012) titled "Estimating coastal recession due to sea level rise: Beyond the Bruun rule" appeared in the influential journal *Climatic Change* in 2012. It took a stance similar to a paper by Cowell et al. in 2006, which sought to add a probability element to the Bruun rule. Pilkey and Cooper (2006) and Cooper and Pilkey (2007a) had engaged in a discussion and rejoinder with Cowell and his co-authors (Cowell et al., 2006; Cowell and Thom, 2006) in the *Journal of Coastal Research.* The editorial approach in that journal enabled a vigorous debate to take place that allowed both perspectives to be aired.

Cooper and Pilkey submitted a discussion on Ranasinghe et al.'s efforts to the journal *Climatic Change*, but this was summarily rejected by the editorial board as "too dogmatic." It was not sent out for review. Although most journals customarily accept discussion papers (assuming the authors have reasonable backgrounds and specialties) and let the authors of the criticized paper respond as they wish, this was not the case with the submission to *Climatic Change.* The editorial decision to reject, without any response from specialists, may reflect an unwillingness to countenance the fact that it may not be possible to forecast shoreline response to sea-level rise. However, countless geomorphologic studies demonstrate that there is no one-size-fits-all approach. It is also an example of the uncritical acceptance of mathematical modeling of earth surface processes.

The estimation of coastal recession due to anticipated sea-level rise is an issue of concern to governments from local to national scale. It has also been of concern to organizations with regional (European Union) and global (Intergovernmental Panel on Climate Change [IPCC], United Nations Environment Programme [UNEP]) remit. For many years, the Bruun rule, in various forms and derivatives, has been widely used in such assessments. We have already reviewed its use and shown that it is an outdated and inappropriate approach that has no basis in reality (Cooper and Pilkey, 2004a, 2004b; Pilkey and Cooper, 2004).

Cowell et al. (2006) presented an approach to estimating coastal recession that was based on the Bruun rule, but that introduced a statistical approach that added an uncertainty element to such predictions. We also discussed this approach (Pilkey and Cooper, 2006; Cooper and Pilkey, 2007a), making the point that predictions made using a "rule" with no basis in reality are not made more valid by adding a statistical component to the calculation.

In their paper, Ranasinghe et al. (2012) acknowledged the shortcomings of the Bruun rule, but they are apparently intrigued by the notion of adding a statistical or probabilistic component as per the approach of Cowell et al. (2006). Their approach is basically the same as that taken by Cowell et al. (2006), but it involves substituting the Bruun rule with a different model (Xbeach, SBEACH, or Larson et al.'s [2004] "Wave Impact Dune Erosion Model"). These models are regarded by Ranasinghe et al. (2012, p. 566) as "process based numerical models."

On the contrary, such models are also gross simplifications of reality, suffering from the multiplicity of shortcomings listed by Thieler et al. (2000). In their paper, Ranasinghe et al. (2012) acknowledged several shortcomings of the models they employ. They assumed that there is a linear relationship between the wave impact and the weight of sand eroded from a dune. Of course, this would be convenient if it were true, but dune erosion is affected by many additional factors, including in particular:

(1) dune state at the time of the wave impact (proximity to past storms);
(2) storm intensity;
(3) storm frequency;
(4) storm-surge ebb;
(5) tidal range;
(6) tidal elevation at time of storm;
(7) degree of saturation of the dune (see discussion in Carter and Stone, 1989);
(8) dune vegetation;
(9) dune size;
(10) grain size; and
(11) overall sand supply to the system.

The importance of these other factors was highlighted by Ruessink and Jeuken (2002, p. 1043), who, in a detailed analysis of dune recession on the Dutch coast, concluded that "dune-foot variability is controlled by temporal and spatial variability in beach characteristics, and not by storm-induced uniform erosion." Ranasinghe et al. (2012, p. 567), however, stated that the Larson et al. (2004) approach is "more representative of the physics associated with the specific process of dune erosion" than the simple avalanching described in SBEACH and Xbeach. None of these approaches comes close to reality.

Another assumption regarding the rate of dune recovery is very vaguely described based on observations and modeling at Narrabeen and the Gold Coast. To reduce the process of dune recovery after storms to a simple volumetric accumulation rate per day (0.1 $m^3/m/d$ in this case) is again a gross simplification (see, for example, Thom and Hall, 1991). Ranasinghe et al. do acknowledge this to be the weak link in the approach, and they consider the implications of up to an order of magnitude variation in this rate. There are, however, many others.

Beaches and dunes respond at time scales of decades to a century to many factors that induce shoreline changes much greater than those commonly attributed to sea-level rise. These include but are not limited to:

(1) beach rotation;
(2) genesis of megarips;

(3) tidal inlet, natural variability, and migration;
(4) sediment supply fluctuations;
(5) storm-surge ebb;
(6) climatic variability;
(7) tidal character;
(8) beach state;
(9) underlying geology;
(10) natural bathymetric change;
(11) inner-shelf wave friction;
(12) beach stabilization, seawalls, nourishment; and
(13) navigation channel maintenance and jetties.

In addition, the timing and sequencing of storms have long been known to impart an unpredictable and strongly nonlinear behavior to sandy beaches. The literature on hurricane impact and interhurricane timing offers abundant examples. Ranasinghe et al. (2012) are stretched to demonstrate the efficiency of their approach against a data set of beach change and storm occurrence. To do so, they have to invoke a different model than the one they advocate as being a more realistic representation of dune behavior. Having stated a preference for Larsen et al.'s (2004) model, the authors revert to SBEACH in order to seek an agreement between storm occurrence and dune response.

Evidently this was not convincing, and so further subsetting of the data set was involved. Even then, the authors found that even so geologically constrained a beach as Narrabeen showed marked spatial variability in behavior that may or may not be related to storm occurrence (e.g., beach rotation, rip current formation). They consequently selected for analysis only a central profile on the beach that was apparently a fulcrum of beach rotation. Only through these manipulations was an apparently convincing relationship found between the storm return period and dune recession. The same shortcoming was true of the Bruun rule, where all efforts to prove it have involved significant subsetting of data, and in this regard, too, the approach advocated by Ranasinghe et al. (2012) offers no improvement on existing modeling approaches.

On the one hand, Ranasinghe et al. (2012) advocated this approach as an appropriate method for assessing coastal recession, while on the other, they both showed and stated that many elements lack universal applicability. Since it is only with difficulty that the results can be fitted to a single data set, the applicability of this approach elsewhere is absolutely unproven and highly unlikely. Like the Bruun rule, seeking a "proof" of the concept would be a pointless exercise, because the underlying assumptions regarding coastal response to storms and sea-level rise are so grossly simplified and the natural environment is so much more complex than that envisaged in the models.

Adding statistics to a faulty model offers no improvement, as we have already discussed in relation to the approach advocated by Cowell et al. (2006) and Cowell and Thom (2006) (Pilkey and Cooper, 2006; Cooper and Pilkey, 2007a). Ranasinghe et al. (2012) acknowledged the failings of the Bruun approach and its inclusion in Cowell et al.'s (2006) approach. They, however, approved of the statistical approach and simply substituted the Bruun equation with another simple model. Substituting one faulty model for another (whether Xbeach, SBEACH, or Larson et al. [2004], etc.) does not remove the issues with seeking a one-model-fits-all solution. Ranasinghe et al. (2012) in fact demonstrated this in having to choose between different "process-based models," and even then having to subset the data to find an apparent relationship between field and modeled data.

The critical and unavoidable fact is that there is not and never will be any universal model for accurately predicting coastal response to sea-level rise at a decadal to century (i.e., management) scale. There are too many factors at play in this time scale to enable the sea-level signature to be discerned. The numerous failed efforts to "prove" the Bruun rule show this, just as much as the mathematical acrobatics employed by Ranasinghe et al. (2012). There are too many degrees of freedom in the antecedent conditions, background geological conditions (sediment supply, bedrock outcrop, etc.), and dynamics (e.g., storm frequency, interstorm period, surge elevation, wave direction, wave-current interactions) for any universal model to be developed at this scale. The approach advocated by Ranasinghe et al. (2012) has nothing to offer coastal management.

CONCLUSIONS

We believe that a fundamental reassessment of beach behavior models is required. The disconnect between reality and the mathematics of the models is extreme and has been demonstrated in a number of technical papers, some quoted herein. Yet, substantial response to these criticisms is lacking. Criticism of models is muted in part because they are said to be state-of-the-art and in part because of the politics of the shoreline.

Systematic back-checking on projects to see if the models worked is also missing. However, even in the few instances where models have been systematically tested against field data (such as the European-funded Coast-3D project), significant discrepancies between models and reality are consistently noted. This is a global problem, reflecting the fact that the mathematical modeling of beach behavior more often than not takes place in a political context related to the economics and the environmental impacts of beach engineering projects.

Once an assumption or simplification is locked into a model, it tends not to be revisited. How else does one explain acceptance of the absurd assumptions in the Bruun rule that have been the foundation of modern beach modeling and have even become accepted field principles used by field geologists. In this sense, mathematical models of beach processes have been a strong impediment to progress in understanding coastal processes. Without careful analysis of model shortcomings, it would be easy for an inexperienced coastal geologist to take these claims at face value and assume that we understand coastal processes well enough and can parameterize them accurately enough to model them.

To many geologists, the mathematical approach is intimidating. This leads to a general lack of model evaluation among the geologic community at large. The peer review of academic papers reporting the use and value of models is left largely to other modelers.

Since storms (which are often blamed for model failure) do much of the work involved in beach evolution, their characterization is critical but impossible. The unknown timing, intensity, direction, and sequencing of coastal storms alone is a fatal flaw for predicting accurate beach behavior.

A complete reappraisal of beach modeling is needed. First and foremost, we need to accept that modeling of beach behavior at time scales useful to society is simply not possible.

In his 2012 memoir, Colin Powell indicated that he gave the following instructions to his intelligence officers: "Tell me what you know. Tell me what you don't know. Then tell me what you think. Always distinguish which is which." We would put it this way in describing prediction using shoreline change models like GENESIS and the Bruun rule: "The models do not help us know anything. There is much that we do not know that is not acknowledged in the models. During calibration, modelers use the model to support what they already think they know. No one is able to distinguish which is which."

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EXHIBIT 2

TOWN OF OCEAN ISLE BEACH
ASSESSMENT OF TERMINAL GROIN FEASIBILITY

Prepared for:

Town of Ocean Isle Beach, North Carolina

Submitted by:

Coastal Planning & Engineering of North Carolina, Inc.

May 2012

TOWN OF OCEAN ISLE BEACH
ASSESSMENT OF TERMINAL GROIN FEASIBILITY

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ASSESSMENT OF TERMINAL GROIN FEASIBILITY
TOWN OF OCEAN ISLE BEACH, NC

Introduction

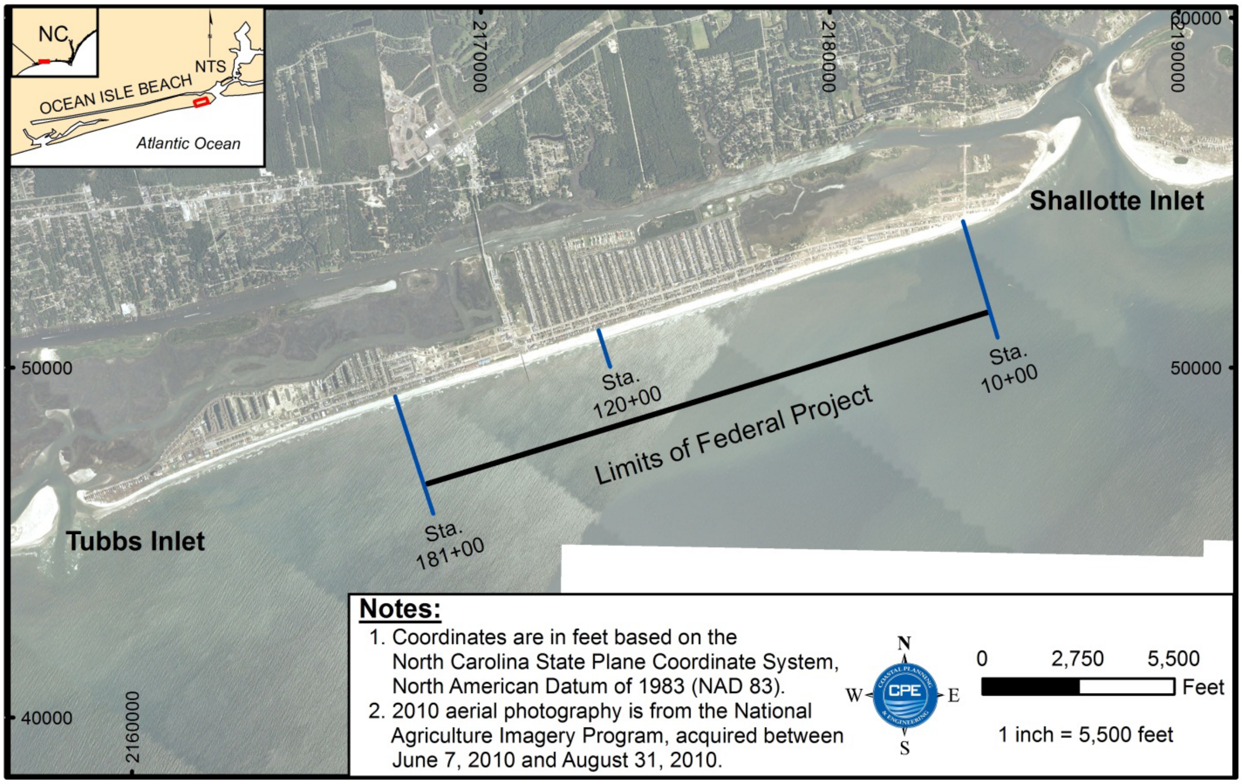
The Town of Ocean Isle Beach (TOWN) is evaluating the feasibility of constructing a terminal groin on the east end of the TOWN's shoreline near Shallotte Inlet to mitigate the chronic erosion problem caused by Shallotte Inlet's influence on the movement of littoral sediment in the area. This report provides information to the TOWN to aid their evaluation of the proposed project. This report includes:

- Information on shoreline and volumetric change rates on the east end of the island,
- An assessment of the vulnerability of existing structures and infrastructure to continued shoreline erosion,
- Conceptual designs for a terminal groin and its potential impact on the shoreline and periodic nourishment rates,
- Construction cost for the terminal groin and accompanying beach fill, and
- Time and cost estimates for obtaining the permits and clearances necessary to implement a shore protection plan involving a terminal groin.

Ocean Isle Beach is approximately 29,200 feet (5.5 miles) long and is situated between Shallotte Inlet on the east and Tubbs Inlet on the west (Figure 1). Between March and May 2001, the U.S. Army Corps of Engineers (USACE) constructed a federal beach fill project for storm damage reduction that covers 17,100 feet (3.25 miles) of the TOWN's shoreline beginning at Shallotte Boulevard (Station 10+00 on the USACE baseline) on the east and extending to a point approximately 3,700 feet west of the Ocean Isle Beach Pier & Arcade (USACE baseline Station 181+00). The westernmost 9,500 feet of the TOWN's shoreline was not included in the federal project as this area is rather stable and is fronted by an established dune system. The eastern end of Ocean Isle Beach between Shallotte Boulevard and Shallotte Inlet was not included in the federal project because the predicted high rates of loss that would occur from a beach fill placed in this area. Based on the USACE economic evaluation, the cost of protecting the extreme east end of the island exceeded the value of the development and infrastructure it would protect and was therefore excluded from the federal project.

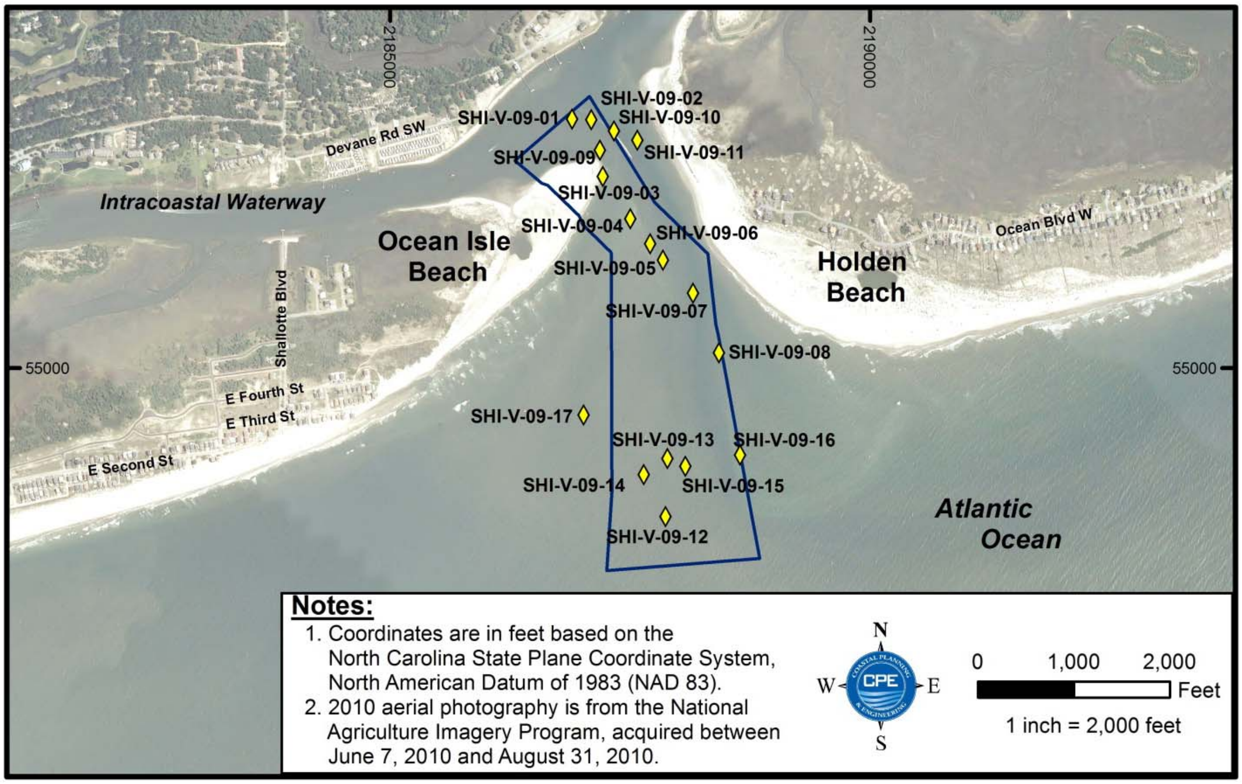
Initial construction of the federal project involved the placement of 1,866,000 cubic yards of material obtained from a borrow area located in Shallotte Inlet (Figure 2). The Shallotte Inlet borrow area was also designated as a source for future periodic beach nourishment, which was scheduled to occur every three (3) years. Based on USACE estimates, 300,000 cubic yards (100,000 cubic yards/year) would be needed every 3 years to maintain the federal project.

The Ocean Isle Beach project has been nourished twice since initial construction. The first periodic nourishment operation was accomplished between December 2006 and January 2007 and involved both a federal and a non-federal component. The federal component, which was completed in December 2006, placed 449,400 cubic yards of material between Stations 10+00 and 72+00, while the non-federal component placed 155,000 cubic yards between Stations -3+00 and 17+00. The non-federal component represented an attempt by the TOWN to address the extreme erosion problem east of Shallotte Boulevard. The second periodic nourishment operation occurred between April and May 2010 and involved the placement of 509,200 cubic yards of material between Stations 10+00 and 120+00. The western 6,000 feet of the federal project continues to perform very well and has not required periodic nourishment since construction in 2001.



Notes:
1. Coordinates are in feet based on the North Carolina State Plane Coordinate System, North American Datum of 1983 (NAD 83).
2. 2010 aerial photography is from the National Agriculture Imagery Program, acquired between June 7, 2010 and August 31, 2010.

Figure 1. Map of Ocean Isle Beach showing the limits of the federal project.



Notes:

1. Coordinates are in feet based on the North Carolina State Plane Coordinate System, North American Datum of 1983 (NAD 83).
2. 2010 aerial photography is from the National Agriculture Imagery Program, acquired between June 7, 2010 and August 31, 2010.

Figure 2. Map of the borrow area at Shallotte Inlet. Note locations of vibracores taken by USACE in 2009.

Over the 9 years since initial construction (2001 to 2010) and excluding the 2007 non-federal effort on the east end, a total of 958,600 cubic yards of periodic nourishment has been placed within the limits of the federal project generally between Stations 10+00 and 120+00. Most of the non-federal effort in January 2007 placed material outside the federally authorized limits of the project. However, assuming the material was equally distributed and allowing for a transition section on the west end, an estimated 30,000 cubic yards was probably placed within the project between Stations 10+00 and 17+00. Thus, including the non-federal nourishment, a total of 988,600 cubic yards of material has been placed within the federally authorized limits of the Ocean Isle Beach project since its initial construction in 2001. This represents an average annual nourishment rate of approximately 110,000 cubic yards/year. The actual nourishment rate is very close to the USACE estimated nourishment requirement of 100,000 cubic yards/year. However, based on an evaluation of USACE survey data discussed below, erosion along the eastern 2,000 feet of the project between Stations 10+00 and 30+00 progressed into the design template prior to each nourishment event. The erosion into the design template indicates the volume of material provided by the nourishment operations has not been sufficient to maintain the full protective value of the project in this area.

In addition to the federal shore protection project, the USACE has periodically deposited material on the east end of Ocean Isle Beach from maintenance of the Atlantic Intracoastal Waterway (AIWW) at the intersection of the AIWW with Shallotte Inlet. Although no definitive total volume has been provided by the USACE at the time of publishing, an estimated 300,000 to 400,000 cubic yards of navigation maintenance material has been placed on the extreme east end of Ocean Isle Beach since 2001. All of this material has been deposited generally within the area fronting the development east of Shallotte Boulevard (i.e., outside the limits of the federal project). The material removed from the AIWW erodes quickly and has been generally ineffective in slowing the rate of erosion in the area east of Shallotte Boulevard.

Recent Erosion Impacts

Even with the rather substantial beach nourishment effort by the USACE and the TOWN, erosion along the east end of Ocean Isle Beach has continued to affect existing structures and infrastructure. Not only has the beach nourishment effort failed to provide adequate and dependable protection against the chronic erosion and the damage caused by coastal storms, the TOWN and affected property owners have undertaken a concerted effort to lessen the erosion impact by installing sandbag revetments along approximately 1,400 feet of shoreline beginning at a point west of Shallotte Boulevard and extending to the east end of the development. Most of the sandbags were initially installed around 2005 and have been periodically repaired and replaced as the bag revetments fail under the continued landward retreat of the shoreline.

Despite the completion of the initial construction of the federal project in 2001 and the installation of temporary sandbag revetments, the TOWN, the State, and private owners have been directly impacted by erosion at the east end of the TOWN. Damages include the following:

a. Five (5) homes have been lost on the east end of Ocean Isle Beach since 2005, four (4) east of Shallotte Boulevard and one (1) just west of Shallotte Boulevard.
b. Portions of the TOWN’s infrastructure were damaged including approximately 560 feet of E 2nd St. and the associated storm sewers, waterlines, and other utilities. The loss of this section of E 2nd St. occurred after sandbags were installed along the entire threatened section of the road.
c. The North Carolina Department of Transportation (NCDOT) has incurred costs including the installation of sandbags, repaving sections of damaged roads, clean-up of damaged section of roads, and the loss of the east ends of 1st and 2nd Streets.

According to data provided by the TOWN, Ocean Isle Beach has spent about $3.7 million responding to erosion on the east end of the Island since 2005. State costs are approximately $1 million. These efforts include the installation of sandbags, dune construction, replacement of public accesses, relocation of water and sewer lines, and beach fill.

Shoreline Changes

Shoreline changes along Ocean Isle Beach were evaluated using LiDAR (Light Detection and Ranging) data collected by USACE JALBTCX (Joint Airborne LiDAR Bathymetry Technical Center of Expertise), USGS (U.S. Geological Survey), NASA (National Aeronautics and Space

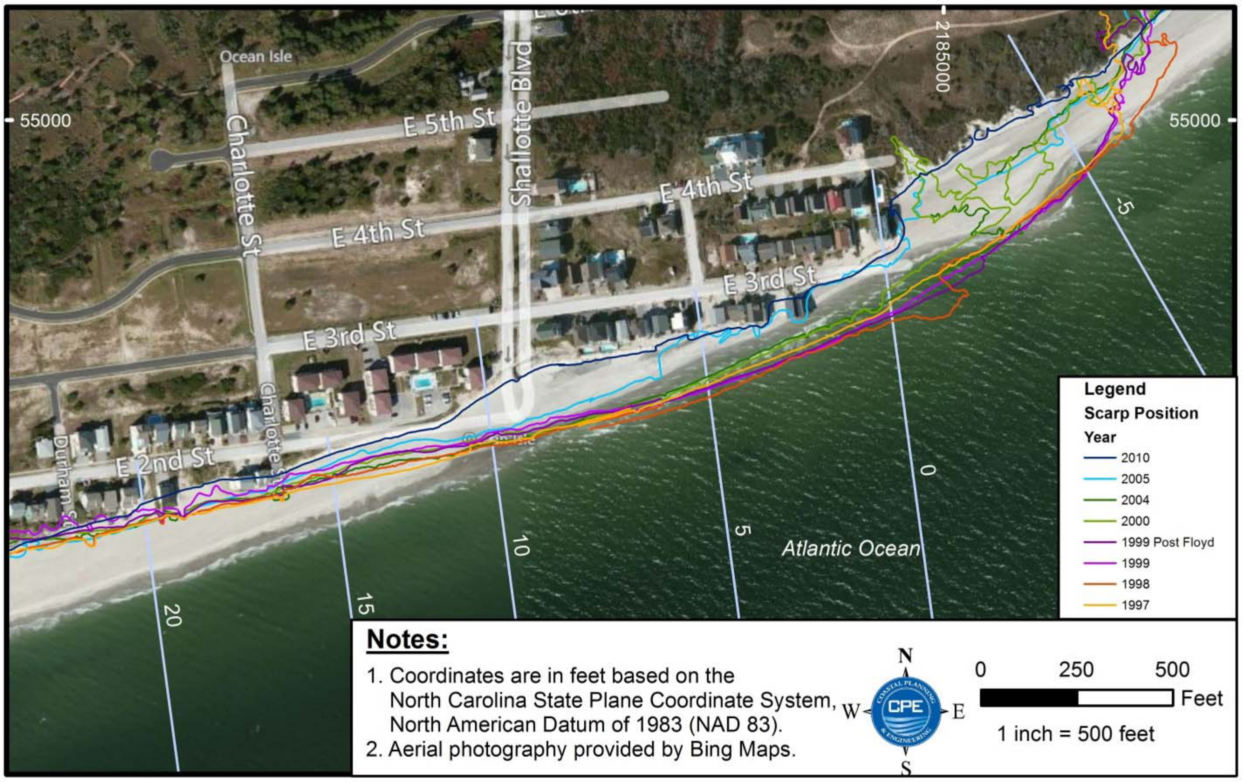
Administration), and NOAA (National Oceanographic and Atmospheric Administration). Raw XYZ data were provided to CPE from USACE JALBTCX and NOAA CSC's (Coastal Services Center) Digital Coast online data management portal. LiDAR is an optical remote sensing technology that can measure the elevation of the ground or seafloor at relatively high spatial resolutions. For areas surrounding Ocean Isle Beach, LiDAR data are better suited for surveying areas above water since the ability of the laser to penetrate through water is compromised by the clarity of the water.

