

STATE OF NORTH CAROLINA

BEFORE THE CHAIRMAN
COASTAL RESOURCES COMMISSION

COUNTY OF BRUNSWICK

IN THE MATTER OF)
THE VILLAGE OF BALD HEAD ISLAND)
AND J. ANDREW SAYRE,)
A REQUEST FOR DECLARATORY)
RULING ON APPROPRIATE SETBACK)
FACTORS FOR WEST BEACH OF)
BALD HEAD ISLAND)

ORDER

Petitioners The Village of Bald Head Island and J. Andrew Sayre (“Petitioners”) request that the North Carolina Coastal Resources Commission (“CRC” or “Commission”) issue a declaratory ruling regarding the applicability of 15A NCAC 7H .0304, .0306 and .0310 (oceanfront erosion setback factors in inlet hazard AEC) as they are applied to the area of Bald Head Island known as “West Beach.”

II. STANDARD OF REVIEW

Under the North Carolina Administrative Procedure Act, a person aggrieved may request that an agency issue a declaratory ruling as to the applicability to a given state of facts of a rule or the agency, except when the agency for good cause finds issuance of a ruling undesirable. N.C.G.S. § 150B-4(a).

The Commission has delegated the authority to its Chairman to grant or deny requests for declaratory rulings, based upon the following factors, set forth in 15A NCAC 7J .0603(a):

1. Whether the Division, the Petitioner, and any other directly affected person have agreed on a set of undisputed facts sufficient to support a meaningful ruling;
2. Whether the matter is the subject of a pending contested case hearing; and
3. Whether a genuine controversy exists as to the application of a statute or rule to a proposed project or activity.

The Commission has also delegated the authority to its Chairman to determine whether notice of the declaratory ruling request should be provided to anyone other than the adjacent property owners. 15A NCAC 7J .0603(a) and (c).

III. FINDINGS OF FACT

- A. Petitioner filed its Request for a Declaratory Ruling on June 9, 2009.
- B. Also on June 9, 2009, the Division of Coastal Management (“Division”), pursuant to 15A NCAC 7J .0603(a), recommended to the Chairman that he consent to issue a ruling and

place the matter on the agenda for the CRC's proposed meeting on June 24, 2009. The Division's Recommendation noted that Petitioner's Request for a Declaratory Ruling was not the subject of a contested case proceeding and agreed that there was a genuine controversy regarding the applicability of the Commission's rules to Petitioners' property, i.e., whether 15A NCAC 7H .0304, .0306 and .0310 apply to Petitioners' property and through that, to the Village. Specifically, the Division agrees that the current rules require the application of the 8-foot erosion rate to "West Beach" which, as recently calculated by Division Staff, actually has a long-term erosion rate average closer to 2.3 feet per year. While this situation is currently addressed by draft inlet-hazard rules the Commission is considering, budget concerns affecting Commission meeting scheduling and possible legislation affecting the rulemaking process may delay passage of the current draft rules.

- C. The Division recommendation noted that DCM agreed with the list of the undisputed facts proposed by Petitioners and upon which the Request for a Declaratory Ruling would be based.

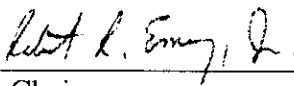
IV. CONCLUSIONS

- A. The Request for a Declaratory Ruling meets the requirements of 15A NCAC 7J .0603(a);
- B. The parties should address in their written and oral arguments all questions reasonably raised by the Request for Declaratory Ruling.
- C. Pursuant to 15A NCAC 7J .0603(b), the Division shall provide written notice of the Declaratory Ruling Request to the individuals identified as adjacent owners, to the public through notice on the Division's website, and to the North Carolina Coastal Federation. Notice shall also be provided to the citizens of the Village of Bald Head Island by publication in a newspaper of general circulation in the community.

V. DECISION

The Petitioner's Request for a Declaratory Ruling will be placed on the Commission's agenda of its June 24, 2009 meeting for decision on the merits of Petitioner's Request.

This the 10th day of June, 2009.



Bob Emory, Chairman
N.C. Coastal Resources Commission

CERTIFICATE OF SERVICE

This is to certify that I have served a copy of the attached Order on Petitioners' Counsel by the methods indicated below:

Charles S. Baldwin, IV
Rountree, Losee & Baldwin, LLP
2419 Market Street
Wilmington, NC 28403

CERTIFIED MAIL/
RETURN RECEIPT REQUESTED
and electronically to
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Assistant Attorney General

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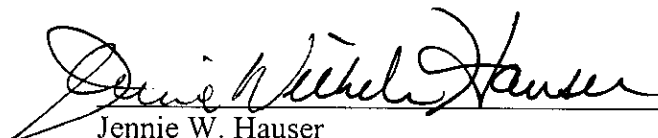
James H. Gregson
Director of DCM

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Angela Willis
Assistant to Director of DCM

electronically Angela.Willis@ncdenr.gov

This the 10th day of June, 2009.



Jennie W. Hauser
Special Deputy Attorney General

STATE OF NORTH CAROLINA
COUNTY OF BRUNSWICK

BEFORE THE NORTH CAROLINA
COASTAL RESOURCES COMMISSION

In the matter of)
REQUEST FOR DECLARATORY)
RULING ON EROSION RATE ALONG)
WEST BEACH OF BALD HEAD ISLAND)
AND APPLICATION OF RELEVANT)
INLET HAZARD AREA REGULATIONS)

REQUEST FOR A
DECLARATORY RULING

The Village of Bald Head Island (the “Village”) and J. Andrew Sayre (“Sayre”) (collectively the “Requestors”), through undersigned counsel, respectfully request a Declaratory Ruling by the Coastal Resources Commission (the “Commission”) setting the annual erosion rate along West Beach of Bald Head Island (“West Beach”). Authority for this petition lies in N.C.G.S. § 113A-124(c)(7), 15A NCAC 07H .0304 and 15A NCAC 07J .0602. In support of the requested ruling, Requestors show the Commission:

A. PROCEDURAL REQUIREMENTS

1. Requestors’ names and addresses: The Village of Bald Head Island, Post Office Box 3009, Bald Head Island, North Carolina 28461; J. Andrew Sayre, Post Office Box 3259, 131 West Bald Head Wynd, Bald Head Island, North Carolina 28461.
2. The Village and Sayre are each a “person aggrieved” under the meaning set forth in N.C. Gen. Stat. § 150B-2(6).
3. Requestors seek a declaration setting an erosion rate along West Beach pursuant to N.C.G.S. § 113A-124(c)(7), 15A NCAC 07H .0304 and 15A NCAC 07J .0602.
4. This Request is being filed with the Director of the Division of Coastal Management, James H. Gregson, at 400 Commerce Avenue, Morehead City, North Carolina 28577, and also the Attorney General’s Office at 9001