Eight (8) sets of LiDAR data were available for Ocean Isle Beach with five (5) sets obtained between 1997 and 2000 which was prior to the initial construction of the federal project. The remaining three (3) sets were obtained after construction in 2004, 2005, and 2010.

Traditional shoreline change analyses are aimed at tracking the movement of the mean high water (MHW) line. For this study, the MHW line was represented as the 1.788 foot NAVD88 contour based on the 1983 to 2001 tidal epoch collected at Yaupon (Oak Island) Pier by NOAA. However, for the east end of Ocean Isle Beach, changes in the position of the MHW line do not adequately define the erosion problem. This is due to the federal beach nourishment program initiated in 2001, additional beach fill events that utilized the placement of navigation maintenance material along the extreme east end of the beach, and the installation of temporary sandbag revetments. As a result of these activities, the mean high water shoreline west of Station 10+00 appears to be accreting while the recent erosion impacts discussed above indicate this is not the case. Therefore, changes in the position of the erosion scarp line, represented to the west of Station 10+00 as the 8 foot contour and to the east of Station 10+00 as the 6 foot contour, was selected as a better indicator of the erosion threat. The higher elevation of the erosion scarp to the west captures the dune vegetation line while the lower elevation to the east captures the scarp line and sandbag revetment positions. Once the erosion scarp moves past the front of a building, that building is situated on the active beach foreshore and is subject to wave and tide action every day. During storm events when the water level is elevated and wave action more severe, these exposed structures stand little chance of survival even if they are fronted by sandbag revetments.

The positions of the erosion scarp line on the east end of Ocean Isle Beach in 1999, 2000, 2004, 2005, and 2010 obtained from the analysis of the LiDAR data are shown in Figure 3. Note that the 2005 scarp line essentially follows the alignment of the sandbag revetment existing at that time (Figure 3). This revetment held the erosion scarp line in place for several years until the temporary structure failed. Figure 3 also shows that the scarp position was relatively stable from about 200 feet west of Station 10+00 to about 100 feet west of Station 5+00 between 1999 and 2005. At some time between 2005 and 2010 the sandbags failed and the vegetation/scarp line migrated rapidly landward, essentially occupying the position it would have assumed had the sandbags not been present. Such behavior is typical of sandbag failures. At the present time, 15 homes are situated seaward of the vegetation/scarp line. These homes are vulnerable to further erosion and could be lost during the next moderate coastal storm.

While the TOWN and residents will likely continue to use sandbags in the future to slow the rate of advance of the vegetation/scarp line, the vegetation/scarp line will continue to move inland in much the same manner as it has in the past, i.e., the sandbags may delay shoreline retreat but will not prevent it.



Notes:

1. Coordinates are in feet based on the North Carolina State Plane Coordinate System, North American Datum of 1983 (NAD 83).
2. Aerial photography provided by Bing Maps.

Figure 3. Position of the erosion scarp line obtained from LiDAR data between 1999 and 2010. The station numbers are in 100's feet and correspond to USACE stations, with the addition of Station -5.

The computed annual rates of movement of the scarp line between 1999 and 2010 at Station -5 to Station 20+00 are presented in Table 1. The rates were calculated by applying a linear regression to the scarp positions and their respective dates. West of Station 20+00, the LiDAR data indicates the scarp line actually moved seaward in response to the beach nourishment program. While the movement of the scarp line east of Station 20+00 was not steady between 1999 and 2010 due to the installation of sandbags and some impact of the periodic placement of beach fill in the area, the impacts of these measures on the long-term movement of the scarp line was minimal as the temporary halt in the landward movement of the scarp line was offset by the rapid adjustment in the scarp line position once the sandbags failed. Therefore, the annual rate of movement of the scarp line between 1999 and 2010 as presented in Table 1 can be used to estimate future positions of the erosion scarp line under existing conditions.

Table 1. Annual rates of change of the erosion scarp line on the east end of Ocean Isle Beach between 1999 and 2010.

Station No. on Figure 3	USACE baseline Station (feet)	Annual Change in Scarp Line (ft/yr)
-5	-5+00	-17.1
0	0+00	-13.6
5	5+00	-14.0
10	10+00	-7.8
15	15+00	-4.1
20	20+00	-1.1

The annual rates of change of the scarp line at each station given in Table 1 were used to project the future position of the scarp line in 2015, 2020, 2025, and 2030. These possible future scarp positions, which are shown in Figure 4, were used to determine potential damages to ocean front development and the TOWN's infrastructure.

Notes:
1. Coordinates are in feet based on the North Carolina State Plane Coordinate System, North American Datum of 1983 (NAD 83).
2. Aerial photography provided by Bing Maps.

Figure 4. Predicted scarp positions on east end of Ocean Isle Beach in 2015, 2020, 2025, and 2030 based on erosion rates at each station.

Assessment of Erosion Impacts

The 2011 assessed tax value of the development on the east end of Ocean Isle Beach was obtained from the Brunswick County GIS. The future positions of the erosion scarp line shown in Figure 4, were superimposed over the development to determine the potential economic damages likely to occur over the next 20 years if the erosion rates on the east end continue. In this regard, the analysis assumes that the TOWN and affected property owners will continue to install temporary sandbag revetments once structures and roads become imminently threatened. Similarly, the sandbags were assumed to only delay the ultimate demise of the threatened structures and infrastructure. Once the sandbags fail, the erosion scarp line would continue to advance landward and eventually assume the positions shown in Figure 4. In addition to the loss of structures and land, water lines, fire hydrants, sewer lines, manholes, pumping stations, electrical lines, and telephone lines would also incur significant damages and losses.

Table 2 summarizes the potential future damages on the east end of Ocean Isle Beach if the situation remains unchanged. The damages to parcels and buildings provided in Table 2 is only for the tax value of the property and does not include other cost such as moving a threatened structure to another lot or the demolition of a threatened structure if it could not be moved for economic or other reasons. Moving a structure to another lot on Ocean Isle Beach could cost between $60,000 and $80,000 depending on the size of the structure. This does not include the cost of purchasing a new lot. Demolition of the structure could range from $25,000 to $35,000, again depending on the size of the structure.

Table 2. Economic Impact to Ocean Isle Beach under Existing Conditions (2011 dollars)

Item	Time Periods				Cumulative 2010 to 2030
	2010 to 2015	2015 to 2020	2020 to 2025	2025 to 2030	
# Parcels affected	41	37	37	35	150
Acers lost	1.35	1.42	1.40	1.34	5.5
Value lost parcels	$885,000	$1,644,000	$2,099,000	$1,998,000	$6,626,000
# Buildings lost(1)	20	9	6	8	43
Value lost buildings	$1,923,000	$1,097,000	$622,000	$796,000	$4,438,000
Total Land & buildings	**$2,808,000**	**$2,741,000**	**$2,721,000**	**$2,794,000**	**$11,064,000**
Length roads lost (ft)	380	200	360	470	1,410
Value lost roads	$95,000	$50,000	$90,000	$118,000	$353,000
Utilities lost					
Sewer	$38,000	$20,000	$36,000	$47,000	$141,000
Water	$7,600	$4,000	$7,200	$9,400	$28,200
Pump Station	$0	$200,000	$0	$0	$200,000
Electric & Telephone	$38,000	$20,000	$36,000	$47,000	$141,000
Total Utilities & Roads	**$178,600**	**$294,000**	**$169,200**	**$221,400**	**$863,200**
Temporary sandbags	$190,000	$100,000	$180,000	$235,000	$705,000
Total Damages	**$3,176,600**	**$3,135,000**	**$3,070,000**	**$3,250,400**	**$12,632,200**

(1) Building assumed lost once scarp line intercepts the structure's footprint.

Ocean Isle Beach Volume Changes

The USACE has obtained 14 sets of beach profile data since 2001 with coverage varying from those areas where fill was placed during initial construction or subsequent renourishment events to nearly the entire length of Ocean Isle Beach. The profile survey data was used to compute volume changes along the eastern half of the Ocean Isle Beach shoreline out to a depth of -18 feet NAVD for two post-nourishment periods, namely; December 2001 to March 2006 following initial construction and April 2007 to April 2010 after the first renourishment. The April 2010 survey ended at baseline Station 120+00, therefore, volume change computations for both periods ended at Station 120+00. Also, the April 2010 survey did not include the area east of Station 10+00. However, an April 2009 survey did include this area and volume change rates measured between April 2007 and April 2009 for the area east of Station 10+00 were assumed to be applicable to the April 2007 to April 2010 time period.

A graph of the computed volume change for the December 2001 to March 2006 time period, expressed in cubic yards/lineal foot of beach/year (cy/lf/yr) is shown in Figure 5 while a similar graph for the April 2007 to April 2010 time period is provided in Figure 6. The average annual rate of volume changes within 1,000-foot shoreline segments for both time periods are provided in Table 3.

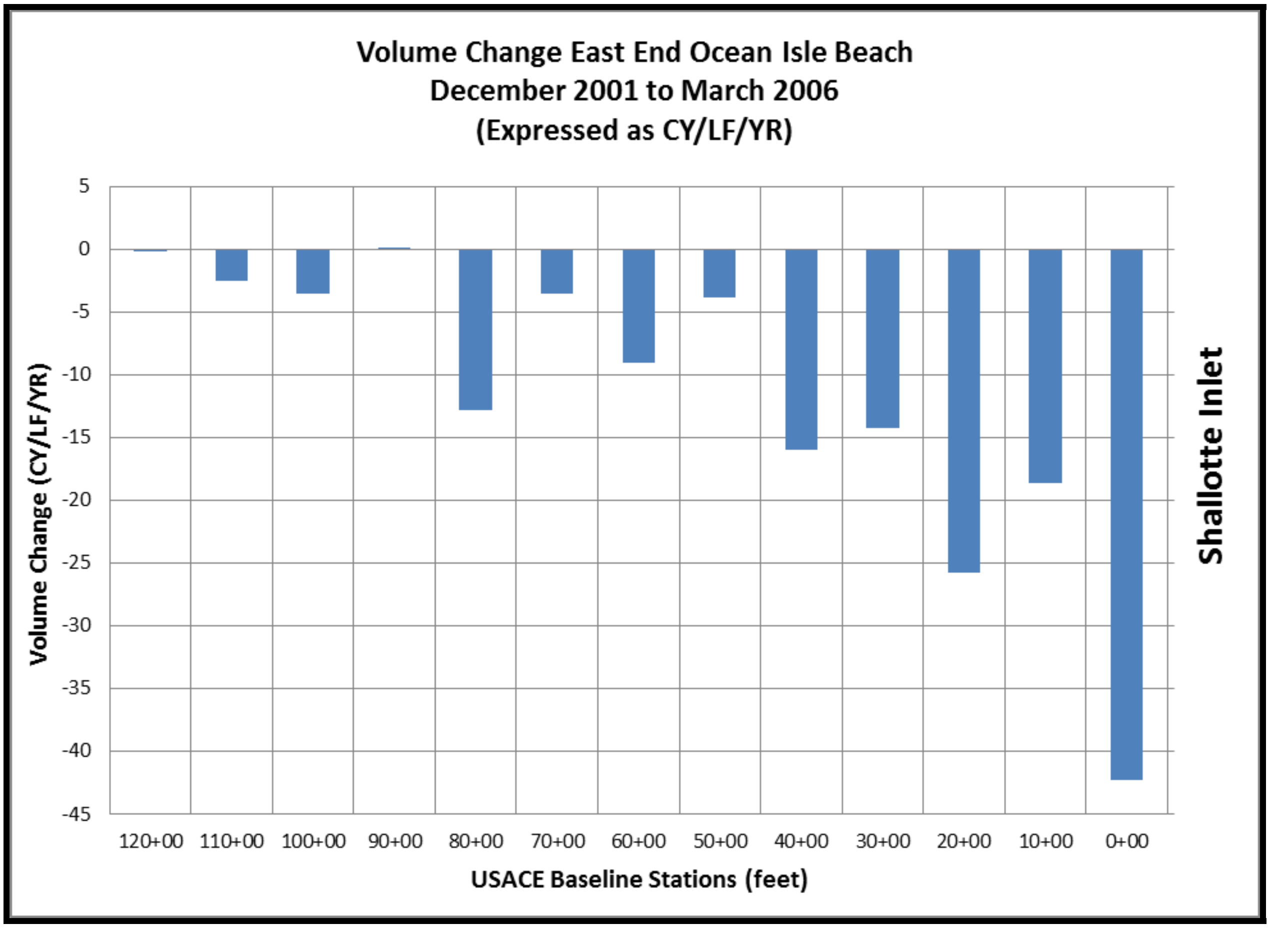


Figure 5. Ocean Isle Beach volume changes December 2001 to March 2006 out to -18 feet NAVD.

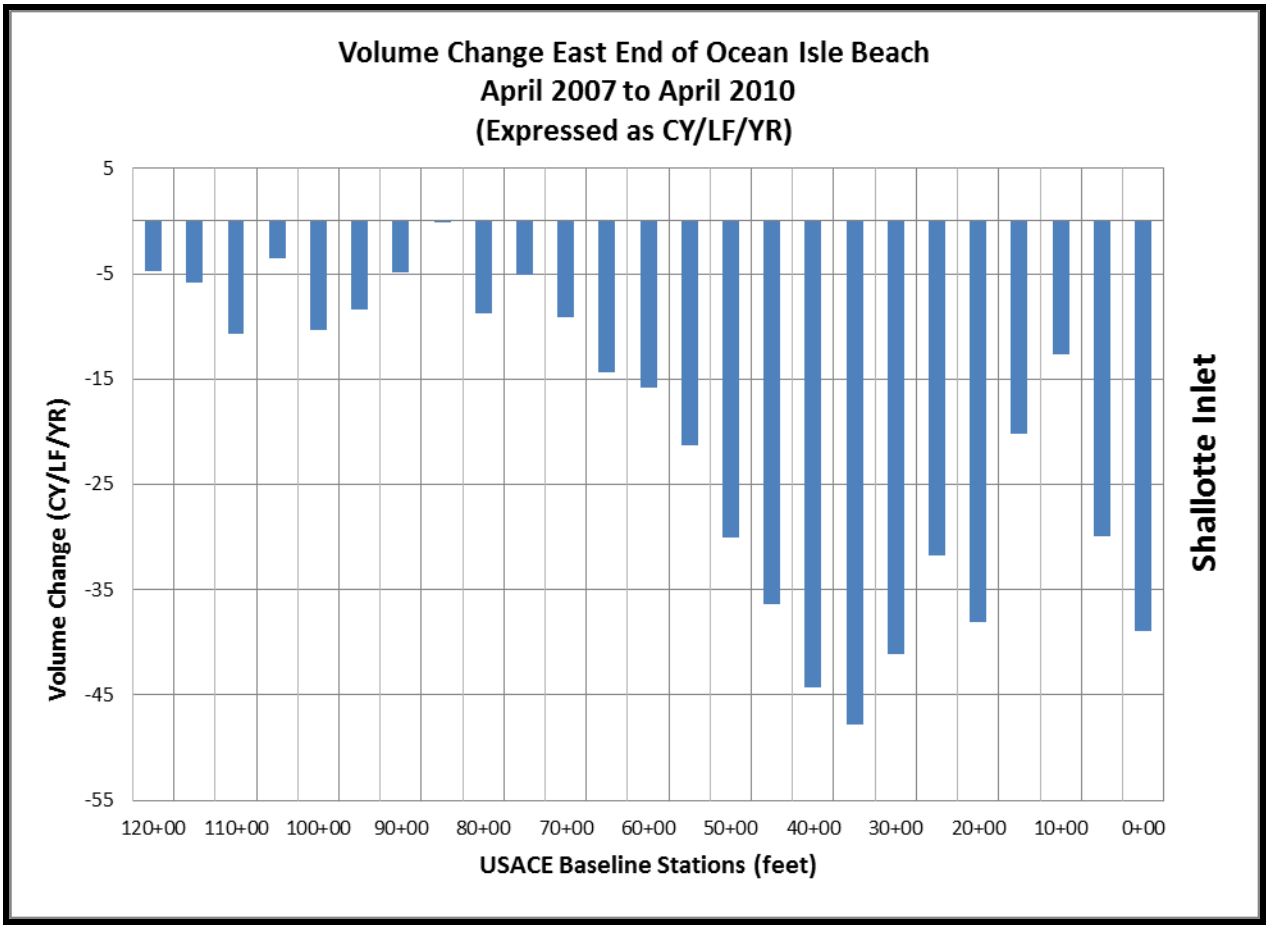


Figure 6. Ocean Isle Beach volume changes April 2007 to April 2010 out to -18 feet NAVD.

Table 3. Volume changes along the east end of Ocean Isle Beach – December 2001 to March 2006 and April 2007 to April 2010.

From Station to Station	Volume Change (cy/yr)	
	Dec 2001 to Mar 2006	Apr 2007 to Apr 2010
0+00 to 10+00(1)	-30,000	-29,000
10+00 to 20+00	-22,000	-19,000
20+00 to 30+00	-20,000	-40,000
30+00 to 40+00	-15,000	-42,000
40+00 to 50+00	-10,000	-38,000
50+00 to 60+00	-6,000	-21,000
60+00 to 70+00	-6,000	-15,000
70+00 to 80+00	-8,000	-7,000
80+00 to 90+00	-6,000	-3,000
90+00 to 100+00	-2,000	-8,000
100+00 to 110+00	-3,000	-7,000
110+00 to 120+00	-1,000	-3,000
Total 0+00 to 120+00	-129,000	-236,000

(1) The shoreline from station 0+00 to 10+00 lies outside the limits of the authorized federal project.

The volume changes shown on Figures 5 and 6 and tabulated in Table 3 indicate high rates of volume loss from the east end of the beach (Station 0+00) to around baseline Station 50+00, which is located near Raleigh Street. Volume losses gradually decrease west of Station 50+00.

The general increase in volume loss from the island in a west to east direction is an indication of the influence Shallotte Inlet and its associated ebb shoal has on the stability of the beach. At the present time, the main bar channel passing through the ebb tide delta of Shallotte Inlet is positioned closer to the west end of Holden Beach than the east end of Ocean Isle Beach. As a result, the west side of the inlet's ebb tide delta is also positioned farther to the east exposing the east end of the beach to higher wave energy and higher rates of sediment transport. Also, waves approaching the area from the southeast interact with the ebb tide delta and refract around the delta in such a way as to strike the shoreline at an angle that produces eastward sediment transport. Since waves approaching from the southwest also drive material to the east, sediment transport along the extreme east end of Ocean Isle Beach moves to the east the vast majority of the time. Finally, flood tide channels running parallel and close to the east end of Ocean Isle Beach accelerates sediment transport into the inlet. The combination of higher wave energy, wave refraction around the ebb tide delta of Shallotte Inlet, and eastward flowing tidal currents running parallel and close to the east end of Ocean Isle Beach increase the rate of sediment transport off the east end of Ocean Isle Beach and into Shallotte Inlet.

For the area located within the limits of the federal project (Stations 10+00 to 120+00) volume losses from the initial beach fill totaled 421,000 cy or 99,000 cy/yr while losses from the first renourishment, completed in January 2006, totaled 621,000 cy or 207,000 cy/yr. The difference in the rate of sediment loss for the two post-nourishment periods may be due in part to the longer time period between survey dates for the initial fill as the rate of volume loss from beach fills tends to moderate over time. However, since the volume loss rate after the first renourishment was double that following initial construction, some of the added loss may have been due to the first nourishment operation only extending to Station 72+00. While analysis of why the first renourishment experienced a greater rate of loss is beyond the scope of the present investigation, the concentration of the fill over the shorter shoreline reach would have produced a wider bulge in the shoreline which would have been conducive to increase spreading losses, i.e., material moving laterally out of the placement area and into the adjacent shorelines. In any event, the primary purpose for considering a terminal groin for the east end of Ocean Isle Beach is to reduce the rate of sediment lost from the area covered by the federal project as well as address the shoreline erosion threat east of Shallotte Boulevard.

Over the course of the two periodic nourishment cycles, the combined volume loss from within the limits of the federal project totals 1,042,000 cubic yards which is equivalent to an annual loss of 144,000 cy/yr. The total measured volume loss is greater than the amount of material placed on the beach during the first two nourishment cycles with essentially all of the excessive volume loss occurring east of baseline Station 35+00. This excess volume loss has compromised the protection provided by the federal project in this area as erosion has progressed into the design template. Under existing conditions, the rate of periodic nourishment should be increased from the past average of 110,000 cy/yr to at least 144,000 cy/yr. However, simply placing more material along the east end would probably not be effective in preventing erosion into the design template due to the inlet related sediment transport process discussed above and demonstrated by the rapid loss of material placed on the east end by the TOWN in 2007.

Preliminary Sediment Budgets – Existing Conditions

Given the volume changes computed for the two post-nourishment conditions, two preliminary sediment budgets were developed to relate how sediment movement varies along the island from Station 120+00 on the west and Station 0+00 on the east. In addition to the volume changes along Ocean Isle Beach, the development of the preliminary sediment budgets require some estimates of the rate of sediment accumulation in Shallotte Inlet, the rate of littoral sediment transport along the island, and volume change estimates for the west end of Holden Beach.

For purposes of constructing the sediment budgets, volume changes along Ocean Isle Beach were computed for each 3,000-foot beach segment between Stations 0+00 and 120+00 with these volume changes provided in Table 4.

Table 4. Average annual volume change in 3,000-foot segments along the east end of Ocean Isle Beach out to a depth of -18 feet NAVD for December 2001 to March 2006 and April 2006 to April 2010.

Beach Segment	Dec 2001-Mar 2006 Average Annual Volume Change (cy/yr)	Apr 2006-Apr 2010 Average Annual Volume Change (cy/yr)
0+00 to 30+00	-72,000	-88,000
30+00 to 60+00	-31,000	-101,000
60+00 to 90+00	-20,000	-25,000
90+00 to 120+00	-6,000	-22,000
Total 0+00 to 120+00	-129,000	-236,000

Shallotte Inlet and Holden Beach Volume Changes. The USACE Wilmington District contracted with Offshore and Coastal Technologies (OCT) of Chads Ford, PA to compile shoreline and inlet volume change data for all of the Brunswick County beaches as part of its on-going reevaluation of federal storm damage reduction projects authorized for Brunswick County (USACE, May 2008). OCT reported an accumulation of about 250,000 cy/yr in the Shallotte Inlet sediment trap for the time period from May 2001 (post-dredging) to May 2004. A September 2010 USACE reassessment of the rate of sediment entrapment in the Shallotte Inlet borrow area determined an average shoaling rate of 16,450 cubic yards/month or 197,400 cy/yr for the two post-dredging periods. Since the inlet complex includes the intersection of the inlet channel with the AIWW, which also experiences shoaling, the 250,000 cy/yr shoaling rate reported by OCT was still used for the development of the preliminary sediment budgets. OTC also estimated that the west end of Holden Beach was losing 100,000 cy/yr. The rate of sediment accumulation in Shallotte Inlet and the rate of volume loss on the west end of Holden Beach were adopted for use in the development of the preliminary sediment budgets for existing conditions.

Longshore Sediment Transport Rates. The OCT report also provided estimates of the rates of sediment movement along the shoreline of Ocean Isle which were derived from earlier sediment transport studies conducted by the USACE Coastal Hydraulics Lab (CHL). Based on this report, sediment transport to the west near the middle of Ocean Isle (approximately Station 120+00) is about 305,000 cy/yr while transport to the east is 279,000 cy/yr. These sediment transport rates were used as a starting point in constructing sediment transport rates applicable to other sections of Ocean Isle east of Station 120+00.

The observed volume changes along Ocean Isle Beach as presented above suggest most of the material lost from the east end of the island is not being transported to the west as the beach between baseline Stations 90+00 and 120+00 as well as the shoreline to the west of these stations did not experience any significant accumulations. Given this observed behavior, an assumption was made that most of the sediment loss from the east end of Ocean Isle was due to accelerated sediment transport rates to the east as one moves from the middle of the island toward Shallotte Inlet. Based on this assumption, the sediment transport rate to the west at Station 0+00 was derived from the transport rates provided in the OTC report which was estimated to be 286,000 cy/yr. The westerly sediment transport rate was assumed to vary linearly from Station 0+00 to Station 120+00 and the implied westerly sediment transport rate at Stations 30+00, 60+00, and 90+00 determined through linear interpolation. The resulting westerly transport rates are:

Station 0+00	286,000 cy/yr (OTC report)
Station 30+00	291,000 cy/yr (interpreted)
Station 60+00	296,000 cy/yr (interpreted)
Station 90+00	300,000 cy/yr (interpreted)
Station 120+00	305,000 cy/yr (OTC report)

For the extreme west end of Holden Beach, the OCT report provided westerly sediment transport rate of 326,000 cy/yr which was also adopted for use in the development of the preliminary sediment budgets. The easterly transport rate on the west end of Holden Beach was derived in the same manner as used for Ocean Isle Beach.

Two preliminary sediment budgets for existing conditions are presented below, one for the first post-nourishment period from December 2001 to March 2006 and the second post-nourishment period from April 2007 to April 2010.

<u>Preliminary Sediment Budgets – Existing Conditions</u>: A schematic of the sediment budget for the December 2001 to March 2006 time period is provided in Figure 7. In this figure, the 3,000-foot beach segments on Ocean Isle Beach are represented by the boxes with sediment transport rates between each beach segments indicated by the arrows between each box. As previously mentioned, the sediment transport rates to the west were interpreted from the information in the OTC report while the sediment transport rates to the east between each segment were computed to produce the measured volume change within each 3,000-foot shoreline segment. For example, the segment between Stations 120+00 and 90+00 had an observed volume change between December 2001 and March of 2006 of -6,000 cy/yr. Based on this observed volume change and given the previously determined westward transport rate between the segments and the eastward sediment transport rate at Station 120+00 (279,000 cy/yr), the eastward sediment transport rate at Station 90+00 would have to be 280,000 cy/yr in order to produce a volume change of -6,000 cy/yr between Stations 120+00 and 90+00. Once the easterly transport rate was determined for

Station 90+00, the required easterly transport rate at Station 60+00 needed to produce a volume change of -20,000 cy/yr between Stations 90+00 and 60+00 was computed. This resulted in an easterly sediment transport rate of 296,000 cy/yr at Station 60+00. This procedure was repeated down the shoreline resulting in the easterly sediment transport rates shown in Figure 7.

A similar computational procedure was used to construct a sediment budget for the April 2007 to April 2010 time period with the results shown in Figure 8.

The sediment budget derived by using the December 2001 to March 2006 volume changes along Ocean Isle Beach indicated a sediment transport nodal point, i.e., the point where predominant sediment transport switches from west to east, existed in proximity to baseline Station 30+00. The sediment budget using the April 2006 to April 2010 volume changes shifted the apparent nodal point to a location west of Station 60+00. Again, the shape of the beach fill placed during the first renourishment probably contributed to this westward shift in the location of the nodal point due to eastward spreading of the fill material. Sediment transport to the east off of the east end of Ocean Isle Beach and into Shallotte Inlet was 389,000 cy/yr for the December 2001-March 2006 time period and 496,000 cy/yr for the April 2007-April 2010 time period. Both of these easterly transport rates into Shallotte Inlet are considerably greater than the eastward transport rate along the middle of the island supporting the conclusion Shallotte Inlet is the primary cause of the high rates of volume loss on the east end of Ocean Isle Beach.

These two preliminary sediment budgets were used to assess the potential impacts a terminal groin on the east end of Ocean Isle Beach could have on volume losses along the east end of the island. If the TOWN proceeds with the design, permitting and construction of a terminal groin, the information used to develop the sediment budgets, particularly the littoral sediment transport rates and volume changes on the west end of Holden Beach and in Shallotte Inlet, will be updated through a more rigorous analyses that would include detailed numerical modeling of the inlet and sediment transport rates along the islands. For this assessment, however, the existing information is deemed adequate to derive “an order of magnitude” of the potential impacts of a terminal groin on shoreline behavior and volume changes.

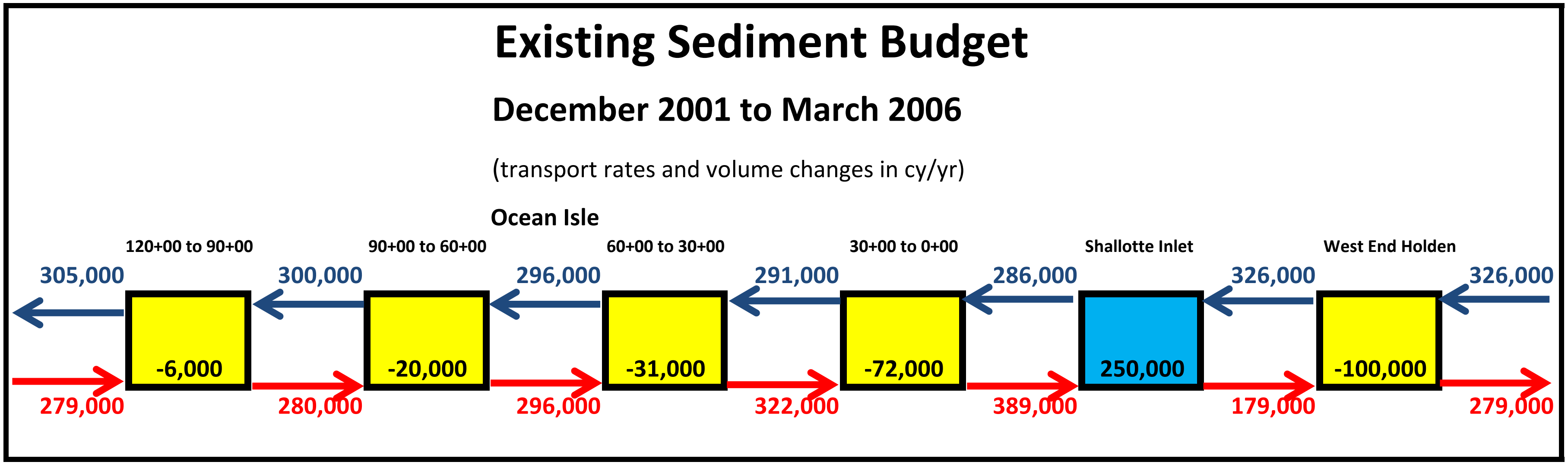


Figure 7. Preliminary sediment budget for December 2001 to March 2006.

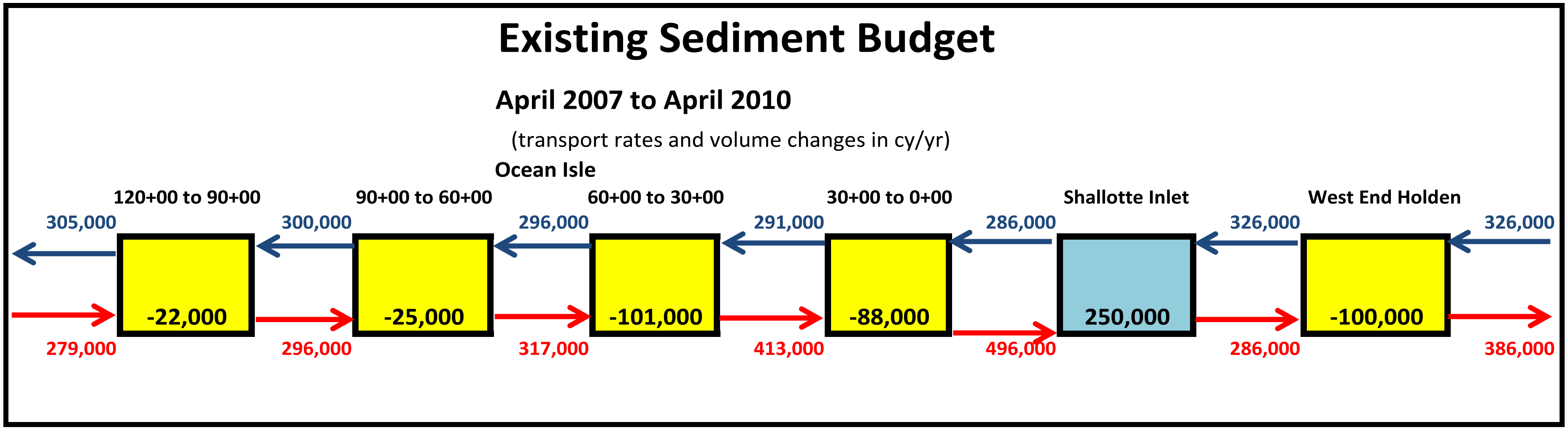


Figure 8. Preliminary sediment budget for April 2007 to April 2010.

Terminal Groin Conceptual Designs

The evaluation of the shoreline and volume changes along Ocean Isle Beach presented above indicates that the impacts of Shallotte Inlet is the primary cause of the high rates of erosion east of Raleigh St. (Station 50+00). One of the features of the island associated with the inlet impacts is the abrupt change in shoreline orientation on the east end that begins just west of Shallotte Boulevard as demonstrated in Figure 9. This abrupt change in shoreline orientation, which is approximately 12 degrees, is a manifestation of the accelerated rate of sediment transport to the east, which, as discussed above, is caused by the combination of higher levels of wave energy striking the shore just west of Shallotte Inlet, flood tidal currents concentrated close to shore, and wave refraction patterns around the ebb tide delta.

The orientation of the shoreline on the east end is also somewhat self-perpetuating since alongshore sediment transport is a function of the angle waves break with the shoreline, more specifically, sediment transport is a function of $\sin(2\alpha_b)$ in which α_b is the angle a breaking wave makes with the shoreline. Therefore, on the east end of Ocean Isle Beach, with the 12 degree difference in shoreline orientation, with everything else being equal, sediment transport on the east end of the island could be accelerated by a factor or 2 to 3 simply due to the orientation of the shoreline compared to the shoreline orientation along the middle of the island.

Notes:
1. Coordinates are in feet based on the North Carolina State Plane Coordinate System, North American Datum of 1983 (NAD 83).
2. Aerial photography provided by Bing Maps.

Figure 9. East end of Ocean Isle Beach showing change in shoreline orientation.

Given the failure of past efforts to address the erosion problem on the east end of the island with beach nourishment and temporary sandbag revetments, an effective way to slow the rate of erosion is to eliminate or reduce the influence of Shallotte Inlet on sediment transport in this area. Constructing a terminal groin on the east end of the island would accomplish this by reducing the influence of flood tidal currents on sediment transport near the shore. A terminal groin would also reduce the impact of Shallotte Inlet on sediment transport by allowing the beach directly west of the terminal groin to assume an alignment comparable to the shoreline alignment farther to the west by retaining sediment in an area known as the accretion fillet.

An examination of the history of Oregon Inlet provides an example of how a shoreline responds to a terminal structure. Figure 10 is an August 2006 aerial photo of Oregon Inlet that has been overlain with a dotted line representing the approximate pre-groin shoreline on Pea Island. The red line represents the August 1991 shoreline shortly after completion of the terminal groin. The dashed line represents the general alignment of the Pea Island shoreline south of and outside the immediate influence of Oregon Inlet, comparable to the yellow dashed line in Figure 9. As is evident from Figure 10, the terminal groin was successful in capturing and retaining sediment within the accretion fillet and reorienting the shoreline immediately south of the terminal groin to an alignment comparable to the alignment of the shoreline on the north end of Pea Island (yellow dashed line). While some navigation maintenance material was deposited on the north end of Pea Island in 1991, the majority of the accretion fillet was created by the entrapment of littoral sediment moving north along Pea Island. In the case of a terminal groin on the east end of Ocean Isle Beach, the legislation allowing consideration of a terminal groin will require beach nourishment west of the terminal groin using material from an outside source to pre-fill the fillet.

The response of Pea Island to the terminal groin as well as the documented response of other inlets to similar structures was used in the conceptual design of a terminal groin at the east end of Ocean Isle Beach. Specifically, past performance of other terminal groins was used in determining how long a terminal groin would need to be to induce changes in the shoreline alignment and shoreline behavior over some targeted distance west of a terminal groin at Ocean Isle Beach.

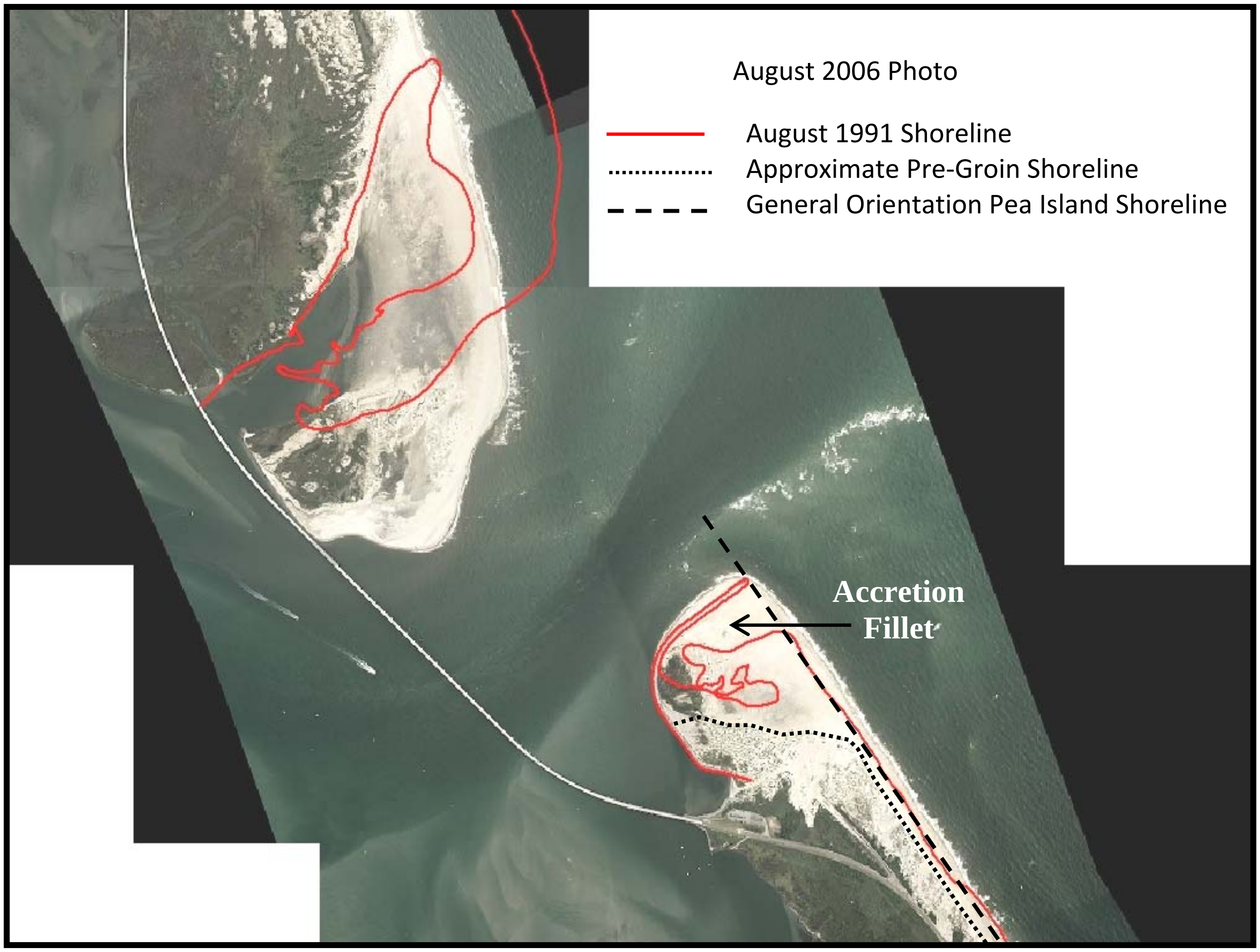
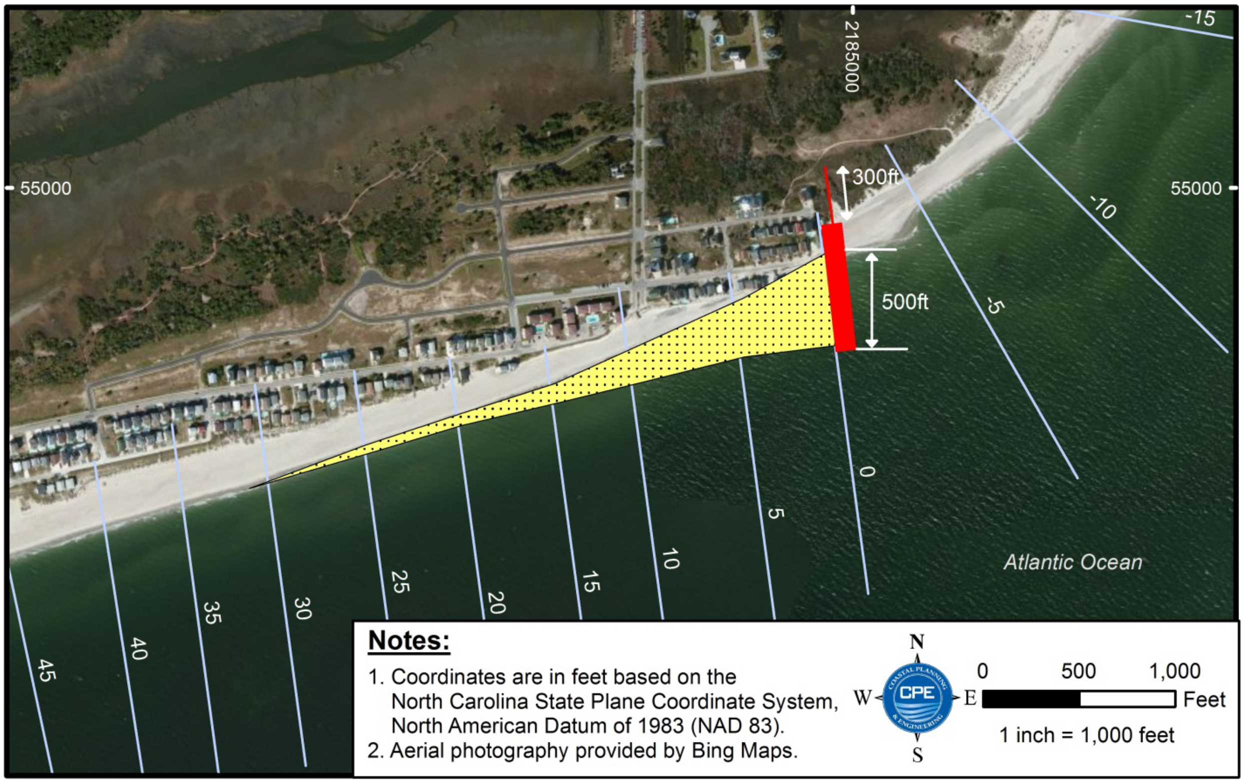


Figure 10. Map of Oregon Inlet/Pea Island terminal groin illustrating changes in shoreline orientation following the construction of the terminal groin.

Two conceptual terminal groin designs were developed and are presented below. One design extends 500 feet seaward of the existing mean high water shoreline (Option 1) and the other 700 feet (Option 2). Schematic drawings of the two terminal groin design concepts are provided in Figures 11 and 12 for the Option 1 and Option 2, respectively. As shown on the figures, the terminal groin would be located near Station 0+00 or just east of the last development on the east end of Ocean Isle Beach.



Notes:

1. Coordinates are in feet based on the North Carolina State Plane Coordinate System, North American Datum of 1983 (NAD 83).
2. Aerial photography provided by Bing Maps.

Figure 11. Schematic of terminal groin Option 1.

Notes:

1. Coordinates are in feet based on the North Carolina State Plane Coordinate System, North American Datum of 1983 (NAD 83).
2. Aerial photography provided by Bing Maps.

Figure 12. Schematic of terminal groin Option 2.

The total length of the terminal groin structures would be somewhat longer than 500 feet and 700 feet due to the need to extend the structures a sufficient distance landward of the existing erosion scarp line to prevent flanking and to cover the 170 feet between the existing erosion scarp line and mean high water. Flanking of the landward end of the structure is not considered to be a major concern given some of the design characteristics, as discussed below, that would allow sediment to move to the east past the structure. However, the shore anchorage section is deemed to be needed given the unpredictable response the shoreline could have to coastal storms. For the conceptual design, the landward starting point would be the 2030 projected position of the erosion scarp line shown in Figure 4, which is approximately 300 feet landward of the existing erosion scarp line. Thus, the total length of the terminal groin for Options 1 and 2 would be approximately 970 feet and 1,170 feet, respectively.

The landward segment of the terminal groin would be constructed using either steel or concrete sheet piles with the sheet pile portion ending near the existing erosion scarp line. The portion of the terminal groin seaward of the erosion scarp line would be constructed as a rubblemound using granitic armor stone founded on a bed of smaller material or possibly a marine mattress foundation consisting of high density polyethylene (HDPE) geogrid baskets lined with filter fabric and filled with small stone.

Option 1 could reorient the shoreline west of the structure to approximately Station 30+00. This is shown schematically in Figure 11. Option 2 could reorient the shoreline as far west as Station 60+00 as shown in Figure 12. These impacts on shoreline orientation should be interpreted as preliminary. More definitive evaluations of their impacts will require the application of numerical models should the TOWN decide to move forward with the development of a terminal groin option. In any event, the shoreline adjustments shown in Figures 11 and 12 would be aided by the placement of beach fill within the area expected to be incorporated into the accretion fillets. For Option 1, the beach fill would extend 3,000 west of the terminal groin and would require approximately 150,000 cubic yards. The Option 2 beach fill would cover 6,000 feet and require approximately 300,000 cubic yards.

Material to construct the beach fill could come from either the existing borrow area in Shallotte Inlet or possibly using material removed to maintain the AIWW at the Shallotte Inlet crossing. Regardless of which source is ultimately used, documentation of the quality of the borrow material and its compatibility with the native beach material as required by 15A NCAC 07H .0312 will have to be provided as part of the major CAMA permit application. In this regard, the permitting requirements for a terminal groin are provided later in this report.

The rock placement to construct the rubblemound portion of the structure would be loosely placed to create voids between the stones which would allow some sediment to pass through the structure. Also, in order to allow sediment to pass over the structure the crest elevation of the structures would be at or just below the natural beach elevation on the east end of the island. With the natural elevation of the beach at the toe of the erosion scarp on the extreme east end of Ocean Isle Beach approximately +6 feet NAVD, the crest elevation for the structures used for this preliminary design concept was set at +5.5 feet NAVD88. The crest elevation would be subject to change based on more detailed design evaluations that would occur if the TOWN elects to pursue a terminal groin. Once the accretion fillet is completely formed, littoral sediment will also pass around the seaward end of the terminal groin. All three of these sediment transport pathways past the terminal groin should maintain the beach east of the terminal groin and lessen the potential for flanking of the landward end of the structure.

Preliminary Construction Cost Estimates

Based on the preliminary structural design of the terminal groins described above, the cost to construct the Option 1 terminal groin could range from $2.0 million to $2.5 million. The cost for the beach fill would also have a similar cost range resulting in a total construction cost for Option 1 of between $4.0 million and $5.0 million. The Option 2 terminal groin could cost between $2.5 million and $3.0 million with the beach fill cost ranging from $3.5 million to $4.0 million resulting in a total construction cost range for Option 2 of $6.0 million to $7.0 million.

Potential Impacts of the Terminal Groin

The potential impacts of the terminal groin options on sediment transport and volume losses along the east end of Ocean Isle Beach were based on modifications to the existing sediment budgets that are likely to accompany their installation. As previously mentioned, littoral sediment transport is a function of the wave breaker angle which in turn is related to the orientation of the shoreline. If the shorelines west of the terminal groin respond in the manner depicted in Figures 11 and 12, the rate of sediment transport along the east end of the island should be comparable to the existing littoral transport rate near the location where the accretion fillet merges with the existing shoreline. Given this assessment, two sediment budgets were developed for each terminal groin option to represent possible changes in the existing sediment budgets developed for the two post-nourishment periods; namely, December 2001 to March 2006 and April 2007 to April 2010. For Option 1, the eastward sediment transport rate at Station 30+00 was assumed to be applicable at Station 0+00 while for Option 2; the eastward sediment transport at Station 0+00 was set equal to the rate at Station 60+00. The resulting sediment budgets for Option 1 are provided in Figures 13a and 13b and the sediment budgets for Option 2 given in Figures 14a and 14b.

A comparison in the results of the sediment budget analysis giving an assessment of the possible changes in volume losses along Ocean Isle Beach for the two terminal groin options and both post-nourishment time periods is provided in Table 5.

Table 5. Potential difference in volume changes along the east end of Ocean Isle Beach with a terminal groin on the east end of the island

Sediment Budget Time Period	Existing volume change (cy/yr) between Stations(1)		volume change between Stations with terminal groin(1)		% change in volume loss between Stations with terminal groin(1)	
	0+00-120+00	10+00-120+00	0+00-120+00	10+00-120+00	0+00-120+00	10+00-120+00
Terminal Groin Option 1						
Dec 01-Mar 06	-129,000	-99,000	-62,000	-60,000	51.9%	39.4%
Apr 07-Apr 10	-236,000	-208,000	-153,000	-151,000	35.2%	36.0%
Terminal Groin Option 2						
Dec 01-Mar 06	-129,000	-99,000	-36,000	-34,000	72.1%	65.7%
Apr 07-Apr 10	-236,000	-208,000	-57,000	-53,000	75.8%	76.7%

(1) Stations 10+00 to 120+00 within limits of federal project.

Based on these preliminary results, volume losses along Ocean Isle Beach between Stations 0+00 and 120+00 were reduced by 35% to around 52% given terminal groin Option 1 while losses within the limits of the federal beach project (Stations 10+00 to 120+00) were reduced by 36% to 39%. These results likely over-estimate the change in volume loss given the assumptions used to develop the conceptual sediment budgets. A more likely estimate is terminal groin Option 1 would reduce volume losses between Stations 0+00 and 120+00 by approximately 30% while losses within the limits of the federal project could be reduced by a comparable amount, i.e., 30%. Further analysis is needed to verify these estimates. For terminal groin Option 2, volume losses between Stations 0+00 and 120+00 were reduced by about 70% to75% and volume losses within the limits of the federal project reduced by 65% to 75%. Again, these results likely over-estimate the change in volume loss given the assumptions used to develop the sediment budgets. A more likely estimate is terminal groin Option 2 would reduce volume losses from the east end of Ocean Isle by approximately 60%. Again, further analysis is required to verify these estimates.

A byproduct of the reduced rate of sediment transport into Shallotte Inlet off the east end of Ocean Isle Beach is a reduction in the shoaling rate within the inlet complex. However, since the reduced rate of sediment loss also translates into a lower periodic nourishment requirement, the reduced shoaling in Shallotte Inlet is unlikely to impact the ability of the borrow area to meet the periodic nourishment needs of Ocean Isle Beach.

The reduced periodic nourishment requirements indicated by the preliminary results discussed herein, could allow a longer time period between periodic nourishment operations. With the current nourishment interval approximately every three years, these preliminary results suggest a 6 year interval could be possible. If so, the periodic nourishment operation for Ocean Isle Beach could still be combined with periodic nourishment of the New Hanover County federal projects as has been done in the past. This would greatly reduce periodic nourishment cost for Ocean Isle Beach due to the reduced number of times a dredge and its ancillary equipment would have to mobilized and demobilized. A second obvious benefit would be the overall reduction in the volume of material that would be placed along Ocean Isle Beach on an average annual basis.

For the 2010 nourishment operation, the total volume placed on Ocean Isle Beach was 509,200 cubic yards for which the TOWN's share was approximately $918,200. With a terminal groin, the nourishment requirement could be reduced by about 30% for the Option 1 terminal groin and 60% for Option 2. Everything else being equal, i.e., nourishment accomplished on a 3 year cycle and the State of North Carolina paying 50% of the non-federal share, the cost savings to the TOWN provided by a terminal groin would range from $275,000 to $550,000 per nourishment event. If the nourishment interval was increased to every 6 years, additional savings would be realized by the TOWN only having to cost share in one mobilization and demobilization rather than two. This could equal an additional cost saving of $1.5 to $2.0 million every 6 years.

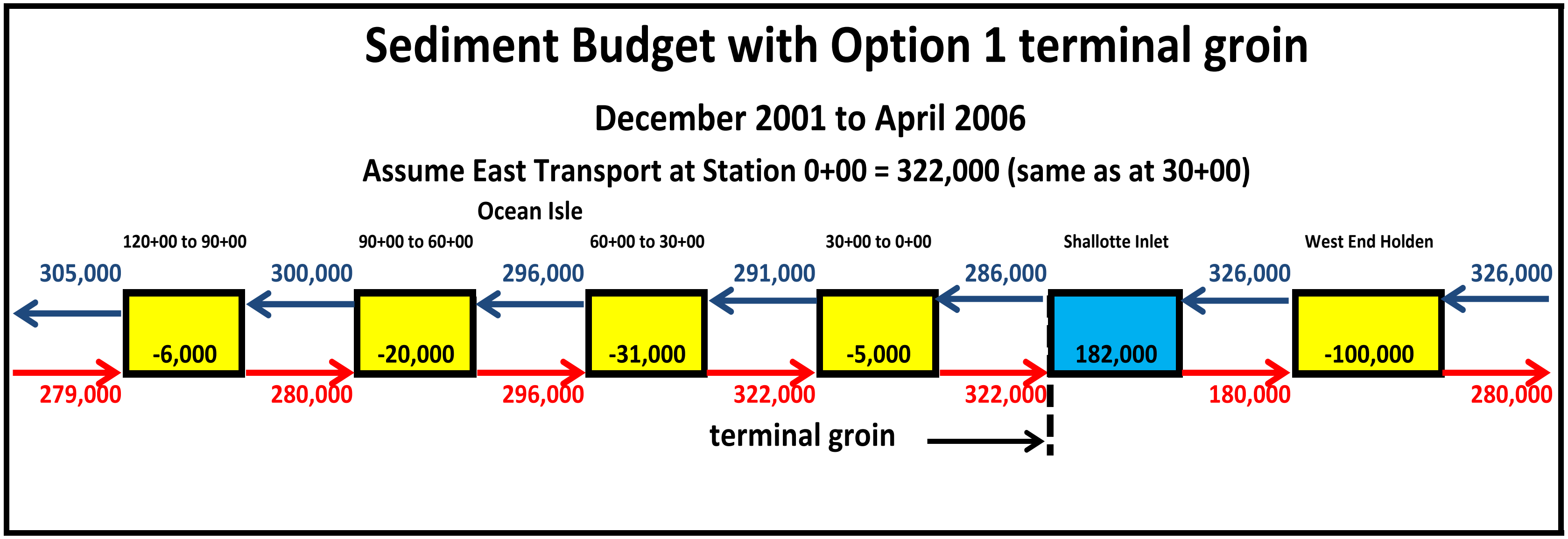


Figure 13a. Sediment budget with Option 1 terminal groin for the December 2001 to March 2006 time period.

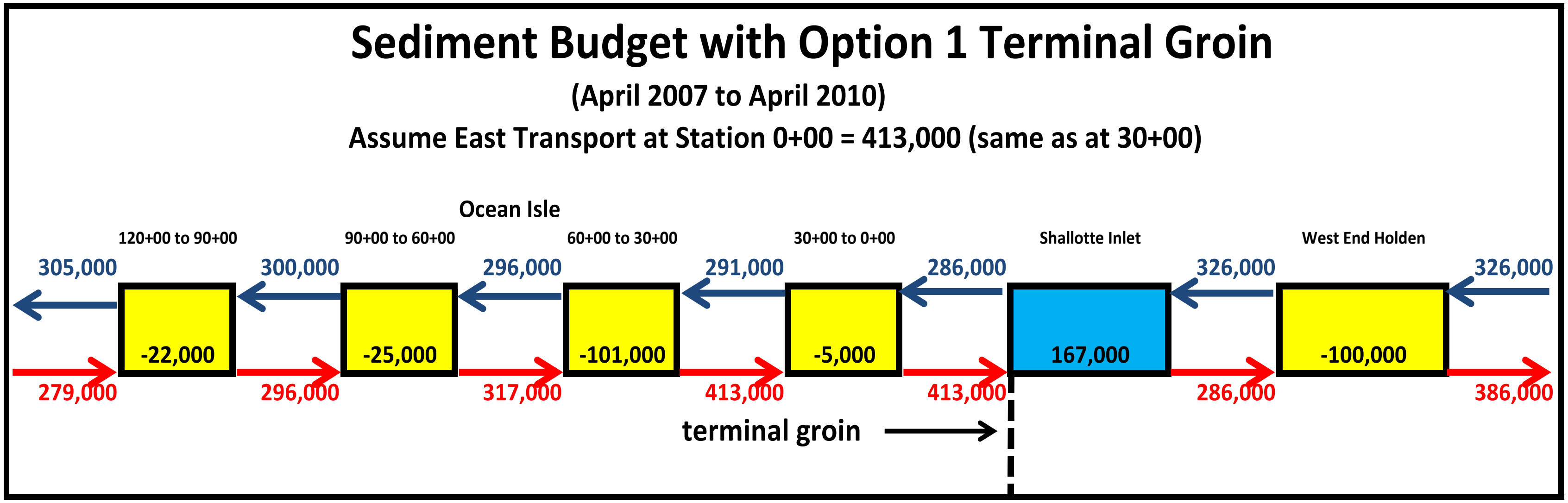


Figure 13b. Sediment budget with Option 1 terminal groin for the April 2006 to April 2010 time period.

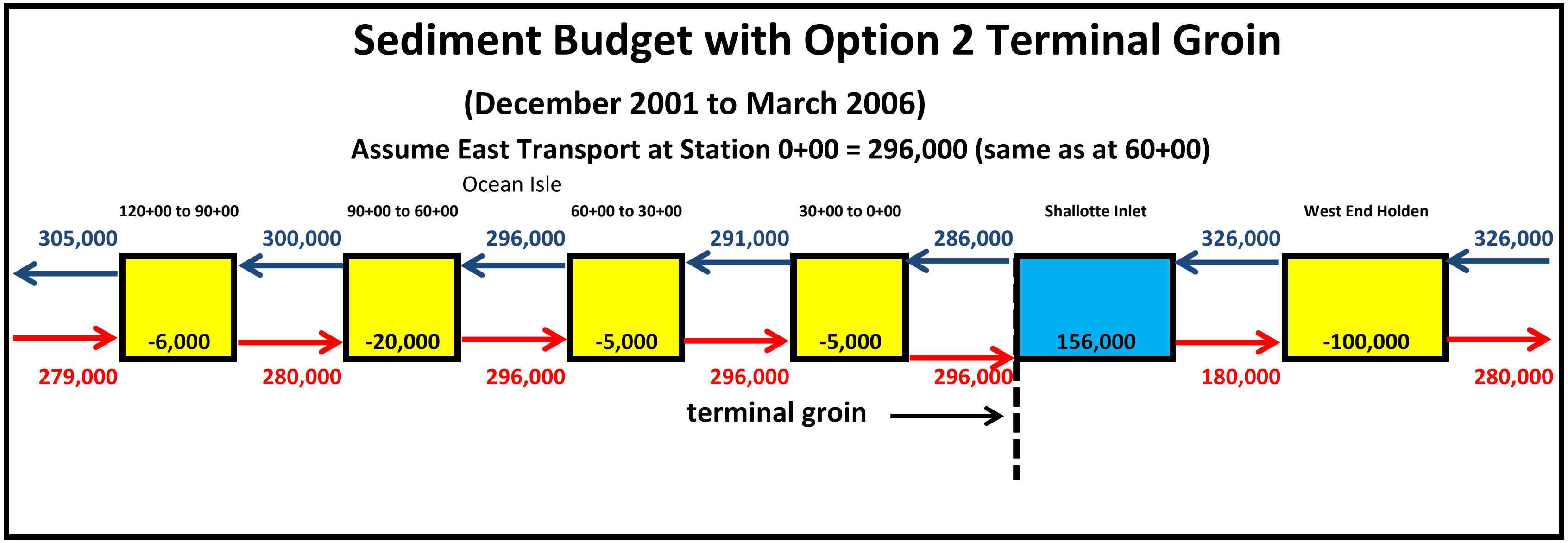


Figure 14a. Sediment budget with Option 2 terminal groin for December 2001 to March 2006 time period.

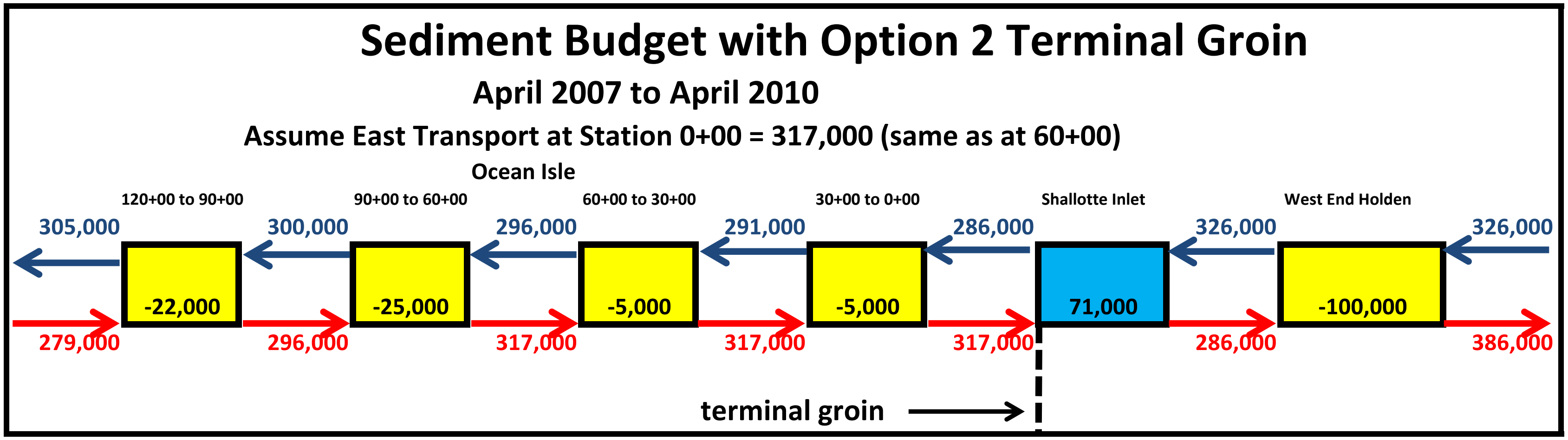


Figure 14b. Sediment budget with Option 2 terminal groin for April 2007 to April 2010 time period.

Terminal Groin Design Cost

The environmental documentation needed to support a permit application for a terminal groin, which is discussed below, will require detailed numerical modeling to identify potential changes to Shallotte Inlet and its associated estuarine environment that could be caused by a terminal groin. The numerical model would have to be able to indicate potential changes in flows in and out of Shallotte Inlet as well as indicate changes in estuarine habitat such as shallow water sand flats and marsh areas that could be associated with a terminal groin. The numerical model would also be used to assess the potential impacts a terminal groin might have on both Ocean Isle Beach and Holden Beach.

The success of the terminal groin will also rely on a structural design that can withstand the tide and wave conditions applicable to the Ocean Isle Beach area. Such conditions would include an assessment of hurricane impacts as well as major non-tropical events. Also, if the shore anchorage section of the terminal groin is built with some type of sheet pile, i.e., steel or concrete, geotechnical investigations will be needed in that area to identify underlying soil conditions.

Finally, once the structural details of the terminal groin have been identified, detailed construction cost estimates would be prepared including the identification of the construction methodology, construction access requirements, and staging areas.

The estimated cost for numerical modeling for the terminal groin and the development of detailed structural designs and cost estimates could range from $213,000 to $240,000.

Environmental Documentation and Permitting

Permitting Requirements. During the 2011 legislation session, the North Carolina Legislature passed Session Law 2011-387, Senate Bill 110 which allows consideration of terminal groins adjacent to tidal inlets. This legislation included a number of provisions and conditions that must be met in order for the terminal groin to be approved and permitted by both the Federal and State government. In order to comply with the federally administered National Environmental Policy Act (NEPA) and North Carolina’s State Environmental Policy Act (SEPA), the Town will be required to obtain the following State and Federal permits for the terminal groin and beach nourishment project:

- Department of Army (DOA) Individual Permit
- Coastal Area Management Act (CAMA) Major Authorization

In addition, approvals will be required from other Federal and State agencies. These include:

- NCDWQ 401Certification
- USACE Section 10/404 Permit

- U.S. Fish and Wildlife Service Biological Opinion (BO)
- National Marine Fisheries Service Concurrence
- NC State Historic Preservation Office (SHPO) Concurrence

Coordination with these respective agencies will be conducted in conjunction with the Federal and State permitting process. Along with the permit applications, additional environmental documentation will be required to satisfy requirements by the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS)- see the section "Environmental Documentation" below for a full description of these requirements.

Geotechnical Investigations. The State of North Carolina has adopted specific sediment criteria which must be adhered to for the emplacement of beach fill along the oceanfront shoreline (15A NCAC 07H.0312). These rules were adopted by the North Carolina Coastal Resource Commission (CRC), in February 2007, and later amended in April 2008. Beach fill projects for the purpose of this rule include beach nourishment, dredged material disposal, habitat restoration, storm protection, and erosion control projects. The material used to pre-fill the terminal groin fillet must adhere to these standards in order to obtain a Major CAMA Permit for the project.

The proposed source of sand for the terminal groin project is the existing authorized borrow source within Shallotte Inlet used by the USACE for the Federal Storm Damage Reduction Project for Ocean Isle Beach (Figure 2). Despite the fact that the USACE has nourished and twice re-nourished the Ocean Isle Beach project since 2001 using sand from the Shallotte Inlet borrow area, the TOWN will be required to comply with the state sediment criteria. In this regard, the USACE operates under the Federal consistency requirement of the Federal Coastal Zone Management Act (CZMA). This requires Federal actions likely to affect any land or water in the coastal zone to be consistent with the state's coastal management program to the maximum extent practicable but does not require the USACE to obtain a state permit. As a result, the geotechnical information for the USACE borrow area for the Federal project may not meet the sediment criteria specified in the state rules, specifically with regards to density of data collection.

As previously stated, the USACE regularly dredges the crossing of the AIWW and Shallotte Inlet as part of their shallow draft navigation program. This material has been routinely placed on the east end of Ocean Isle Beach. At this time it is unknown whether or not the volume of material that regularly shoals into the channel at the crossing would be sufficient to construct the fillet for the terminal groin. Regardless, the same level of investigations would be required if the TOWN elected to pursue this borrow source as an alternative. CPENC will coordinate closely with the Wilmington District throughout the permitting process. If changes in USACE operations suggest the TOWN could realize significant cost savings by using this alternative borrow source rather than the Shallotte Inlet borrow area, the TOWN will be briefed on the situation and the most cost effective plan will be implemented. It is more likely that the TOWN could work with the USACE to continue its disposal of beach quality material on the east end of

Ocean Isle Beach as part of the AIWW maintenance work, which would likely satisfy any maintenance of the beach fill west of the terminal groin outside of the Federal Project.

The state's sediment criteria specify the type of information needed to determine the compatibility of native vs. beach fill sediments. An assessment of the technical information available for the borrow area used by the USACE for the Ocean Isle Beach is included herein.

The current sediment criteria rules include special conditions for projects using sand from Federal or State maintained navigation channels. Recently, CPENC and other private and public entities have proposed revisions to the state sediment criteria. The proposed changes focus on the special condition exceptions in the rules for Federal or State maintained navigation channels. The proposed changes would modify the rules to allow for the inclusion of projects associated with inlet sources of sand that are not confined to Federal or State maintained navigation channels. The basis for this modification is that material that is removed from a portion of the inlet repeatedly and has been historically demonstrated to be of good quality should not be held to the same standards as unproven sand sources. At the time of this report, the State is currently reviewing these proposed changes and may adopt the changes as early as October 1, 2012. These changes would reduce the level of effort necessary for the Town of Ocean Isle Beach to obtain State permits.

Given the uncertainties in future Federal Funding for advanced engineering and design and the timeframe for potential rule changes in the sediment criteria to be adopted, a range of cost has been provided herein. The minimum estimate reflects minimum efforts required on behalf of the TOWN assuming proposed changes to the sediment criteria rules are adopted and the USACE performs the types of pre-construction investigations they have done in the past, including bathymetric surveys of the Inlet and beach profile surveys throughout the Federal Project. The maximum estimate assumes the TOWN will be responsible for collecting all data needed to comply with the current state sediment criteria rules. This would include tasks previously conducted by the USACE such as vibracores, bathymetric surveys, and beach profiles.

Existing Borrow Site: The borrow area that was used for the initial construction and subsequent maintenance of the Federal Ocean Isle Beach Storm Damage Reduction Project is contained within the Shallotte Inlet complex as shown in Figure 2. The borrow area extends from the Atlantic Intercostal Waterway through the inlet gorge and out across the ebb tide delta to a depth of -15.0 ft. MLW. The entire area is designed to be cut to a depth of -15.0 ft. MLW. Discussions between CPENC and Michael Wutkowski of the USACE Wilmington District suggest that the current borrow area could support both routine maintenance of the Federal Project and the construction and maintenance of the proposed terminal groin project. This conclusion is based on the volume of material available within the borrow site, the volume of material removed from the borrow site during routine maintenance, and the shoaling rates measured for the inlet.

Native Beach: A State permit for disposal of material onto Ocean Isle Beach as part of the proposed terminal groin project would require the characterization of native material. During preparation of the General Reevaluation Report for the Ocean Isle Beach project, completed in 1994, the USACE collected beach samples along three profiles within the project area. Samples were collected from the Dune out to a depth of -30 ft NGVD29. The state sediment standards dictate a specific number of samples along at least five profiles within the project area (15A NCAC 07H.0312)(1)(c and d). However, 15A NCAC 07H.0312 (1)(i) provides language that would allow special consideration of projects which were constructed prior to the adoption of the rules. Given this exception, the Division of Coastal Management would likely allow the USACE samples to be used as part of the required characterization of the native beach. It is likely that the TOWN would have to obtain additional samples along two profiles in the vicinity of Shallotte Inlet to further define the native beach in accordance with the sediment criteria.

In addition to the native beach samples, the state sediment criteria require beach profile surveys and a quantification of clasts larger than 3 inches in diameter along a representative section of the beach. Depending on future funding by the USACE, the Town may need to survey between 8 and 16 beach profiles between Shallotte Inlet and USACE baseline Station 60+00. The TOWN would have to quantify the number of clasts greater than 3 inches in diameter on the existing beach to support its permit application.

The changes to the state sediment criteria would not affect the level of effort necessary to characterize the native beach. Therefore both Scenario 1 and Scenario 2 would include the work described herein to characterize the native beach.

Borrow Area Investigations. Geotechnical information that may be needed to obtain a State permit for the existing Shallotte Inlet Borrow Area includes:

- Collection and analysis of 10 vibracores within the proposed borrow area.
- Conduct a bathymetric survey of the borrow area.

The USACE has routinely collected vibracores prior to re-nourishment events on Ocean Isle Beach. Figure 2 shows the location of the vibracores taken in 2009 as part of the advanced engineering and design for the project. Although this has been common practice in the past, recent funding shortfalls have the potential to result in the elimination of this step by the USACE in conducting advanced engineering and design. The USACE also conducts hydrographic surveys of the borrow area which would satisfy State requirements. CPENC understands at this time that the USACE would continue to conduct hydrographic surveys in preparation for maintenance events.

The USACE conducted a submerged cultural resource investigations of the Shallotte Inlet borrow site in association with the Environmental Assessment drafted as part of the Federal project. Based on the findings of the submerged cultural resource investigation and the fact that the material that would be used by the TOWN is material that has shoaled in over time since initial construction and/or maintenance, no additional cultural resource investigations would be necessary to support a permit for a terminal groin.

The proposed changes to the state sediment criteria would eliminate the need to conduct the vibracores within the Shallotte Inlet borrow area. Some additional coordination and data mining would be required to obtain, review, and document the existing USACE data to conform with the modified sediment criteria rules. Although the hydrographic survey of the borrow area would still be required, it is likely that the USACE would conduct this survey based on past maintenance operations.

The cost of obtaining the necessary data and analyzing the characteristics of the native and fill material could range between $70,000 and $150,000. The lower range assumes that modifications of the proposed rule changes to the sediment criteria will be adopted and that the USACE will conduct beach profiles of the Federal project and a bathymetric survey of the borrow area. The upper range assumes that the TOWN will be required to obtain vibracores, conduct beach profile surveys, and conduct a bathymetric survey of the borrow site, in addition to the characterization of the native material that will be required under either scenario.

<u>Environmental Documentation</u>. Senate Bill 110 states that the applicant for the construction of a terminal groin must prepare an Environmental Impact Statement (EIS) under both the National Environmental Policy Act (NEPA) and the State Environmental Policy Act (SEPA). The formulation of the EIS will require extensive research and evaluation of existing environmental data for the study area to determine the nature and extent of those resources that may be affected by project construction. This information will pertain to the nearshore marine, estuarine, and terrestrial habitats within and adjacent to the project areas. In addition, the EIS will include the formulation of project alternatives which will require the integration of engineering and geotechnical services.

The first stage of EIS development is the scoping process which is the means by which substantive issues are identified for further study in the EIS. A Project Delivery Team (PDT) comprised of agency representatives and stakeholders will be selected and will convene several times to steer this process. A Draft EIS (DEIS) will be released to the Federal Register followed by a commenting period. Once all comments are received, a Final EIS (FEIS) will be developed taking comments into consideration and will released to the Federal Register. Following the release of the FEIS, the USACE will issue a Record of Decision (ROD).

In addition to the EIS, three other environmental documents will need to be developed prior to the issuance of permits. An Essential Fish Habitat assessment (EFH) will be drafted and submitted to the National Marine Fisheries Service (NMFS). An EFH assessment is a review of the proposed project and its potential impacts to EFH. As set forth in the rules, EFH assessments must include: (1) a description of the proposed action; (2) an analysis of the effects, including cumulative effects, of the action on EFH, the managed species, and associated species by life history stage; (3) the Federal agency’s views regarding the effects of the action on EFH; and (4) proposed mitigation, if applicable. This document will ensure that the project will identify and protect important marine and estuarine fish habitat in accordance to the amended Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

The USFWS will require the submittal of a Biological Assessment (BA). The purpose of the BA is to determine whether a proposed action is likely to: (1) adversely affect listed species or designated critical habitat; (2) jeopardize the continued existence of species that are proposed for listing; or (3) adversely modify proposed critical habitat. Biological assessments must be prepared for "major construction activities". The BA will serve to document the USACE’s conclusions and rationale to support those conclusions regarding the effects of their proposed actions on protected resources.

Finally, a Cumulative Effects Assessment (CEA) will be submitted as an appendix to the EIS and will serve to evaluate the anticipated cumulative effects of the Applicant's Preferred Alternative, as identified in the EIS. Cumulative effects generally refer to impacts that are additive or interactive (synergistic) in nature and result from multiple activities over time, including the project being assessed. The U.S. Council on Environmental Quality (CEQ) defines cumulative effects as "the impacts on the environment that result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or nonfederal) or person undertakes such other actions".

<u>Anticipated Timeline for Permitting.</u> On January 18, 2012, the TOWN held an interagency meeting with representatives from Federal and State agencies to discuss initial environmental concerns regarding the project. During this meeting, it was determined that along with the development of an EIS, an EFH, and BA would also be required. Based on CPENC's involvement with the Figure Eight Island terminal groin EIS, and other NEPA documents for similar projects, we anticipate that drafting the necessary documents and coordinating with the USACE could take approximately 24 months. Assuming a contract could be executed by the TOWN in June 2012, it is possible for the Draft EIS to be submitted to the relevant agencies by June 2014. In conjunction with the release of the Draft EIS, a Public Hearing and Public Notice will be issued and will provide commenting periods to the public and Federal and State agencies. This commenting period generally lasts for 75 days. Once comments to the draft documents are received, revisions will be made within approximately 90 days resulting in the release of the final documents. This would result in an anticipated timeframe of approximately 30 months from the time a contract is executed to the release of the necessary environmental documents.

During the above mentioned 30-month timeframe, the contractor will also prepare applications for a State CAMA Major Permit Application and a Department of Army Individual Permit. The Division of Coastal Management (DCM) will review the CAMA Major Permit application while the USACE will review the Individual Permit application. The USACE will issue a Record of Decision (ROD) within approximately 3 months following the receipt of the fully completed permit application. Typically, the DCM will issue their CAMA Major permit following the release of the ROD as part of the "Federal consistency" authority under the Federal Coastal Zone Management Act. This will also result in the issuance of the state 401 Water Quality Certificate. It is expected that these permit applications would be submitted in conjunction with the release of the Final environmental documentation. Therefore, it is expected that all requirements necessary to obtain permits will be fulfilled within approximately 33 months. Actual issuance of all Federal and State permits could occur within 3 months of all information being submitted for a total of 36 months to permit.

By this schedule it is anticipated that permits for a terminal groin could be issued to the TOWN by June, 2015. Bid documents including plans and specifications could be prepared in parallel with some of the previous mentioned tasks. Bidding and contract negotiations could be accomplished in time to construct the project in the dredging season between November 2015 and March 2016. Although the construction of the terminal groin would not necessarily be limited by the turtle nesting season, placement of fill would likely limit pre-filling of the fillet to the winter months.

Cost for Environmental Documentation

The cost to coordinate and develop all the required environmental documents including the EIS, BA, EFH, and CEA could range from $290,000 to $380,000.

Cost for Permitting

The cost to develop and submit complete and approvable permit applications would be approximately $25,000 but could be higher if the State and/or USACE make a request for additional information.

Summary Environmental Documentation and Permitting Cost:

a.	EIS, BA, EFH, & CEA documents	$290,000 to $380,000
b.	Geotechnical Investigations	$70,000 to $150,000
c.	Permit Application	$25,000 to $35,000
	Total cost range	**$385,000 to $565,000**

Physical and Biological Monitoring

Permit conditions will specify the monitoring activities that will be required as a result of the terminal groin and beach nourishment project. Although it is not possible to predict the permit conditions at this time, the stipulations within Senate Bill 110, discussions at the pre-application meeting, and experience with similar projects provide insight on the likely monitoring scenarios. These include monitoring for shoreline change, bird monitoring, and biotic community monitoring. In addition, monitoring for sea turtle nests would be anticipated, however a cost estimate for this activity is not included below because this monitoring program is already coordinated by the volunteer group Ocean Isle Beach Sea Turtle Patrol.

- Shoreline Change Monitoring

  The Town of Ocean Isle Beach, in conjunction with USACE, is presently involved with an inlet management program for Shallotte Inlet as part of the Federal Ocean Isle Beach Erosion and Hurricane Wave Protection Project. The existing inlet management plan includes a full complement of surveys along the ocean shorelines of both Ocean Isle Beach and the west end of Holden Beach as well as surveys of Shallotte Inlet and the adjoining waters. Periodic aerial photographs are also taken to supplement the survey information. An inlet management plan for the terminal groin alternative is mandated by Senate Bill 110 and would include the same components for the Federal project as outlined above. In addition, Senate Bill 110 requires the inlet management plan to include shoreline change thresholds that would be used to determine if the terminal groin is having an adverse impact on the adjacent shorelines.

- Bird Monitoring

During the pre-application meeting, agency representatives from the North Carolina Wildlife Resources Commission and USFWS expressed concerns regarding piping plover critical habitat located within the proposed project area. Along with piping plovers, it is recognized that other shorebirds and colonial waterbirds often use beach habitats for nesting, foraging, resting, and roosting. As a result, it is anticipated that a pre-construction, during construction, and post-construction waterbird and shorebird monitoring program will be required for this project. The duration of the post-construction surveys would be dependent upon the determination by the USACE, NCDCM, and NCWRC based off the results of the study. The purpose of this monitoring would be to monitor bird use of the beach habitats and collect data to assess the impacts of beach nourishment and the terminal groin on these birds. This will entail periodic surveys of the portions of the oceanfront shoreline, inlet shoreline, and intertidal flats and shoals. These surveys would be conducted throughout the year including during the breeding season and migration season. A similar bird monitoring program along Ocean Isle Beach was previously performed in response to the Federal Ocean Isle Beach Erosion and Hurricane Wave Protection Project. The monitoring program designed in response to the terminal groin project, if required, would be designed to complement the methodology from the previous study such that long-term trends could be elucidated.

- Biotic Community Mapping

Because it is anticipated that the implementation of the terminal groin and beach nourishment project will potentially impact a number of biological resources found within the project area, an effort to delineate baseline conditions of various biological communities will most likely be required. These communities include resources found within the supratidal, intertidal, and subtidal habitats. Existing data and newly acquired data will be gathered and utilized to delineate and characterize habitats and select species within the proposed project area. The data gathered from these activities will provide the basis for the EIS, CEA, BA, and EFH evaluations which, as described above, will be used to review the proposed project at both the State and Federal levels.

To determine the extent of various biotic communities within the project area, high resolution aerial photography (< 2 ft) will be acquired and digitized. The biotic communities to be delineated from these photographs will include, but are not limited to, wet beach, dry beach, subtidal environments, intratidal shoal, dune, fringing terrestrial, marine intratidal, submerged aquatic vegetation (SAV), shellfish, and salt marsh and associated fringing terrestrial (MFT) communities. Developed areas will also be mapped. Analysis will be conducted via hand digitalization utilizing a Geographic Information System (GIS) platform. A comprehensive biotic community habitat map and acreage estimate for each community type will be generated and serve as baseline conditions for each habitat or community type. In addition, *in situ* groundtruthing field investigations will be performed to verify the presence and distribution of these delineated biotic communities.

Summary of Annual Physical and Biological Monitoring Costs:

a. Shoreline Change Monitoring	$15,000 to 20,000
b. Bird Monitoring	$40,000 to $100,000
c. Biotic Community Mapping	$35,000 to $45,000
Total cost range	**$90,000 to $165,000**

The cost estimates for these monitoring efforts are estimated annual costs. Permit conditions will specify the duration of each component of the monitoring plan. Beach nourishment projects permitted in North Carolina in the recent past have typically included 1 year of pre-construction surveys, 2-3 years of post-construction bird monitoring and 3 years of post-construction biotic community mapping. Because the State has not issued permit conditions associated with the recent terminal groin legislation, the required duration of the shoreline change monitoring effort is not known at this time.

Summary of Findings

Under existing conditions, the east end of Ocean Isle Beach will continue to remain vulnerable to erosion damages associated with the impact Shallotte Inlet has on the east end of the island. Even if the TOWN and affected property owners continue to install temporary sandbag revetments as they have in the past, the erosion threat will continue to move inland over the next 20 years and possibly beyond. Based on the projected movement of the erosion scarp on the east end of the island over the next 20 years, a total of 150 parcels with a current tax value of approximately $6.6 million will be lost. Also by the year 2030, 43 existing buildings on the east end with a current tax value of $4.4 million will be lost. Thus, the total projected loss for the tax value of parcels and buildings will be about $11.0 million if conditions on the east end of the island remain the same. These projected losses do not include the additional cost that could be associated with moving or demolishing threatened buildings.

The existing TOWN infrastructure will also continue to suffer damages totaling about $900,000 with additional cost of over $700,000 for the installation of temporary sandbags. Over the next 20 years, the total damages to the east end of the island could be more than $12.6 million.

Under existing conditions, the federal storm damage reduction project is losing between 100,000 200,000 cy/yr with about two-thirds of the volume loss occurring east of Raleigh St. (baseline Station 50+00). The east end of the island is also losing additional material east of Shallotte Boulevard which lies outside the authorized limits of the federal project.

A preliminary assessment of the impacts of a terminal groin on sediment losses along Ocean Isle Beach including from within the limits of the federal project indicated possible reductions in volume loss of between 30% and 60% depending on the length of the terminal groin. In this regard, two terminal groin options were evaluated, one having a total length of 970 feet (Option 1) that would project 500 feet seaward of the existing mean high water shoreline and the other measuring 1,170 feet (Option 2) that would project 700 feet seaward of the mean high water.

Reductions in the periodic nourishment requirements indicated by the preliminary assessment could save the TOWN $275,000 to $550,000 per nourishment operation. Additional savings of $1.5 to $2.0 million would be possible if the nourishment interval could be increased to 6 years rather than the current 3 years.

In addition to the cost constructing a terminal groin, implementation of either terminal groin option would have to be accompanied with a beach fill west of the structure. Table 6 provides a probable cost range for both terminal groin options.

Table 6. Construction cost range for terminal groin options.

Terminal Groin Option	Construction Cost Terminal Groin	Cost of Beach Fill	Total Cost
1	$2.0 to $2.5 million	$2.0 to $2.5 million	$4.0 to $5.0 million
2	$2.5 to $3.0 million	$3.5 to $4.0 million	$6.0 to $7.0 million

Engineering and design cost for the terminal groin which would include a detailed assessment of its potential impacts on Shallotte Inlet and the adjacent islands as well as the structural design and detailed cost estimates could range from $213,000 to $240,000.

Environmental documentation and permitting of the terminal groin, which would be supported by the results of numerical modeling, could range from $345,000 to $525,000. Physical and environmental monitoring that would likely be required as part of the permit conditions for a terminal groin could range from $90,000 to $165,000 per year. However, except for shoreline monitoring, most of the monitoring activities are expected to be limited to 3 years.

Assuming a contract could be executed by the TOWN by June 2012, it is possible for the Draft EIS along with other required environmental documentation to be submitted to the relevant agencies by June 2014. The Final EIS, additional NEPA documents, and submittal of permit applications could be completed by March, 2015. By this schedule it is anticipated that permits for a terminal groin could be issued to the TOWN by June, 2015. Although the construction of the terminal groin would not necessarily be limited by the turtle nesting season, placement of fill would likely limit pre-filling of the fillet to the winter months. Therefore, the anticipated timeframe of project construction would be the winter of 2015/2016.

In summary, the total costs associated with permitting a terminal groin is expected to range from $648,000 to $930,000 (Table 7).

Table 7. Total costs associated with permitting a terminal groin.

Task	Cost Range
Terminal Groin Design	$213,000 to $240,000
Environmental Documentation and Permitting	$385,000 to $565,000
Physical and Biological Monitoring	$90,000 to $165,000
TOTAL	**$688,000 to $970,000**

References

USACE, May 2008. Brunswick Data Compilation, Analysis and Sediment Budget, Phase I, by Offshore and Coastal Technologies, Chadds Ford, PA, May 2008.

EXHIBIT 3

SOUTHERN ENVIRONMENTAL LAW CENTER

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October 13, 2014

Col. Kevin P. Landers, Sr.
Commander
U.S. Army Corps of Engineers
Wilmington District
69 Darlington Avenue
Wilmington, NC 28403

Sent via email to: Kevin.P.Landers@usace.army.mil

RE: Figure Eight Island Terminal Groin Proposal

Dear Col. Landers:

It has come to our attention that the U.S. Army Corps of Engineers ("Corps") plans to imminently release a final environmental impact statement ("FEIS") for the proposed terminal groin on the north end of Figure Eight Island. As our organizations have raised with the agency previously, however, the Corps cannot legally approve this project for numerous reasons. On behalf of the North Carolina Coastal Federation and Audubon North Carolina, the Southern Environmental Law Center again calls on the Corps to discontinue work on the FEIS until the Figure Eight Island Homeowners' Association ("HOA") demonstrates that it possesses the necessary property rights to build the proposed project and goes through the necessary application process with the Corps. In addition, the Corps must issue a new draft environmental impacts statement ("DEIS") that analyzes the existing environmental conditions on Figure Eight Island and the associated effects of the project, and the Corps must complete consultation with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service regarding impacts to threatened and endangered species under the Endangered Species Act ("ESA").

I. The HOA Has Not Met Basic Prerequisites for Implementation of the Project.

Despite the Figure Eight Island terminal groin project having been in the works since at least 2012, it is our understanding that basic prerequisites for building the project still have not been completed. In particular, the Figure Eight HOA does not own the property rights necessary to construct the project and the HOA has not submitted a formal application for approval of the project. We alerted the Corps to these significant deficiencies during the public comment period on the DEIS, see Letter from D. Carter, SELC, to M. Sugg, Corps, at 2 (July 27, 2012), yet further corrective action as not been taken. These issues must be addressed before the Corps can legally take any further action with regard to this project.

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The beachfront where the groin would be built intersects more than a dozen lots. These lots would be affected by both the construction of the groin, as well as by the erosion and loss of beachfront that would be caused by the groin. The HOA does not have easements that would allow it to build across the lots and cannot demonstrate "that the applicant possesses or will possess the requisite property interest to undertake the activity proposed in the application." 33 C.F.R. § 325.1(d)(8).

Further, more than two years since publication of the DEIS, the HOA has yet to even submit an application to the Corps. It is a waste of agency time and resources, and a disservice to the public, for the Corps to invest substantial efforts into a project that the proponent cannot build and has not applied for.

II. The Corps Has Not Complied With NEPA.

In addition to the HOA still needing to meet the fundamental prerequisites for proceeding with the project of obtaining the necessary property rights and submitting an application, the Corps and the HOA also must entirely reexamine their May 18, 2012 DEIS. The underlying basis for the DEIS has fundamentally changed since 2012, rendering the document unable to serve its required role under the National Environmental Policy Act ("NEPA"). At base, the DEIS evaluates an inlet that no longer exists in the state analyzed and is, therefore, purely hypothetical. The DEIS cannot provide any information about the existing inlet or the effect of the revised terminal groin project on that inlet, and therefore cannot be finalized as the FEIS for the project.

The accretion at the northern end of Figure Eight Island has dramatically changed baseline physical conditions, even since our July 27, 2012 letter. As a result, the assumptions relied on in the DEIS no longer hold and cannot be relied upon as a basis for analyzing environmental impacts.

NEPA regulations require the Corps to re-analyze the project in a new DEIS if it is to move forward. "If a draft statement is so inadequate as to preclude meaningful analysis, the agency shall prepare and circulate a revised draft of the appropriate portion." 40 C.F.R. § 1502.9(a). This situation is present under the current circumstances, where the DEIS assumes both that "erosion rates [will] continue at their current level," DEIS at 38, and that future erosion will occur approximately as predicted by the Delft3D model. Both assumptions are demonstrably invalid. The north end of Figure Eight Island is accreting, fundamentally altering the baseline conditions represented in the DEIS. As shown in the attached report, satellite imagery clearly demonstrates that the ebb channel has naturally realigned and deposited significant volumes of sand on the northern end of the island. See Rich Inlet Bird Surveys, 2008-2014: Preliminary Summary of Results, L. Addison and T. McIver at 5 (Sept. 2014).

A. The DEIS environmental baseline is demonstrably false.

The entire analysis in the DEIS rests on the assumption that the north end of Figure 8 Island will erode at rates observed between 1999 and 2007. See DEIS at 22, DEIS at 168 ("Under Alternative 1, the shorelines on both islands would be expected to continue to behave as they have in the past."). Under the No-Action Alternative, it is assumed that "the Figure Eight HOA and individual property owners would continue to respond to erosion threats in the same manner as in the past." DEIS at 25. The analysis of the No-Action Alternative assumes a "[c]ontinuation of the present rate of shoreline recession on the extreme north end of Figure Eight Island." DEIS at 26. Based on that analysis, it predicts that up to 40 houses will have to be demolished or relocated within the next 30 years. Id. The DEIS estimates similar consequences for Alternative 2: Abandon/Retreat. DEIS at 28. Over two years after preparation of the DEIS, exactly the opposite has occurred.

The Fourth Circuit has made clear that "[w]ithout [accurate baseline] data, an agency cannot carefully consider information about significant environment impacts'" and therefore the analysis will "result[] in an arbitrary and capricious decision." N.C. Wildlife Fed'n v. N. C. Dep't of Transp., 677 F.3d 596, 603 (4th Cir. 2012) (quoting N. Plains Res. Council, Inc. v. Surface Transp. Bd., 668 F.3d 1067, 1085 (9th Cir. 2011)). It is fundamental that baseline data for the analysis of environmental impacts represent reality. See Friends of Back Bay v. U.S. Army Corps of Eng's, 681 F.3d 581, 588 (4th Cir. 2012) ("A material misapprehension of the baseline conditions existing in advance of an agency action can lay the groundwork for an arbitrary and capricious decision."). Without an accurate assessment of baseline conditions, "the [impact statement] process cannot serve its larger informational role, and the public is deprived of [its] opportunity to play a role in the decision-making process." N.C. Wildlife Fed'n, 677 F.3d at 603 (quoting N. Plains Res. Council, Inc. v. Surface Transp. Bd., 668 F.3d 1067, 1085 (9th Cir. 2011)).

The DEIS errors regarding the existing conditions on Figure 8 are further demonstrated by the model projections used to evaluate environmental and economic impacts of the alternatives. See DEIS at 29 ("The performance of Alternative 3, as well as the other alternatives, was based on the results of a numerical model known as Delft3D."). The 2012 projections of conditions at Rich Inlet could not have been more inaccurate. Figure 5.7 in the DEIS predicts substantial movement of the ebb-flow channel outlet to the northeast with final orientation to the east-northeast. See DEIS at 173. It also predicts that the main channel of Nixon Channel approaching the inlet will swing away from the interior marsh bank and that the higher elevation tip of the spit on Figure Eight Island will substantially erode away. As shown in the attached report, the ebb channel has not migrated as predicted by the model and the northern end of the island has not eroded.

In sum, the scenario that is the foundation of the DEIS simply does not exist and cannot, therefore, serve as the basis for a lawful NEPA analysis or any agency action. Friends of Back Bay, 681 F.3d at 588 ("An unjustified leap of logic or unwarranted assumption, however, can erode any pillar underpinning an agency action . . . ."). The assumptions that the island will continue to erode and that the model provides a reasonable prediction of future erosion are more than "unjustified leap[s] of logic or unwarranted assumption[s]," they are demonstrably false. Reliance on "demonstrably incorrect assumption[s]" violates NEPA. Id. at 589.

B. The Project Purpose and Need Has Been Rendered Obsolete.

In addition to invalidating the DEIS's projections of baseline conditions in the action area, the inlet's natural migration has also rendered the Proposed Action unnecessary, undermining the DEIS's statement of Purpose and Need. The entire DEIS analysis depends on the continuation of "chronic erosion problems along the northern section of Figure Eight Island's ocean shoreline." DEIS at i. The DEIS analysis focuses on preventing "economic losses resulting from damages to structures and their contents due to . . . progressive shoreline erosion." Id. The alternatives analysis evaluated options "[t]o alleviate these problems attributed to erosion." Id.

Taking into account the accretion of the beach on the north end of Figure Eight Island, all of the DEIS's erosion-based purpose and need statements are satisfied by the No Action alternative. Erosion rates have reversed. No houses are imminently threatened. There is no indication that the inlet will migrate and erode the northern end of the island within the next 30 years. In sum, these developments undercut the rationale and justification for the proposed action, as well as the entire analysis presented in the DEIS.

III. The Corps Has Not Completed The Required Endangered Species Act Consultation.

Rich Inlet provides habitat for threatened and endangered piping plovers, Atlantic sturgeon, and sea turtles, as well as the rufa red knot, which has been proposed for listing. Because this project "may affect" these listed species and designated critical habitat, the Corps must consult with the expert wildlife agencies – U.S. Fish and Wildlife and the National Marine Fisheries Service – to determine the effects of the project on these resources. 16 U.S.C. § 1536(a)(2). While the DEIS stated that the Corps intended to conduct the consultation required by section 7 of the ESA, DEIS at 5, Corps staff confirmed in an email to the North Carolina Coastal Federation that such consultation has not been initiated, much less completed by the production of a biological opinion. See 16 U.S.C. § 1536(b). Production of such a "biological opinion" is required by the ESA and its implementing regulations unless the Corps determines, with the written concurrence of the expert wildlife agencies, "that the proposed action is not likely to adversely affect any listed species or critical habitat." 50 C.F.R. § 402.14.

The need and basis for formal consultation on this project were gestured at in the DEIS, but as noted in our 2012 comments, the biological information used there was woefully insufficient. The attached reports regarding shorebird use of Rich Inlet and Masonboro Inlet for 2008-2014 provide significantly more detailed, updated, and useful information regarding shorebird use of this habitat. In particular, these surveys examine the superior habitat of the unimproved Rich Inlet, versus the adjacent managed Masonboro Inlet, and document that both piping plovers and red knots used Rich Inlet in "significantly higher numbers" than Masonboro Inlet in 2014. The September 25, 2014, cover letter presenting this data to the U.S. Fish and Wildlife Service stated explicitly, "The amount and quality of shorebird habitat is much greater at Rich Inlet. These habitats include emergent roosting areas and inter-tidal sand and mud flats. These habitats are largely absent from Masonboro Inlet." Letter from L. Addison, Audubon, to P. Benjamin, USFWS, at 1-2 (Sept. 25, 2014).

Notably, Rich Inlet is providing important wintering habitat for the highly endangered Great Lakes population of piping plover. While all piping plovers in the United States are protected by the ESA, the Great Lakes population is listed separately as endangered. In 2013, the Fish and Wildlife Service observed 66 nesting pairs of this small population. Piping Plover-Great Lakes: 2013 Field Season Journal, Field Season 2013 Wrap Up (Sept. 9, 2013), available at http://www.fws.gov/midwest/EastLansing/te/pipl/2013FieldSeason.html. Rich Inlet has proven to be essential migrating and wintering habitat for this small population, with 20 individuals observed in the Inlet since 2008. Rich Inlet Survey at 13. In fact, the majority of banded piping plovers observed at Rich Inlet since 2008 (63%) were from the endangered Great Lakes population. Id.

This recent data indicates that the terminal groin project at Figure Eight Island may be likely to both jeopardize the continued existence of this endangered population of piping plover and adversely modify or destroy its designated critical habitat. Indeed, the Recovery Plan for the Great Lakes population identifies loss of wintering habitat due to "artificial structures, such as breakwalls and groins" as a primary reason that the species is endangered. Recovery Plan for the Great Lakes Piping Plover (*Chadrius melodus*), Dep't of the Interior, U.S. Fish and Wildlife Service at 22 (Sept. 2003). A finding that this project may jeopardize the continued existence of the Great Lakes population of piping plover or adversely modify its critical habitat and may require the modification or abandonment of the project. This is exactly why the ESA requires initiation of consultation early in the project development and provides that a completed biological opinion be presented, at the latest, with a completed FEIS. The Corps may not finalize the EIS until it can comply with this important requirement.

IV. Conclusion.

The Corps may not lawfully issue an FEIS for this project. As we stated in our 2012 comments, the HOA does not have, and cannot acquire through eminent domain, rights to the property needed to construct its preferred alternative. The DEIS evaluates an inlet with erosion rates that simply do not exist. Finally, the Corps has not conducted the required analysis of impacts to protected species required by the ESA. As a result, the Corps cannot comply with NEPA at this time and should not issue an FEIS for the proposed project.

Thank you for your consideration of these comments. Please contact either of us at (919) 967-1450 if you have any questions regarding this letter.

Sincerely,

Sierra B. Weaver
Senior Attorney

Geoffrey R. Gisler
Senior Attorney

Enclosures

cc: Todd Miller, North Carolina Coastal Federation
Walker Golder, Audubon North Carolina
Mickey Sugg, USACE

EXHIBIT 4

North Carolina’s Terminal Groins at Oregon Inlet and Fort Macon

Descriptions and Discussions

Oregon Inlet Terminal Groin

Introduction/Background

Oregon Inlet was created by a hurricane on September 8, 1846. The inlet separates Bodie Island to the north and Pea Island/Hatteras Island to the south (Figure 1). For the purpose of this report, Pea Island/Hatteras Island will be referred to as the Pea Island National Wildlife Refuge (PINWR).

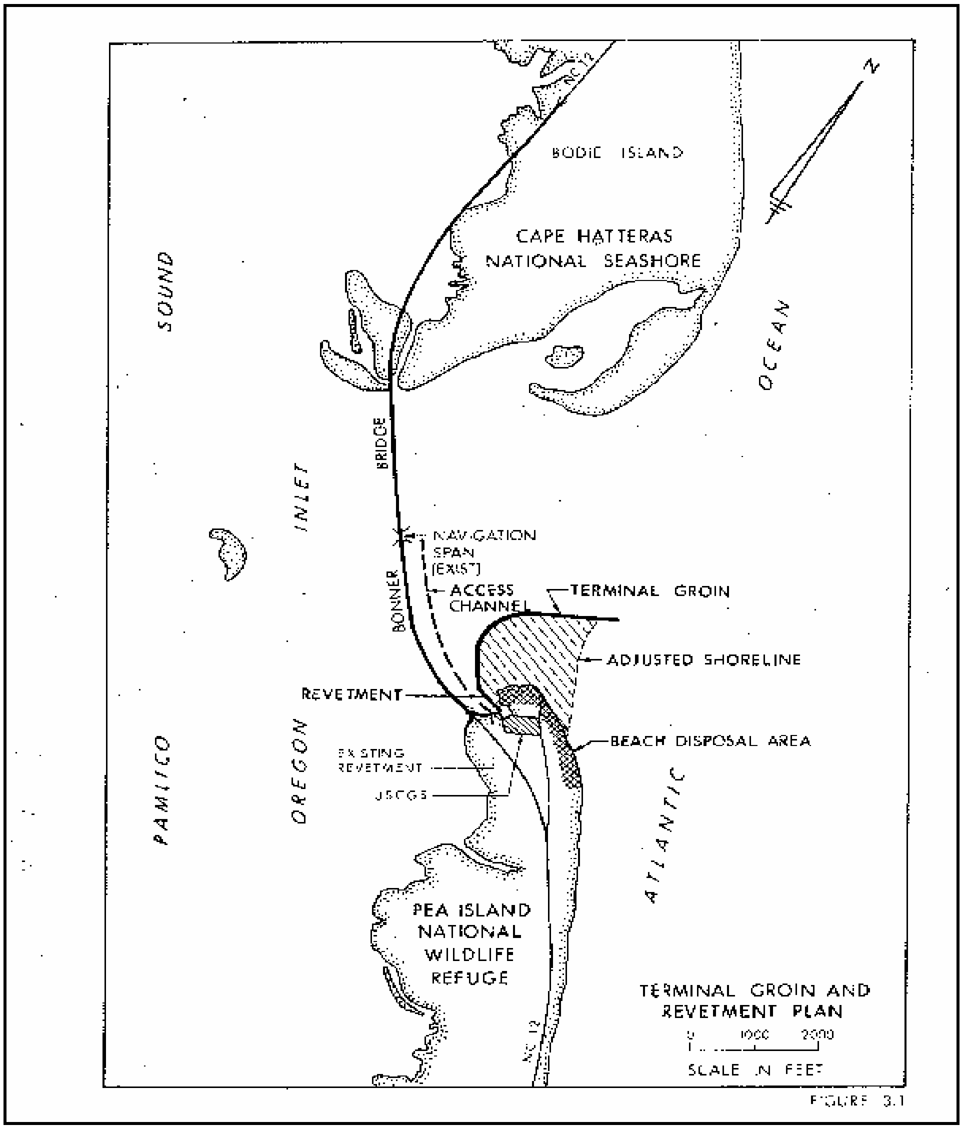

Figure 1. Location of Oregon Inlet and Terminal groin.

As with most natural tidal inlets, Oregon Inlet has had a history of dynamic change and migration since it's opening, having migrated more than 2 miles south of its original location. Because of the constantly shifting features of Oregon Inlet (Figure 2), the existing Herbert C. Bonner Bridge has been a maintenance issue for the North Carolina Department Of Transportation (NCDOT) since it was constructed in 1962. This highly turbulent area requires the US Army Corps of Engineers (USACE) to spend approximately five million dollars per year for dredging the Oregon Inlet channel. The USACE is only able to maintain the authorized 14-foot depth of the channel, on average about 25% of the time (Bill Dennis Pers Comm 2008). Shoreline change rates along both sides of the inlet are highly erosive with long-term rates of –5 ft to –17 ft/yr (Dennis and Miller 1993). The persistent southward Oregon Inlet migration has resulted in shorter-term erosion rates documented from 1981-1988, of approximately 180 ft/yr (Dennis and Miller 1993). Moreover, between April 1988 and March 1989, the erosion at the northern end of PINWR occurred at a rate of 1,150 ft/year. During one severe "nor'easter" in March 1989, the northern end of PINWR eroded 350 to 400 feet southward. This series of storms created the potential of destroying the southern abutment of the Bonner Bridge and severing the land transportation link between Bodie Island and PINWR. NCDOT data from 2002 show an average daily traffic of 5,400 vehicles per day with the highest daily traffic volume being 14,270 vehicles on Saturday, July 6. To ensure the Highway 12 transportation corridor was not lost, the USACE utilized engineering and design analysis of navigation jetties for Oregon Inlet in conjunction with the Manteo Shallowbag Bay project (NCDOT 1989) to design a terminal groin for the northern end of PINWR. The terminal groin was designed to be a portion of and incorporated into the jetties if and when they were constructed. The terminal groin construction was financed by the Federal Highway Administration with any maintenance and monitoring to be completed by the NCDOT.

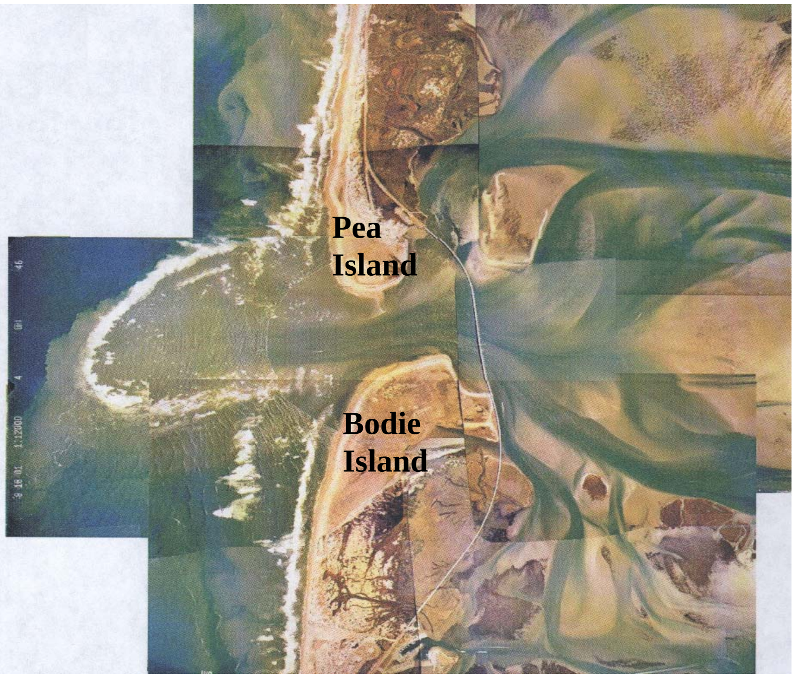

Figure 2. Dramatic aerial view of Oregon Inlet. Note the extensive sand bodies on the ocean (left) and sound side (right).

Terminal Groin Structure and Construction Description

The terminal groin at Oregon Inlet is located on the southern side of the inlet along the north end of the PINWR (Figure 1). The project consists of a terminal groin and revetment (3,125 and 625 feet long, respectively) starting at the US Coast Guard Station bulkhead. The groin extends from the bulkhead in a northwest direction, curving 90 degrees towards the northeast, and then straightening out again to be perpendicular with the natural inlet shoreline of PINWR. This alignment places the groin near the position that the north point of PINWR occupied in April 1985. An accretionary fillet was designed to impound sediment transported alongshore towards the inlet in order to provide enough wave sheltering for protection of the southern Bonner Bridge abutment. Once filled, the areal extent of this fillet was planned to be 60 acres. The groin was designed to withstand a still water level of eight feet above mean sea level (msl) and waves between 9 and 15 feet. The groin ranges in width between 110 to 170 feet at the base and 25 feet at the landward end to 39 feet at the seaward end. The design elevation ranged between 8 and 9.5 feet above msl (NCDOT 1989). Toe protection on the inlet side of the groin is provided by a 43 feet wide single layer of armor stone on top of a layer of core material (NCDOT 1989). Construction began in 1989 and was completed in October 1991 at a cost of 13.4 million dollars (1991 dollars).

The freestanding nature of the terminal groin in a position mimicking the 1985 shoreline relied on the natural coastal processes to deposit sediment along its landward (southern) side. For example, sediment transported towards the structure would begin to occupy the fillet until its design capacity was exceeded, at which point sediment would be transported around the end of the structure and towards the inlet. Therefore, the principal of a terminal groin is a temporary interruption of the sediment pathways with normal restoration of sediment pathways once the terminal groin fillet was impounded to capacity and sediment moved around the structure.

Although the net sediment transport direction at Oregon Inlet is from the north to the south, a substantial south-to-north component also exists in this area. 1992 estimates used for design and construction purposes by the USACE assumed an average northward transport (toward the inlet from PINWR) of 611,000 cubic yards with the southward transport (from Bodie Island) to be 1,473,000 cubic yards.

Terminal Groin Monitoring and Local Impacts

A monitoring program, developed by the USACE, NC DOT and the US Fish and Wildlife Service (USFWS), was required as part of the USACE permit by the Department of the Interior. Specifically the permit required that the six miles of shoreline south of the groin be monitored (Overton and Fisher 2007), and that the structure be designed to ensure that any accretion within the terminal groin fillet was not at the expense of the erosion along downdrift beach shorelines. Any adverse impacts above the historical erosion rates for this area would be mitigated by beach nourishment provided by NCDOT (Overton 2007). The monitoring program, which has been in place since construction, includes aerial photography, flown every other month and immediately after severe storms, as well as bi-annual seasonal (spring and autumn) field surveys during high tide, the NC DOT completes the flights and surveys, and the shoreline analysis is contracted to North Carolina State University (NCSU).

Whenever possible, dredged material from Oregon Inlet is to be placed on PINWR to mitigate the naturally occurring high erosion rates. Based on the most recent erosion data calculated by the North Carolina Division of Coastal Management (NCDCM), the long-term averages (50-60 years) for the 6 miles of shoreline south of the terminal groin range from 16 to 6.5 feet per year.

The quantity and disposal location(s) of sediment derived from dredging of the channel beneath the navigation span of Bonner Bridge and/or the ocean sand bar between August 31, 1989 and November 3, 2005 is shown in Table 1.

Table 1: Dredging activities for Oregon Inlet from
August 31, 1989 through November 3, 2005.

Disposal Method/Location	**Quantity (cubic yards)**
Offshore	522,799
Nearshore of PINWR (1.5 miles south, 16-20 ft water depth)	2,100,390
Piped to PINWR Beaches	4,914,920
Placed on a Disposal Island	167,258
Total	7,705,367
Total possible to affect PINWR	7,015,310

Inlet Migration and Sediment Bypassing

The inlet has persistently migrated southward since it opened in 1846, albeit with considerable variability. Alternate widening and narrowing of the inlet, due to hurricanes and northeasters, have accompanied this southward movement. Moreover, the channel throat has also undergone significant changes in both position and alignment. The channel has tended to follow two basic alignments, one approximately perpendicular to the adjacent shorelines (indicative of post-storm periods), and the other a more northerly alignment almost parallel to the shore (storm-free periods) (Figure 3.) (Sheldon et al. 1992). The latter description occurs when the north shoulder of the inlet (i.e., the southern end of Bodie Island) is in the form of an elongated spit, and the channel tends to rotate towards a more northerly alignment. As the inlet alignment changes, the inlet cross-section changes as well. A narrow and deep cross-section with steep banks occurs in relatively storm-free periods, while a shallow channel with wide overbanks occurs after stormy periods.

The construction of the terminal groin at the north end of PINWR does alter the natural processes described above at Oregon Inlet. With the PINWR groin in place, the migration of the north end of PINWR has ceased because the terminal groin immobilizes the south shoulder of the inlet. Therefore, future changes in inlet widths, channel depths, and channel orientations may not be in strict accordance with established historical norms. The inlet's stability, updrift and downdrift erosion rates are highly dependent on the natural bypassing of material across the inlet. Unfortunately, with or without the terminal groin, natural bypassing is not efficient at Oregon Inlet (Miller et al. 1996). The causes for this decrease in downdrift bypassing efficiency (producing downdrift shoreline erosion) include: periodic increases of sediment immediately updrift of Oregon Inlet causing accretion along southern Bodie Island, the renewed use of hopper dredges to maintain the navigation channel across the ocean bar removing sediment out of the nearshore system; and high retention rates of sand in the sound caused by frequent water circulation changes from storms. All of these factors influence Oregon Inlet's ability to bypass sediment downdrift.

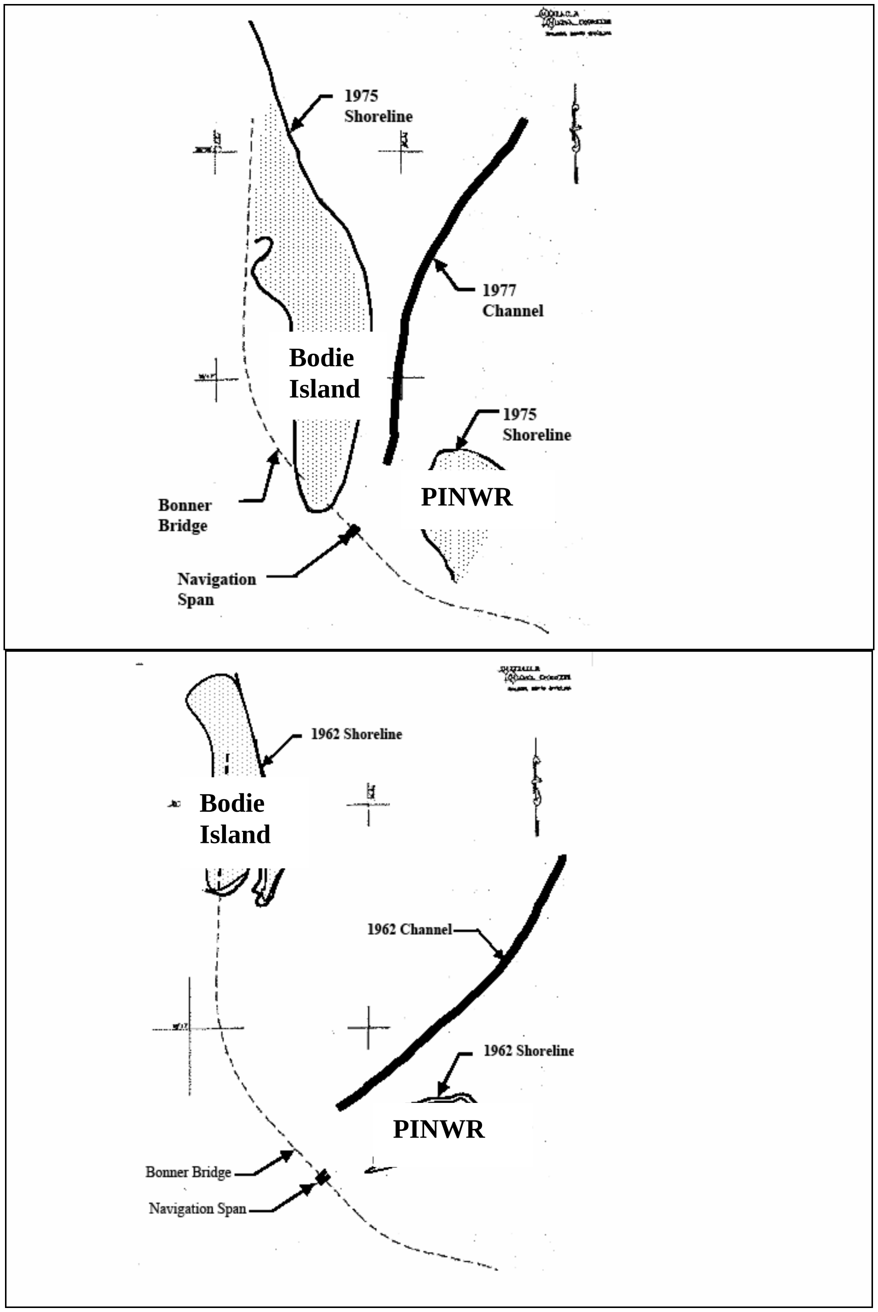

Figure 3. Top picture (1975) is indicative of pre-storm configurations of the Barrier Islands and channel orientation. Bottom picture (1962) is a typical post-storm configuration. (Sheldon et al 2000)

Shoreline Changes and Downdrift Impacts (1990-2006)

The USACE conducted a study in 1993 (Dennis and Miller 1993) of the pre- and post-construction shoreline changes in order to assess the overall impact of the terminal groin on the northern end of PINWR. The study assessed the shoreline up to four miles south of the terminal groin and reviewed five years of pre-construction and 2.5 years of post-construction data. The 50-acre fillet became impounded to capacity two years after the terminal groin entered the water (Jan 1990 to Jan 1992). This fairly short-term effect was attributed to a number of factors: (1) the fairly large south to north (toward the terminal groin) sediment transport rate of 611,000 cy/yr; (2) in the fall of 1991, the rate of northward sediment transport was greatly accelerated to 202,900 cy/month, due to two very large storms (1991 Halloween storm, and January 1992 storm); and (3) the placement of approximately 470,000 cy of fill material on to the PINWR beach from April to November of 1991. All of these factors contributed to positive impacts (i.e. oceanfront accretion) along an area that was approximately two miles south of the terminal groin. For the remaining two miles of shoreline to the south of this area, there has been no generalized trend in the shoreline response. In other words, the measured shoreline changes appear to be within the range of natural variability for this area. Similar findings over an area of six miles south of the terminal groin were reported by monitoring conducted by NCDOT (Overton, et al. 1996)

Inlet Navigation Morphological Changes

Joyner et al in 1998, conducted a study of the post-stabilization morphology of Oregon Inlet. The investigation examined data from the USACE and NCDOT programs from October 1989 through April 1997, to determine the relationship between the growth of the Bodie Island spit to the north and the resulting bathymetric changes in the inlet. This study provided insight as to the expected changes in configuration of the main inlet channel as the southern migration of Bodie Island spit approached the terminal groin along northern PINWR. Changes in the inlet's bathymetric configuration were observed in both the inlet width and orientation. Accretion of the spit on Bodie Island and the location of the terminal groin were responsible for a change in location and orientation of the main channel section. The shifting of the channel became noticeable in April 1995, which coincided with the beginning of a significant widening of the Bodie Island spit at the bridge. The shift of the channel bayward (landward) required a rotation of the inlet channel section, since the terminal groin remained fixed at the southern extent of the inlet. The inlet channel continued to move bayward and orient it self in a more northerly direction. Channel deepening also occurred along with its lateral migration. In order to maintain a constant cross-sectional area, a narrowing inlet must become deeper to accommodate the same discharge volume (also known as tidal prism). The data shows that this has happened since the terminal groin was constructed. According to Joyner et al. (1998), Oregon Inlet exhibited changes as expected with the stabilization of a single side of a tidal inlet.

Structure Maintenance

There has not been any maintenance needed to date on the Oregon Inlet terminal groin. Any maintenance that becomes necessary is to be conducted by the North Carolina Department of Transportation with potential federal funding from the Federal Highway Administration.

Summary and Conclusions

The terminal groin has stopped the southerly migration of Oregon Inlet and protected the base of the southern end of the Herbert C. Bonner Bridge. The terminal groin has impounded sediment resulting in a fillet with an approximate area of 50 acres.

The six miles of PINWR shoreline south of the terminal groin fillet that was monitored, continues to erode at rates that range from slightly more to slightly less than the pre-terminal groin shoreline erosion rates, in spite of frequent dredging and beach nourishment efforts.

Approximately 7.7 million cubic yards of sediment have been dredged from Oregon Inlet and mined from the terminal groin fillet to be either deposited on the PINWR beaches or in the nearshore ocean environment from one to six miles south of the terminal groin.

The main navigation channel has shifted laterally and has deepened to adjust to the reduced inlet width between the northern side of Bodie Island and the stabilized downdrift side of PINWR.

The consequences of this continued channel migration south are problematic for the maintenance of a navigation channel within the current fixed navigation span of the bridge, and require increased frequencies of channel dredging.

Locking an inlet in place with a terminal groin takes away the natural self-adjusting mechanisms that inlets possess (e.g., sediment bypass across the inlet, migration and depth change of the channel(s) within the inlet, shoreline migration along the inlet, changes in ebb tidal delta morphology). One of the most observable effects is the impact to sediment bypassing between the adjacent shorelines, and the exchange of sediment to the shoals that lie on the ocean side (ebb-tidal delta) and the estuarine side (flood-tidal delta). Overall, the sum of all coastal processes active within an inlet, and how these processes affect the transport and storage of sediment, are extremely important in not only how inlets function but also to the long-term survival and evolution of the barrier islands.

Over time, potentially within the next 10-20 years, and with continued southward migration of the Bodie Island spit, the main channel in Oregon Inlet may migrate against the terminal groin structure itself. If this were to occur, the result would be severe scour and an increase in the maintenance necessary to preserve the threatened integrity of the structure itself.

Beaufort Inlet/Fort Macon Terminal Groin

Introduction/Background

Beaufort Inlet has been continuously open since 1585, although the exact year of its creation is unknown (Payne 1985). Beaufort Inlet's adjacent beaches, Bogue Banks (west) and Shackleford Banks (east), are south facing beaches. The Bogue Banks area is sheltered somewhat from the damaging effects of winter extratropical nor'easters because of the very large shoal complex of Cape Lookout that lies approximately 12 miles to the east (Figure 4). Beaufort Inlet is utilized as part of the commercial navigation project connecting the Atlantic Ocean to the waterways of the NC State Ports' Morehead City (MHC) harbor and the Town of Beaufort (Figure 5). Improvements for navigation at Beaufort Inlet began in 1911 when a 300-ft wide channel was dredged through the ebb tidal shoal to a depth of –20 ft. In 1936, the outer bar channel was deepened to –30 ft and widened to 400 feet, and the channel location became fixed at this time. In 1997, the channel was dredged to -47 feet and 450 feet wide along the outer channel for approximately 2.5 miles. Interior channels and the Port of MHC are maintained at –45 ft depth. Since 1911, the navigation project channel depth and width has steadily increased, hastening the erosion along Beaufort Point (western side of inlet). Property in this area includes the historical Fort Macon, which was incorporated into the State Park system in 1924. In 2007, 1.2 million guests made the park the most visited State Park in the State. Erosion control structures have been a common occurrence adjacent to Beaufort Inlet since the construction of Fort Macon from 1829 to 1834. Around Fort Macon, there have been approximately 25 "hardened" erosion control structures including groins, breakwaters, timber cribbing, revetments, sand-fencing, and seawalls as well as numerous beach nourishment projects ("soft" erosion control). When emplaced, a hardened shoreline was deemed necessary to save Fort Macon from being lost to the sea (Figure 6).

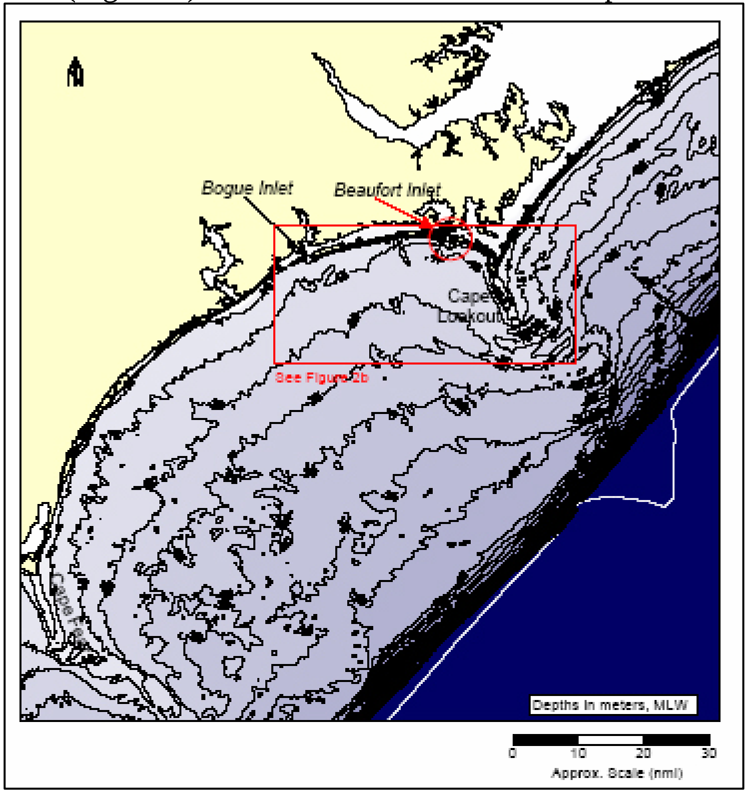

Figure 4. Location of Beaufort Inlet in proximity to Cape Lookout shoals (Olsen and Associates, 2004)

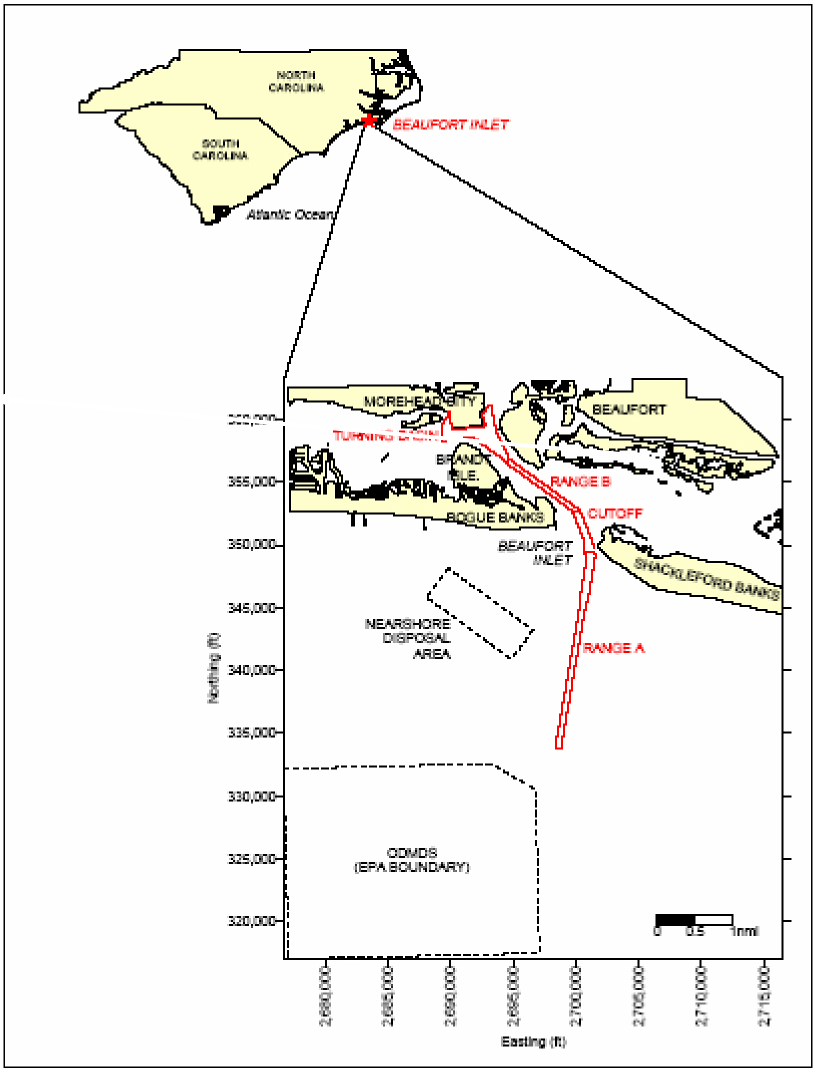

Figure 5. Location of federal navigation channel (red dotted line) in Morehead City and adjacent to Beaufort (Olsen and Associates, 2004)

Figure 6. Picture of Fort Macon terminal groin under construction from Nov 1961, and showing all the hard structures placed around the perimeter to try and offset the shoreline erosion.

In 2004, a study was prepared by Jacksonville, Florida-based Olsen Associates for Carteret County entitled “Regional Sand Transport Study: Morehead City Harbor Federal Navigation Project.” A plethora of information regarding the impacts of construction and maintenance of the navigation channel on the inlet and the adjacent barrier island complex of Bogue and Shackleford banks was detailed and quantified. The pre- (prior to 1936) and post-navigation project changes in the inlet morphology and adjacent shorelines helped establish a better understanding of the active coastal processes in the area and what effect, if any, the terminal groin at Fort Macon could have in stopping this erosion. The results discussed herein are taken mostly from their report.

Structure Description and Local Impacts

The construction of the Fort Macon terminal groin, revetment, and seawall was completed in three phases. The first phase began in 1961 and featured the construction of a seawall, revetment, and a portion of the terminal groin that, due to financial constraints, was only built to a length of 720 feet at an elevation of six feet instead of nine and excluded the structure's top armor layer. The revetment (250 feet) and seawall (530 feet) were constructed along the dune bank starting just north of the present-day Fort Macon parking lot in a southeastern direction.

Phase two began in 1965 and extended the groin by an additional 410 feet oceanward. An additional groin was constructed west of the revetment due to extensive erosion on the back, or sound side, of the island and its impact to the US Coast Guard Station. Beach fill (93,000 cubic yards) was also placed on the beach between the present day bathhouse and boardwalk region and the terminal groin.

The third and final phase began in August 1970, extended the terminal groin by an additional 400 feet to a total length of 1,530 feet. A stone groin, 480 feet long, was built near the bathhouse in an effort to stabilize beach fill placed in the area. Another 100,000 cubic yards of sand was placed in the bathhouse and boardwalk area for erosion mitigation.

The total cost of the terminal groin, beach fill, seawall, and revetment was $1,348,000 (1960s dollars). The two-thirds Federal cost share was $894,000.

A study completed by the USACE Wilmington District (USACE 1970) on possible placement of jetties at Beaufort Inlet discusses the impacts of the terminal groin between 1961 and 1970. According to that report, the terminal groin was functioning somewhat as a littoral barrier, with some sand passing through voids in the structures. By 1968, the fillet was full and sand was bypassing the outer end of the structure. Erosion had continued near the boardwalk and bathhouse area (approximately 7,000 feet west of the terminal groin) and is the reason for the additional groin placement during the third phase of construction. The volume of the westward accretion of sediment that began to occur when the fillet reached capacity was not calculated by the USACE in their 1970 investigation, but was determined not to have any effect on shoaling in the Port of MHC. DCM has approximated from a series of ortho-photographs dating back from 1962 – 2004, that the shoreline has migrated seaward approximately 400 feet over the past 40 years.

Inlet Morphological Changes

Records prior to 1839 indicate that the direction of the main ebb channel within the inlet had varied from somewhat west of south to southeast (USACE 1962). The inlet channel naturally migrated between the two islands. To illustrate this point, the locations of the inlet channel from a number of time periods between 1850 and 1960 are shown in Figure 7. Sand was exchanged between the adjacent shorelines and the inlet, and bypassed across the bar. The sediment transport movement was east to west, bypassing approximately 94,000 cy/yr, and the ebb shoal gained volume at a net rate of approximately 200,000 cubic yards per year. The inlet morphology was broader in nature with a semi-symmetrical ebb tidal shoal extending out into 10 to 15 feet of water (Figure 8).

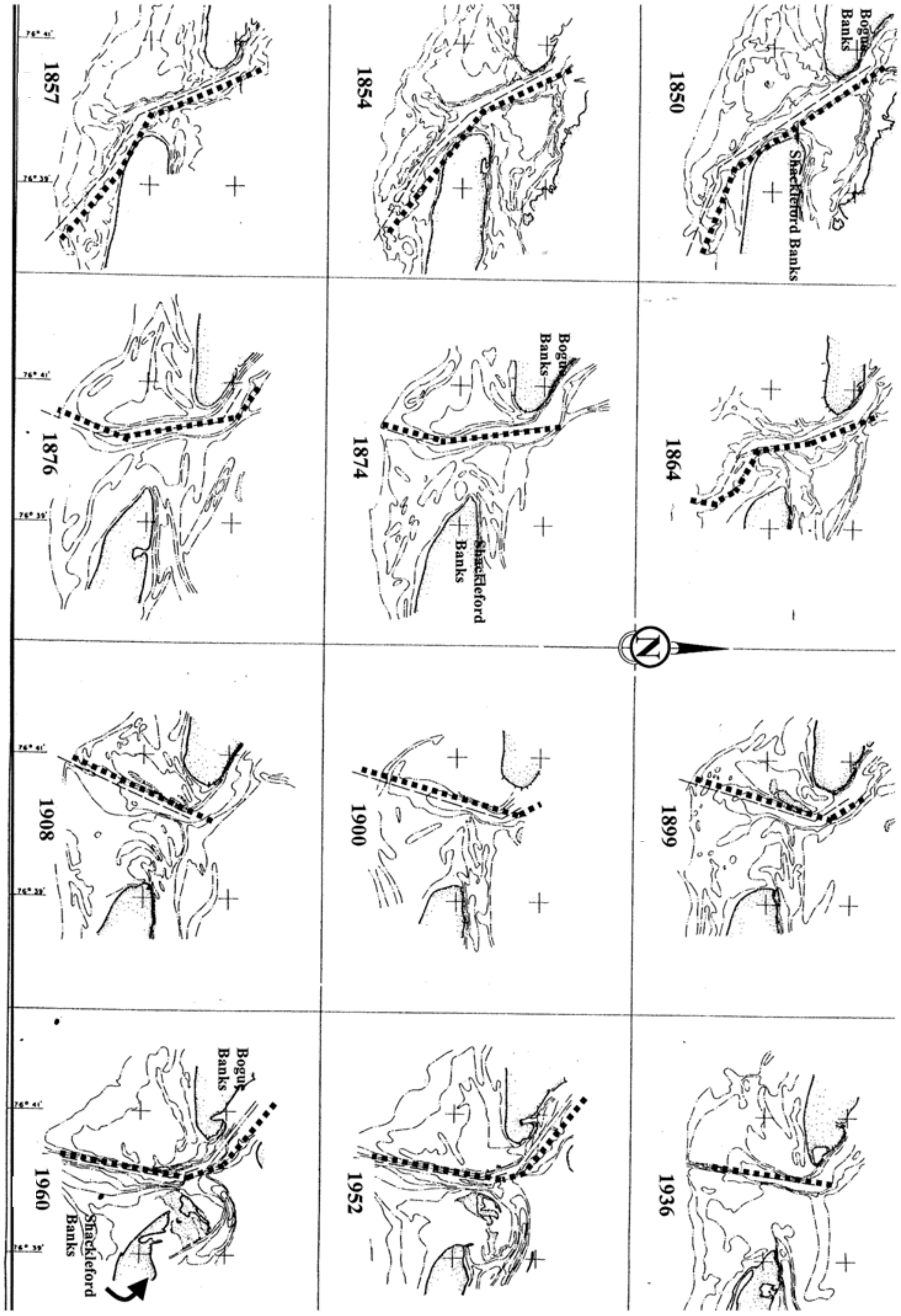

Figure 7. Various locations of the inlet channel from 1850 – 1908 (pre-project) and 1936-1960 (post project) (Modified from USACE 1962)

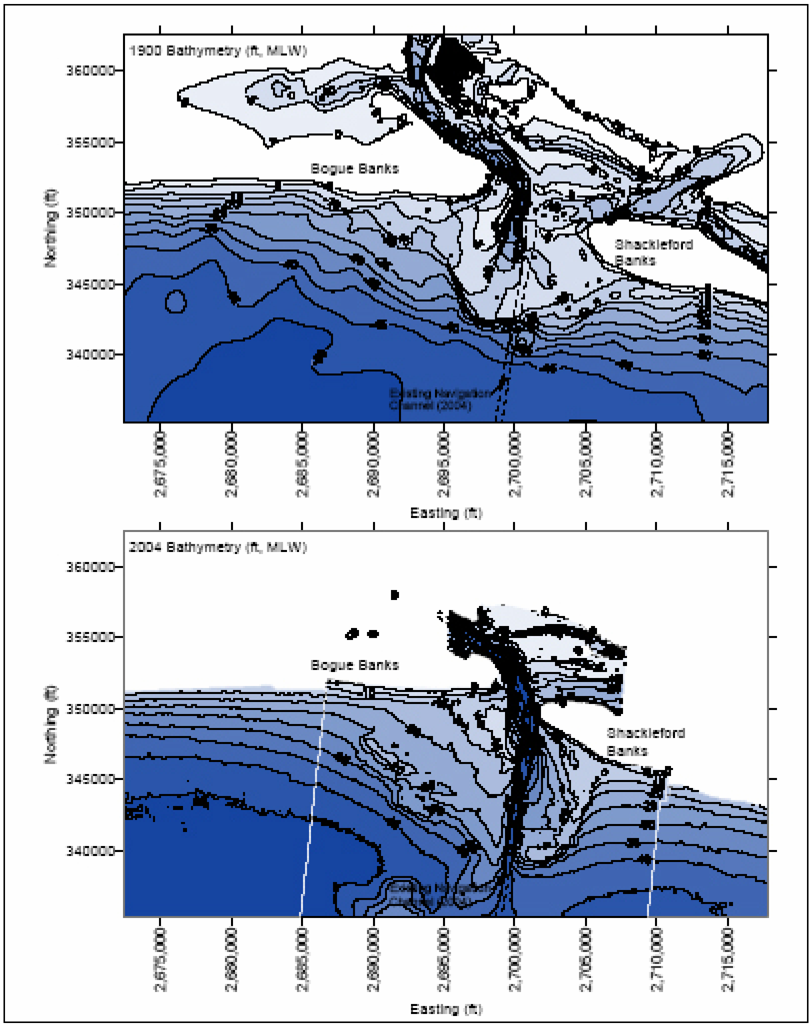

Figure 8. Differences in the shape of the inlet morphology from pre-project condition (1900) and Post project conditions (2004) (Olsen and Associates, 2004)

In contrast to the pre-project conditions (prior to 1936), the ebb tidal shoal is now much more elongated and non-symmetrical. The controlling depth through the inlet is now at 47 feet, extending seaward for approximately 2.5 miles. The seaward extent of the ebb shoal and ocean bar is influenced entirely by the seaward terminus of the navigation channel, and the channel precludes any natural sand bypassing across the inlet. The channel serves as a huge trap for any littoral material transported to the inlet from adjacent beaches. Currently, once the material is deposited into the channel it cannot be removed from the channel by natural processes, rather, it has to be removed by dredging during navigation maintenance operations. The removal of sediment from the inlet system at a volume in excess of the rate of longshore sediment transport has resulted in deflation or erosion of the ebb tide delta (USACE 2001) and deepening of the offshore beach profiles adjacent to the west side of the inlet along Bogue Banks (Figure 9; Olsen and Associates 2004).

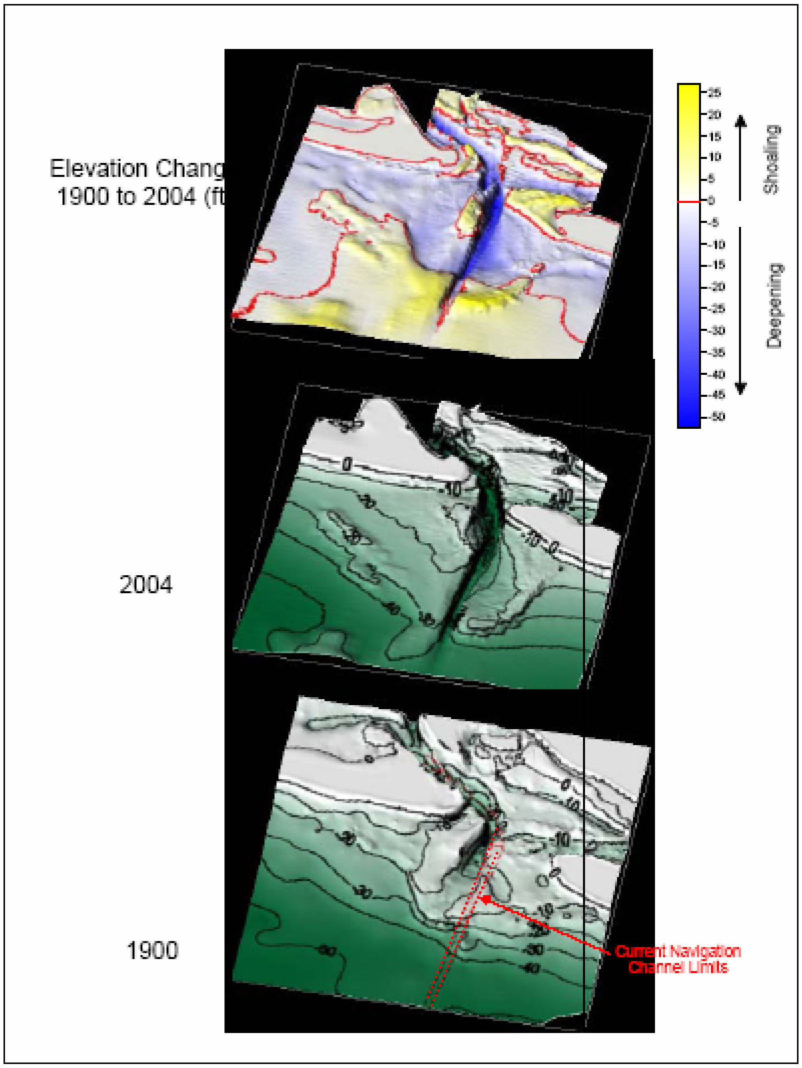

Figure 9. With the amount of material being removed from the inlet system by dredging exceeding the rate of longshore sediment transport, the result is deflation or erosion of the ebb tide delta (Olsen and Associates, 2004)

The deepening of the ebb tidal delta and offshore beach profiles has increased the wave energy along the western side of the channel along the Bogue Banks/Fort Macon area (Figure 10). This increase along Bogue Banks was three times greater than along Shackleford Banks. Future increases in wave energy are predicted, based upon the continued deflation of the ebb tidal shoal. This increase in wave energy will undoubtedly have an adverse impact on navigation and increase the wave energy within the inner harbors and sound including portions of the Rachel Carson National Estuarine Research Reserve (Olsen and Associates 2004).

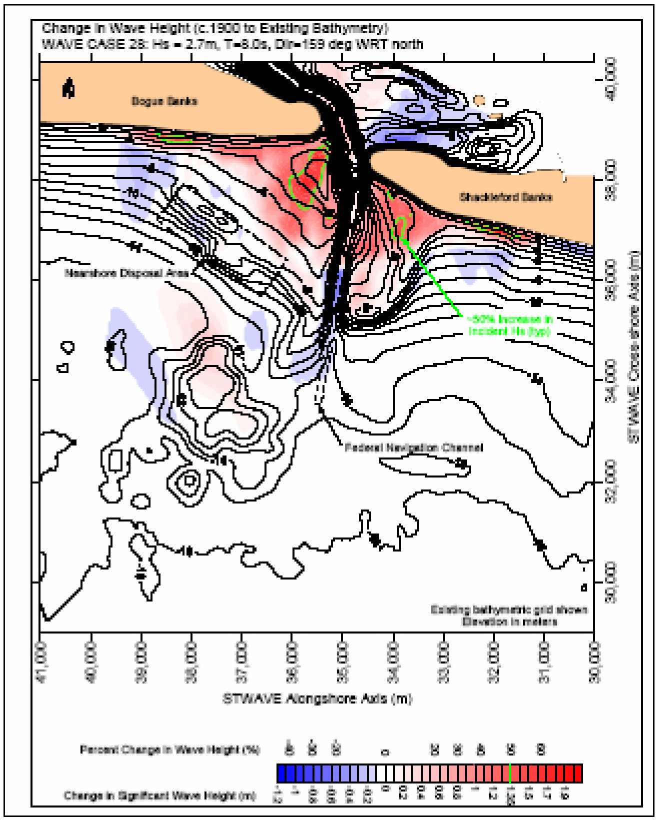

Figure 10. The deepening of the ebb tidal delta and offshore beach profiles has increased the wave energy along both sides of the channel

Sediment Transport and Shoreline Changes

The net littoral drift transport found along both Shackleford and Bogue Banks is east to west. However, at the east end of Bogue Banks, within 2.4 miles of Beaufort Inlet, there is a nodal point (a net easterly reversal) in sediment transport directed towards the inlet. The general location of this point is near the Triple S and Oceanna Piers in Atlantic Beach, although seasonal variation of its exact location occurs. The sediment that moves back towards Beaufort Inlet (east of this nodal point) is captured by the navigation channel and, thus, becomes unavailable for westward transport as it would in a natural system. This sediment deficit results in erosion on the inlet's western shoreline.

Prior to navigation improvements spanning 1876 to 1933, Beaufort Inlet was migrating in an eastward direction. During the first 40 years after navigation improvements from (i.e., 1933 to 1974), the migratory trend reversed, and Bogue Banks retreated rapidly back toward its 1876 location. Efforts were made to stabilize the inlet's eastern shoreline and protect Fort Macon with hardened structures. Between 1974 and 1994, beach disposal of inner harbor dredged material has resulted in a fairly stable Bogue Banks shoreline. Since 2004, the sand spit at Fort Macon has advanced along and into the western bank of the navigation channel inside the inlet throat, suggesting the terminal groin is now very inefficient at trapping sediment (Figures 11 and 12).

Figure 11. As nourished sand is put on the beach, the sand moves toward the inlet and through the terminal groin to just inside the western edge of Beaufort Inlet.

Figure 12. Sand spit growth showing the inability of the terminal groin to trap sediment.

Summary and Conclusions

Existing structures along Fort Macon include a terminal groin east of the fort and a relic groin field along the oceanfront and inlet throat shorelines. The low elevation and porous nature of these structures allow significant quantities of sand to be transported into the inlet resulting in persistent deposition of sand along the west bank of the inlet.

Ten years of shoreline change data (1997 to 2007) provided by Carteret County show no shoreline change along the five miles of oceanfront west of the groin. Since 2002, approximately 600,000 cubic yards were placed along this stretch of beach. This beach fill, at least in part, accounts for the “no net change” in shoreline position.

The ebb shoal deflation over time has exasperated the erosion along the Fort Macon side of the inlet. This loss of sediment volume steepened the nearshore beach profiles that, in turn, increased the wave energy reaching the coast and inner harbor area. Erosion of the shorelines adjacent to the inlet occurs as the inlet attempts to move sediment into the inlet to establish equilibrium and maintain its own sediment balance. Overall, Beaufort Inlet’s historical sediment bypassing capability, and its ability to maintain some form of stability/equilibrium with its adjacent shorelines, has been impeded, if not totally lost, by the additional trapping effect of the USACE-maintained navigation channel through the inlet.

The placement of sediment along the shoreline to the west of the inlet is still required for the Fort Macon State Park area, without which the vulnerability of Fort Macon to the forces of nature would be increased. The terminal groin and other hard structures, by themselves, would not be able to provide adequate protection to coastal hazards such as storms, tides and sea level rise. Without constant beach nourishment, the terminal groin would no longer perform as observed historically and, potentially fail altogether.

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EXHIBIT 5

From: Weaver, Cameron
Sent: Monday, December 19, 2011 12:11 PM
To: Wilson_Laney@fws.gov
Cc: Wilson, Debra; Snider, Holley; Huggett, Doug
Subject: RE: Ocean Isle Beach Terminal Groin Scoping
Attachments: Ocean Isle Beach Terminal Groin.pdf

Mr. Laney:

Thank you, sir, for your input. With this reply, I have forwarded your comments to the DCM District Manager, the DCM Field Representative and to Doug Huggett so that they are aware of your concurrence with USFWS' position on this issue. And I have added you to the distribution list for information on this project should I receive/distribute anything further. If you did not receive the entire email string and attachment that I originally sent to John Ellis, they are attached here.

Let me know if I may be of assistance.

Cameron

Cameron Weaver
Cameron.Weaver@ncdenr.gov
Environmental Assistance Coordinator
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910-796-7303 (F) 910-350-2004
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E-mail correspondence to and from this address may be subject to the North Carolina Public Records Law and may be disclosed to third parties.

From: Wilson_Laney@fws.gov [mailto:Wilson_Laney@fws.gov]
Sent: Monday, December 19, 2011 1:43 PM
To: Weaver, Cameron
Cc: Pete_Benjamin@fws.gov; John_Ellis@fws.gov; Tom_Augspurger@fws.gov
Subject: Ocean Isle Beach Terminal Groin Scoping

Cameron:

Reference Pete Benjamin's e-mail message to you dated/time-stamped December 16, 2011, 10:49 am [text pasted below in bold for your information].

I see Fish and Wildlife Service participation in this discussion as a very low priority. The issues are clear. A project of this nature will destroy the ecological functioning of this inlet and the surrounding areas. The science is unequivocal. I see no unique issues or areas of significant uncertainty in need of further evaluation. We oppose this project. There is nothing more to discuss. FYI, the Holden Beach side of the inlet (including the unnamed sandbars and islands in the inlet) is piping plover critical habitat. The project would destroy critical habitat and as such would require formal consultation. It would also adversely affect sea turtles under our jurisdiction and sea beach amaranth, so we will need to consult regarding them as well when and if the time comes. I know the regulatory agencies are fully familiar with

the Section 7 process and the information that will be needed to initiate consultation. I also understand that as regulatory agencies NCDENR and the Corps must go through the steps of reviewing this request and preparing the necessary assessments to document the effects of the proposed action. I have full confidence in your ability to do so. Feel free to keep us apprised via email as you move through the review process, and feel free to contact me or John Ellis if you have any specific questions, but we are operating on a very limited budget and are short staffed, so we must focus our limited resources where there are substantial natural resource issues to be resolved. The implications of this project on the area's natural resources are clear. As such, at this time our resources are needed elsewhere.

I concur with Pete's assessment of the impacts of the proposed Ocean Isle Beach Terminal Groin. I serve to provide technical support to him and his staff, with regard to fisheries-related issues which fall under the jurisdiction of the Atlantic States Marine Fisheries Commission, and the South Atlantic Fishery Management Council. I serve as the FWS Regional Director's (for ASMFC) or Assistant Regional Director-Fisheries (for the SAMFC) representative on these two institutions.

Construction of the proposed groin would likely have a significant impact on the transport of larval fish, shrimp, crabs and other estuarine-dependent species which are under the jurisdiction of either the Atlantic States Marine Fisheries Commission, and/or the South Atlantic Fishery Management Council. One or both of these management institutions may wish to comment on the proposed project, therefore I am requesting that you add me to your distribution list for the proposed project.

Should you have questions regarding the jurisdiction of either of these institutions with regard to fishery resources which would be impacted by the proposed project, please feel free to contact me.

/s/ Wilson
R. Wilson Laney, Ph.D., Coordinator
South Atlantic Fish and Wildlife Conservation Office
U.S. Fish and Wildlife Service
P.O. Box 33683
Raleigh, North Carolina 27636-3683
Voice: 919-515-5019
Cell: 252-339-5717
Fax: 919-515-4454
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----- Forwarded by John Ellis/R4/FWS/DOI on 12/13/2011 09:40 AM -----

"Weaver, Cameron"
<cameron.weaver@ncdenr.gov>

12/08/2011 02:34 PM

To "Baker, Jessi E" <jessi.baker@ncdenr.gov>, Ron Sechler <ron.sechler@noaa.gov>, "Snider, Holley" <holley.snider@ncdenr.gov>, "Wilson, Debra" <debra.wilson@ncdenr.gov>, "Simpson, Shaun" <shaun.simpson@ncdenr.gov>, "Huggett, Doug" <doug.huggett@ncdenr.gov>, "Timpy, David L SAW" <David.L.Timpy@usace.army.mil>, "Ellwood, Molly M." <molly.ellwood@ncwildlife.org>, "Hall, Rhonda" <rhonda.hall@ncdenr.gov>, "Humphrey, Jeremy" <jeremy.humphrey@ncdenr.gov>, "Coburn, Chad" <chad.coburn@ncdenr.gov>

cc Daisy Ivey <daisy@oibgov.com>, "james.Jarrett@shawgrp.com" <james.Jarrett@shawgrp.com>, "john_ellis@fws.gov" <john_ellis@fws.gov>, "Willis, Linda" <linda.willis@ncdenr.gov>, Brigit Flora <bflora@brunsco.net>

Subject Ocean Isle Beach Terminal Groin Scoping meeting

EXHIBIT 6

A Fiscal Analysis of Shifting Inlets and Terminal Groins in North Carolina

Andrew S. Coburn, Associate Director

Program for the Study of Developed Shorelines
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Executive Summary

North Carolina contains some of the most unique and biologically rich coastal ecosystems in the United States, providing immeasurable aesthetic, habitat, recreational and economic benefits. In order to successfully - and equitably - balance long-term environmental and sustainability needs with short-term economic development concerns, state and local coastal management policies, rules and laws must be both technically and fiscally-sound.

Nowhere is this more evident than at North Carolina's tidal inlets where these dynamic natural features, once used to lure economic development, are now considered the primary threat to the very development they were used to attract.

In response to the risk shifting inlets pose to static economic development, NC coastal communities and property owners typically rely on three mechanisms to protect vulnerable coastal property: 1) Beach restoration 2) Inlet channel realignment and 3) Sandbags.

Beach restoration involves the import and emplacement of sand on an eroding beach in order to artificially stabilize inlet and ocean shorelines. Inlet channel realignment modifies the position and orientation of an inlet's main ebb channel in an effort to reduce impacts and erosion rates along adjacent shorelines. Sandbags are a temporary measure intended to provide short-term protection to imminently threatened structures until a more "permanent" solution can be implemented.

A fourth approach, now being actively promoted by some in North Carolina, is the use of terminal groins: shore-perpendicular erosion control structures made of rock or steel placed at the ends of islands near dynamic coastal inlets.

Session Law 2009-479 in 2009 instructed the NC Coastal Resources Commission (CRC) to study the feasibility and advisability of terminal groins as erosion control devices. The study, completed in April 2010 at a cost of $280,000, included an assessment of the potential economic impacts of shifting inlets to the state, local governments and the private sector from erosion due to shifting inlets, but failed to provide compelling evidence regarding the economic or fiscal benefits of terminal groins.

As a follow-up to that study, the Program for the Study of Developed Shorelines (PSDS) at Western Carolina University examined the economic role of coastal property at ten North Carolina tidal inlets (Bogue, New River, New Topsail, Rich, Mason, Carolina Beach, Cape Fear, Lockwood Folly, Shallotte and Tubbs) to evaluate the potential fiscal costs of property loss as well as fiscal benefits of terminal groins in ten coastal municipalities (Emerald Isle, North Topsail Beach, Topsail Beach, Wrightsville Beach, Carolina Beach, Bald Head Island, Caswell Beach, Oak Island, Holden Beach and Ocean Isle Beach), five coastal counties (Carteret, Onslow, Pender, New Hanover and Brunswick) and one private island (Figure 8 Island).

Based on this study, PSDS has determined that:

1) Assessed value does not reflect the potential fiscal impacts of shifting inlets to the state or local governments from erosion due to shifting inlets,
2) The fiscal benefits of protecting property at-risk to shifting inlets are small compared to the costs of protection,
3) The use of terminal groins would provide limited fiscal and economic benefits to state taxpayers and local communities and
4) Long-term costs of a terminal groin exceed potential long-term benefits at every developed NC inlet.

This analysis indicates that, even ignoring environmental concerns, terminal groins are not a fiscally-sound strategy for dealing with coastal property at-risk to shifting inlets and, due to their limited fiscal benefits, the expenditure of state funds for groin construction/maintenance is bad public policy.

1) Assessed value does not accurately reflect the fiscal contribution investment property at-risk to shifting inlets makes to North Carolina's coastal municipal and county economies

According to the CRC terminal groin study, the purpose of the economic assessment component of the study was to assess economic value within areas around developed inlets called 30-year risk areas (30 YRAs) that contain a level of risk approximately equal to the risk indicated by setbacks in adjacent oceanfront areas, as well as the economic value of properties in 30 YRAs having temporary sandbag protection (Table 1).

Table 1: North Carolina 30-Year Risk Areas

1. Emerald Isle/Bogue Inlet	8. Bald Head Island/Cape Fear Inlet
2. North Topsail Beach/New River Inlet	9. Caswell Beach/Cape Fear Inlet
3. Topsail Beach/New Topsail Inlet	10. Oak Island/Lockwood Folly Inlet
4. Figure 8 Island/Rich Inlet	11. Holden Beach/Lockwood Folly Inlet
5. Figure 8 Island/Mason Inlet	12. Holden Beach/Shallotte Inlet
6. Wrightsville Beach/Mason Inlet	13. Ocean Isle Beach/Shallotte Inlet
7. Carolina Beach/Carolina Beach Inlet	14. Ocean Isle Beach/Tubbs Inlet

A number of components of economic value within these 30 YRAs were considered including residential property, commercial property, government property, road infrastructure, waterline infrastructure, sewer infrastructure, property tax base and revenues and recreation and environmental value. The greatest potential economic impact of shifting inlets, according to the CRC study, is to residential property, which the study quantifies in terms of assessed value.

But an economic assessment that focuses almost exclusively on assessed coastal property value - the dollar value of an asset assigned by a public tax assessor for the purposes of taxation - is misleading because changes in value do not accurately reflect actual fiscal impacts coastal counties, municipalities and the state may experience as a result of shifting inlets.

Taxation or, more specifically, ad valorem tax revenue based on assessed value and generated by residential property, does, however, reflect the potential fiscal impacts various levels of government may experience due to shifting inlets along the North Carolina coast.

Ad valorem taxes comprise an average of about 57% of all revenue collected by North Carolina coastal county and municipal governments (Table 2). From the perspective of a public entity such as a coastal municipality or county, the potential loss of ad valorem (and to a similar extent occupancy and sales) tax revenue generated by at-risk residential coastal property represents an accurate and meaningful way to quantify the tangible costs of shifting inlets.

Table 2: NC Coastal Municipal and County Ad Valorem Tax Revenue

Jurisdiction	Budget Year	General Fund (GF) Revenue	Ad Valorem Tax Revenue	Ad Valorem Tax Revenue as a % of GF Revenue
Bald Head Island	FY 2010/11	$8,246,160	$6,815,618	83%
Carolina Beach	FY 2009/10	$8,203,250	$4,125,000	50%
Caswell Beach	FY 2010/11	$1,011,618	$547,000	54%
Emerald Isle	FY 2010/11	$7,016,691	$3,437,423	49%
Holden Beach	FY 2009/10	$2,417,773	$1,507,023	62%
Kill Devil Hills	FY 2009/10	$12,035,612	$5,278,985	44%
Kitty Hawk	FY 2009/10	$5,721,795	$2,476,750	43%
Kure Beach	FY 2010/11	$2,891,452	$1,538,914	53%
Nags Head	FY 2009/10	$11,292,993	$4,490,743	40%
North Topsail Beach	FY 2010/11	$3,339,166	$1,903,186	57%
Oak Island	FY 2010/11	$11,341,185	$6,472,902	57%
Ocean Isle Beach	FY 2010/11	$4,156,762	$2,349,000	57%
Sunset Beach	FY 2009/10	$4,748,773	$2,213,468	47%
Surf City	FY 2010/11	$5,887,153	$3,120,586	53%
Topsail Beach	FY 2010/11	$2,092,670	$1,314,690	63%
Wrightsville Beach	FY 2008/09	$7,722,822	$2,644,346	34%
Brunswick County	FY 2010/11	$136,232,066	$100,331,000	74%
Carteret County	FY 2010/11	$74,918,385	$43,290,000	58%
Currituck County	FY 2010/11	$44,028,000	$24,936,000	57%
Dare County	FY 2010/11	$99,244,631	$49,309,278	50%
New Hanover County	FY 2010/11	$253,919,849	$158,778,525	63%
Onslow County	FY 2010/11	$163,799,539	$70,261,500	43%
Pender County	FY 2009/10	$49,261,230	$30,238,766	61%
Municipal and County Combined Total		**$919,529,575**	**$527,380,703**	**57%**

Ad valorem tax rates for coastal municipalities and counties adjacent to a developed coastal inlet in North Carolina are $.1559/$100 and $.4455/$100 respectively (Table 3). The loss of a residential coastal property assessed at $1 million, therefore, would result in an annual loss of $6,014 in ad valorem tax revenue [$1,000,000/100 * (.1559 +.4455)] - or just 0.6% of the property's $1 million assessed value.

Table 3: NC Coastal Municipal and County Ad Valorem Tax Rates

Municipality	FY 2010-11 Tax Rate
Bald Head Island	0.2700
Carolina Beach	0.1750
Caswell Beach	0.1300
Emerald Isle	0.0800
Holden Beach	0.0690
North Topsail Beach	0.2355
Oak Island	0.1400
Ocean Isle Beach	0.0900
Topsail Beach	0.3100
Wrightsville Beach	0.0800
AVERAGE	**0.1559**

County	FY 2010-11 Tax Rate
Brunswick County	0.3050
Carteret County	0.2300
New Hanover County	0.4525
Onslow County	0.5900
Pender County	0.6500
AVERAGE	**0.4455**

According to the CRC study, 1,983 residential properties with an assessed value of about $1.4 billion are within the state's fourteen 30 YRAs. While losing all at-risk properties is unlikely, the potential fiscal impact to North Carolina's coastal municipalities and counties would be $7,127,087 - the combined local and county ad valorem tax revenue these properties currently generate but would not in the future (Table 4). Over 30 years, using a discount rate of 3% and price appreciation rate of 5%, the loss of 1,983 at-risk coastal properties would result in a loss of ad valorem tax revenue totaling about $292 million - or about 25% of assessed value.

Table 4: Properties "At-Risk" to Shifting Inlets

Municipality	Year	Total Ad Valorem Tax Revenue Collected	"At-Risk" Properties	Ad Valorem Tax Revenue Generated by At-Risk Properties
Bald Head Island	FY 2010/2011	$6,815,618	323	$1,017,647
Carolina Beach	FY 2009/2010	$4,125,000	39	$60,776
Caswell Beach	FY 2010/2011	$547,000	100	$135,483
Emerald Isle	FY 2010/2011	$3,437,423	96	$71,560
Figure 8 Island	N/A	N/A	114	N/A
Holden Beach	FY 2009/2010	$1,507,023	343	$207,756
North Topsail Beach	FY 2010/2011	$1,903,186	376	$157,356
Oak Island	FY 2010/2011	$6,472,902	102	$181,335
Ocean Isle Beach	FY 2009/2010	$2,349,000	124	$54,931
Topsail Beach	FY 2010/2011	$1,314,690	184	$103,165
Wrightsville Beach	FY 2008/2009	$2,644,346	182	$83,863
		$31,116,188	**1983**	**$2,073,872**
County				
Brunswick County	FY 2010/2011	$100,331,000	992	$2,705,286
Carteret County	FY 2010/2011	$43,290,000	96	$205,735
New Hanover County	FY 2010/2011	$158,778,525	335	$1,531651
Onslow County	FY 2010/2011	$70,261,500	376	$394,224
Pender County	FY 2009/2010	$30,238,766	184	$216,313
		$402,899,791	**1983**	**$5,053,209**
Total Ad Valorem Tax Revenue generated by properties in 30 YRA				**$7,127,087**

The use of assessed value grossly overstates the value of coastal property at risk to, and the potential fiscal impacts of, shifting inlets, thereby resulting in the misperception that much more is at risk than actually is.

Using ad valorem tax revenue rather than assessed value provides a pragmatic approach for evaluating the true value of "at-risk" properties as well as estimating the potential fiscal impact state, county and municipal economies could experience as a result of shifting inlets.

An issue that should be considered when evaluating the value of coastal property at risk to shifting inlets, but not discussed in the CRC report or this white paper, is the contribution public policies and actions such as state and federally-subsidized insurance and shore protection projects make to assessed values and, ultimately, ad valorem tax revenue.

2) The fiscal benefits of protecting investment property at-risk to shifting inlets are small compared to the costs of protection

While ad valorem, sales and occupancy tax revenue is critical for maintaining the economic viability of coastal North Carolina, an analysis of 30 YRAs at ten NC tidal inlets shows that the contribution residential properties at-risk to shifting inlets make to North Carolina's coastal municipal and county economies is insignificant.

Table 5 shows the contribution residential property at risk to shifting inlets makes at the municipal and county level. While coastal counties have more than twice the amount of ad valorem tax revenue at risk than coastal municipalities ($5,053,216 vs. $2,073,872), the relative importance of ad valorem tax revenue generated by at-risk property is greater for municipalities than counties. For example, the total loss of all at-risk residential properties in the Caswell Beach/Cape Fear 30 YRA would eliminate $135,483 - nearly 25% of the municipal ad valorem tax revenue collected by Caswell Beach. Brunswick County's loss of $317,865 in county ad valorem tax revenue - 2.3 times more than Caswell Beach – represents only 0.32% of its ad valorem tax revenue.

Table 5: Assessed Value of, and Ad Valorem Tax Revenue Generated by, At-Risk Coastal Properties by 30 YRA

Community	County	Inlet	Assessed Value of At-Risk Property	2010 Municipal Ad Valorem Tax Revenue Generated by At-Risk Properties	2010 County Ad Valorem Tax Revenue Generated by At-Risk Properties
Bald Head Island	Brunswick	Cape Fear	$310,732,000	$1,017,647	$947,733
Carolina Beach	New Hanover	Carolina Beach	$34,729,000	$60,776	$161,664
Caswell Beach	Brunswick	Cape Fear	$104,218,000	$135,483	$317,865
Emerald Isle	Carteret	Bogue	$89,450,000	$71,560	$205,735
Figure 8	New Hanover	Rich	$163,186,000	N/A	$759,631
Figure 8	New Hanover	Mason	$46,408,941	N/A	$216,034
Holden Beach	Brunswick	Lockwood Folly	$27,240,000	$18,796	$83,082
Holden Beach	Brunswick	Shallotte	$273,855,000	$188,960	$835,258
North Topsail Beach	Onslow	New River	$66,817,693	$157,356	$394,224
Oak Island	Brunswick	Lockwood Folly	$109,900,000	$181,335	$335,195
Ocean Isle Beach	Brunswick	Shallotte	$25,069,000	$22,562	$76,460
Ocean Isle Beach	Brunswick	Tubbs	$35,966,000	$32,369	$109,696
Topsail Beach	Pender	New Topsail	$33,279,000	$103,165	$216,314
Wrightsville Beach	New Hanover	Mason	$84,710,027	$83,863	$394,325
			$1,405,560,661	**$2,073,872**	**$5,053,216**

Of the ten municipalities with a 30 YRA, only three have more than 10% of their ad valorem tax base in a 30 YRA: Caswell Beach: 24.8%, Bald Head Island: 14.9% and Holden Beach: 12.5%. The remaining municipalities have an average of 3.2% of their ad valorem tax base in a 30 YRA. No coastal county has more than 1% of its ad valorem tax base in a 30 YRA (Table 6).

Table 6: The Contribution of At-Risk Coastal Properties to Ad Valorem Tax Revenue by 30 Year Risk Area

Community	Inlet	County	2010 Municipal Ad Valorem Tax Revenue Generated by At-Risk Properties	% of Municipal Ad Valorem Tax Revenue At-Risk	2010 County Ad Valorem Tax Revenue Generated by At-Risk Properties	% of County Ad Valorem Tax Revenue At-Risk
Bald Head Island	Cape Fear	Brunswick	$1,017,647	14.9%	$947,733	0.96%
Carolina Beach	Carolina Beach	New Hanover	$60,776	1.5%	$161,664	0.10%
Caswell Beach	Cape Fear	Brunswick	$135,483	24.8%	$317,865	0.32%
Emerald Isle	Bogue	Carteret	$71,560	2.1%	$205,735	0.46%
Figure 8	Rich	New Hanover	N/A	N/A	$759,631	0.48%
Figure 8	Mason	New Hanover	N/A	N/A	$216,034	0.14%
Holden Beach	Lockwood Folly	Brunswick	$18,796	1.2%	$83,082	0.08%
Holden Beach	Shallotte	Brunswick	$188,960	12.5%	$835,258	0.85%
North Topsail Beach	New River	Onslow	$157,356	8.3%	$394,224	0.54%
Oak Island	Lockwood Folly	Brunswick	$181,335	2.8%	$335,195	0.34%
Ocean Isle Beach	Shallotte	Brunswick	$22,562	1.0%	$76,460	0.08%
Ocean Isle Beach	Tubbs	Brunswick	$32,369	1.3%	$109,696	0.11%
Topsail Beach	New Topsail	Pender	$103,165	7.8%	$216,314	0.70%
Wrightsville Beach	Mason	New Hanover	$83,863	3.2%	$394,325	0.25%
			$2,073,872		**$5,053,216**	

In order to provide an assessment of the current or imminently at-risk property due to potential erosion from shifting inlets, the CRC study identified properties having temporary sandbag protection. These properties are considered at imminent risk, rather than at risk over a 30-year period. Properties located immediately adjacent to erosion control sandbag locations, or between two nearby sandbag locations, were considered to be Imminent Risk Properties (IRPs). Sandbag locations on ocean facing or inlet-facing beaches within the 30 YRAs were considered to be inlet IRPs.

Of the state's 1,983 properties within a 30 YRA, 204 (10.3%) are classified as an inlet IRP (Table 7). These properties have an assessed value of $89.6 million and generate $445,767/year in municipal ($102,244) and county ($343,523) ad valorem tax revenue (Table 8).

Table 7: Imminent Risk Properties Within 30-Year Risk Areas

Community	Inlet	County	At-Risk Properties	Imminent Risk Properties (IRP)	IRPs as a % of At-Risk Properties
Bald Head Island	Cape Fear	Brunswick	323	22	6.8%
Carolina Beach	Carolina Beach	New Hanover	39	0	0.0%
Caswell Beach	Cape Fear	Brunswick	100	0	0.0%
Emerald Isle	Bogue	Carteret	96	13	13.6%
Figure 8 Island	Rich	New Hanover	89	16	18.0%
Figure 8 Island	Mason	New Hanover	25	0	0.0%
Holden Beach	Lockwood Folly	Brunswick	150	32	21.3%
Holden Beach	Shallotte	Brunswick	193	0	0.0%
North Topsail Beach	New River	Onslow	376	37	9.8%
Oak Island	Lockwood Folly	Brunswick	102	0	0.0%
Ocean Isle Beach	Shallotte	Brunswick	85	24	28.2%
Ocean Isle Beach	Tubbs	Brunswick	39	3	7.7%
Topsail Beach	New Topsail	Pender	184	57	31.0%
Wrightsville Beach	Mason	New Hanover	182	0	0.0%
		TOTAL	**1983**	**204**	**10.3%**

Table 8: Summary of Imminent Risk Properties (IRP)

# Imminent Risk Properties (IRP)	204
% of all Properties in 30 YRA that are IRP	10.3%
Assessed Value of IRPs	$89,610,211
2010 Municipal Tax Revenue generated by IRPs	$102,244
2010 County Tax Revenue generated by IRPs	$343,523
Total 2010 Tax Revenue generated by IRPs	$445,767

As table 9 shows, the loss of all imminent risk properties, a more plausible scenario than the loss of all at-risk properties, would result in an insignificant loss of municipal and county ad valorem tax revenue in every 30 YRA:

- Bald Head Island has $35,920 in municipal ad valorem tax revenue at imminent risk in the Bald Head Island/Cape Fear 30 YRA – the most of any NC coastal municipality. This amount, however, represents only 0.55% of the town's total ad valorem tax revenue.
- New Hanover County has $120,881 in county ad valorem tax revenue considered in imminent risk in the Figure 8/Rich 30 YRA – the most of any NC coastal county. This amount represents only 0.08% of the ad valorem tax revenue collected by the county in 2010.
- Topsail Beach is the only municipality with more than 1% of its ad valorem revenue classified as being in imminent risk. Pender County is the only county with even 0.1% of its ad valorem tax revenue in imminent risk.

Table 9: Contribution of IRPs to Ad Valorem Tax Revenue by 30 Year Risk Area

Community	Inlet	County	2010 Municipal Ad Valorem Tax Revenue Generated by IRPs	% of Municipal Ad Valorem Tax Revenue in Imminent Risk	2010 County Ad Valorem Tax Revenue Generated by IRPs	% of County Ad Valorem Tax Revenue in Imminent Risk
Bald Head Island	Cape Fear	Brunswick	$35,920	0.55%	$33,452	0.03%
Carolina Beach	Carolina Beach	New Hanover	$0	0.00%	$0	0.00%
Caswell Beach	Cape Fear	Brunswick	$0	0.00%	$0	0.00%
Emerald Isle	Bogue	Carteret	$11,500	0.34%	$33,062	0.07%
Figure 8	Rich	New Hanover	$0	0.00%	$120,881	0.08%
Figure 8	Mason	New Hanover	$0	0.00%	$0	0.00%
Holden Beach	Lockwood Folly	Brunswick	$12,024	0.79%	$53,152	0.05%
Holden Beach	Shallotte	Brunswick	$0	0.00%	$0	0.00%
North Topsail Beach	New River	Onslow	$6,863	0.35%	$17,193	0.02%
Oak Island	Lockwood Folly	Brunswick	$0	0.00%	$0	0.00%
Ocean Isle Beach	Shallotte	Brunswick	$2,312	0.10%	$7,835	0.01%
Ocean Isle Beach	Tubbs	Brunswick	$5,760	0.24%	$19,520	0.02%
Topsail Beach	New Topsail	Pender	$27,865	2.11%	$58,428	0.19%
Wrightsville Beach	Mason	New Hanover	$0	0.00%	$0	0.00%
			$102,244		**$343,523**	

3) The use of terminal groins would provide limited fiscal and economic benefits to state taxpayers and local coastal communities

Because the CRC study leaves the efficacy of constructing terminal groins at developed North Carolina inlets unresolved, it is difficult to accurately quantify the long-term fiscal benefits terminal groins may or may not produce over a period of 30 years.

It is possible, however, to make two assumptions about terminal groins based on the study:

1. All IRPs in North Carolina will be lost over the next 30 years without terminal groins and
2. If they work intended, terminal groins may protect IRPs for the next 30 years.

Because the effectiveness of terminal groins beyond IRPs is highly uncertain, IRPs represent at-risk coastal properties most likely to benefit from terminal groins and the continued generation of municipal and county ad valorem tax revenue by IRPs within 30 YRAs is the primary fiscal benefit of constructing a terminal groin in a 30 YRA.

In the Ocean Isle Beach/Shallotte Inlet 30 YRA, for example, the primary annual benefit of constructing a terminal groin is $10,147 - the combined municipal and county ad valorem tax revenue currently generated by 24 IRPs in this 30 YRA. Over 30 years, using a discount rate of 3% and price appreciation rate of 5%, the primary fiscal benefit of constructing a terminal groin in Ocean Isle Beach at Shallotte Inlet is $415,633 (Table 10).

Table 10 shows that the estimated annual primary fiscal benefit of constructing a terminal groin in each of the state's 30 YRAs is $445,767. Over 30 years, using a discount rate of 3% and price appreciation rate of 5%, the primary fiscal benefit of constructing terminal groins in all 30 YRAs (even though six have no IRPs) is $18,259,148. Note that this table includes only municipal and county ad valorem tax revenue due to the small number of impacted properties (204) and limited contribution of other revenue sources.

Table 10: Primary Fiscal Benefit of a Terminal Groin by 30 Year Risk Area

Community	Inlet	County	2010 Municipal Ad Valorem Tax Revenue Generated by IRPs	2010 County Ad Valorem Tax Revenue Generated by IRPs	2010 Combined Ad Valorem Tax Revenue Generated by IRPs	NPV of Ad Valorem Tax Revenue Generated by IRPs Over 30 Years
Bald Head Island	Cape Fear	Brunswick	$35,920	$33,452	$69,372	$2,841,560
Carolina Beach	Carolina Beach	New Hanover	$0	$0	$0	$0
Caswell Beach	Cape Fear	Brunswick	$0	$0	$0	$0
Emerald Isle	Bogue	Carteret	$11,500	$33,062	$44,562	$1,825,313
Figure 8	Rich	New Hanover	$0	$120,881	$120,881	$4,951,430
Figure 8	Mason	New Hanover	$0	$0	$0	$0
Holden Beach	Lockwood Folly	Brunswick	$12,024	$53,152	$65,176	$2,669,687
Holden Beach	Shallotte	Brunswick	$0	$0	$0	$0
North Topsail Beach	New River	Onslow	$6,863	$17,193	$24,056	$985,362
Oak Island	Lockwood Folly	Brunswick	$0	$0	$0	$0
Ocean Isle Beach	Shallotte	Brunswick	$2,312	$7,835	$10,147	$415,633
Ocean Isle Beach	Tubbs	Brunswick	$5,760	$19,520	$25,280	$1,035,499
Topsail Beach	New Topsail	Pender	$27,865	$58,428	$86,293	$3,534,664
Wrightsville Beach	Mason	New Hanover	$0	$0	$0	$0
			$102,244	**$343,523**	**$445,767**	**$18,259,148**

4) Long-term costs of a terminal groin exceed potential long-term benefits at every developed NC inlet

The CRC study estimates the initial cost of constructing a 1,500-foot terminal groin, similar in size to the structure currently at Fort Macon, to be $10,850,000 with total annual maintenance costs of about $2,250,000. Using a 3% discount rate and price appreciation rate of 5%, the estimated total cost of constructing and maintaining one terminal groin in North Carolina over 30 years is approximately $54,950,993.

This amount is more than ten times greater than the potential long-term fiscal benefit of constructing a groin at Figure 8/Rich Inlet ($4,951,430) and about three times greater than the combined long-term benefit of constructing terminal groins at all fourteen 30 YRAs ($18,259,148).

Given the CRC study and an evaluation of other terminal structures, a scenario in which terminal groins protect only IRPs over a 30-year period is rational. However, due to uncertainty in the efficacy of terminal groins, PSDS also assessed a “best-case” scenario in which the benefits of terminal groins extend to every at-risk property within every 30 YRA for 30 years.

In this scenario, long-term costs are projected to exceed potential long-term benefits (measured by the continued generation of ad valorem tax revenue) in every 30 YRA except Bald Head Island/Cape Fear (Table 11). It should be noted that the potential fiscal benefits of constructing and maintaining a terminal groin at Bald Head Island over a period of 30 years are split almost equally between Bald Head Island ($41,684,034) and Brunswick County ($38,820,273).

Table 11: Estimated "Best-Case" Fiscal Benefit of a Terminal Groin by 30 Year Risk Area

Community	Inlet	County	2010 Municipal Ad Valorem Tax Revenue Generated by all At-Risk Properties	2010 County Ad Valorem Tax Revenue Generated by all At-Risk Properties	2010 Total Ad Valorem Tax Revenue Generated by all At-Risk Properties	NPV of Ad Valorem Tax Revenue Generated by all At-Risk Properties Over 30 Years
Bald Head Island	Cape Fear	Brunswick	$1,017,647	$947,733	$1,965,380	$80,504,307
Carolina Beach	Carolina Beach	New Hanover	$60,776	$161,664	$222,440	$9,111,408
Caswell Beach	Cape Fear	Brunswick	$135,483	$317,865	$453,348	$18,569,674
Emerald Isle	Bogue	Carteret	$71,560	$205,735	$277,295	$11,358,334
Figure 8	Rich	New Hanover	N/A	$759,631	$759,631	$31,115,391
Figure 8	Mason	New Hanover	N/A	$216,034	$216,034	$8,849,010
Holden Beach	Lockwood Folly	Brunswick	$18,796	$83,082	$101,878	$4,173,044
Holden Beach	Shallotte	Brunswick	$188,960	$835,258	$1,024,218	$41,953,190
North Topsail Beach	New River	Onslow	$157,356	$394,224	$551,580	$22,593,374
Oak Island	Lockwood Folly	Brunswick	$181,335	$335,195	$516,530	$21,157,684
Ocean Isle Beach	Shallotte	Brunswick	$22,562	$76,460	$99,022	$4,056,059
Ocean Isle Beach	Tubbs	Brunswick	$32,369	$109,696	$142,065	$5,819,152
Topsail Beach	New Topsail	Pender	$103,165	$216,314	$319,479	$13,086,241
Wrightsville Beach	Mason	New Hanover	$83,863	$394,325	$478,188	$19,587,150

Discussion

Assessed property values do not reflect the potential costs of shifting inlets to coastal municipalities, counties or the state. Ad valorem tax revenue generated by at-risk coastal property represents a more realistic and accurate way to quantify the potential fiscal impacts a North Carolina coastal county or municipality might expect as a result of shifting inlets.

The assessed value of 1,983 properties at-risk to shifting inlets in North Carolina is approximately $1.4 billion. Losing every at-risk property, however, would translate into an annual loss of $7,127,087 in county and municipal ad valorem tax revenue – a figure that is 0.5% of assessed value. Over 30 years, using a discount rate of 3% and price appreciation rate of 5%, the NPV of this statewide loss is $292 million.

While $7,127,087 in annual lost ad valorem tax revenue seems significant, it represents less than 5% of municipal ad valorem tax revenue and 0.37% of county ad valorem tax revenue collected by NC coastal communities and counties containing a developed in 2010.

Of the state's 1,983 at-risk properties, 204 are classified as Imminent Risk Properties (IRPs). These properties represent 0.45% of coastal municipal ad valorem tax revenue and 0.04% of coastal county ad valorem tax revenue collected in 2010.

IRPs also represent the primary beneficiaries of terminal groins, and the continued generation of ad valorem tax revenue by IRPs resulting from the emplacement of terminal groins can be used to quantify the potential fiscal benefits of terminal groins.

Using IRPs as a proxy to estimate the impacts of terminal groins, annual municipal benefits range from $0 in seven locations (Carolina Beach/Carolina Beach Inlet, Caswell Beach/Cape Fear Inlet, Figure 8/Rich Inlet, Figure 8/Mason Inlet, Holden Beach/Shallotte Inlet, Oak Island/Lockwood Folly Inlet and Wrightsville Beach/Mason Inlet) to $35,920 in Bald Head Island.

Annual County benefits using IPRs as a proxy range from $0 in six locations (Carolina Beach/Carolina Beach Inlet, Caswell Beach/Cape Fear Inlet, Figure 8/Mason Inlet, Holden Beach/Shallotte Inlet, Oak Island/Lockwood Folly Inlet and Wrightsville Beach/Mason Inlet) to $120,881 in Figure Eight Island.

The NPV of ad valorem tax revenue generated by IRPs and assumed to be protected by a terminal groins over 30 years, using a discount rate of 3% and price appreciation rate of 5%, ranges from $0 in six locations (Carolina Beach/Carolina Beach Inlet, Caswell Beach/Cape Fear Inlet, Figure 8/Mason Inlet, Holden Beach/Shallotte Inlet, Oak Island/Lockwood Folly Inlet and Wrightsville Beach/Mason Inlet) to $4,951,430 at Figure Eight Island/Rich Inlet.

The annual fiscal benefit of constructing and maintaining a terminal groin at every developed NC inlet, in terms of protecting municipal and county ad valorem tax revenue generated by IRPs, is $445,767. The NPV of this ad valorem tax revenue over 30 years, using a discount rate of 3% and price appreciation rate of 5%, is $18,259,148.

When the protective benefits of terminal groins are extended to all 1,983 at-risk properties, the NPV potential fiscal benefits (over the next 30 years) range from about $4 million at Ocean Isle Beach/Shallotte Inlet to about $80.5 million at Bald Head Island/Cape Fear.

The cost of constructing and maintaining one terminal groin in North Carolina over 30 years, using a discount rate of 3% and price appreciation rate of 5%, is estimated by the NC CRC to be $54,900,993. When put in proper context, the cost of constructing and maintaining a terminal groin exceeds potential fiscal benefits at every North Carolina inlet.

Summary of Findings

- Assessed property value is not an accurate metric for quantifying the fiscal impacts of chronic erosion and coastal storm impacts and should not be used to justify the expenditure of public funds for erosion control measures.
- A fiscal analysis of tax revenue impacts to NC coastal municipalities, counties and the state is a sound methodology by which to evaluate the potential impacts of shifting inlets as well as potential costs and benefits of constructing and maintaining terminal groins.
- The average annual fiscal impact, in terms of property tax revenue, of losing a $1 million coastal property in NC is $6,014.
- The combined impact of losing a coastal property at-risk to shifting inlets in NC is about 0.6% of the property's assessed value.
- 1,983 residential coastal properties are considered at-risk to shifting inlets in NC.
- Properties at-risk to shifting inlets represent about 9% of all municipal and county ad valorem tax revenue collected coast-wide in 2010.
- Of the ten NC municipalities adjacent to a shifting inlet only Caswell Beach, Bald Head Island and Holden Beach have more than 10% of their ad valorem tax base at risk to shifting inlets. The remaining coastal municipalities have an average of 3.2% of their ad valorem tax base at-risk to shifting inlets.

- Of the 1,983 coastal properties at risk to shifting inlets, 204 (10.3%) are classified as being in imminent risk.
- Properties in imminent risk to shifting inlets represent about 0.08% of all municipal and county ad valorem tax revenue collected coast-wide in 2010.
- The CRC study estimates the cost of constructing and maintaining one terminal groin in North Carolina over 30 years to be approximately $54,950,993.
- Using IRPs as a proxy for estimating the impacts of terminal groins, annual fiscal benefits of constructing a terminal groin at every developed NC inlet is $445,767. Over 30 years, the primary fiscal benefit of constructing a terminal groin at every developed inlet is $18,259,148.
- Terminal groins are not a fiscally-sound strategy for dealing with coastal property at-risk to shifting inlets
- The limited fiscal benefits produced by terminal groins do not justify the expenditure of state funds.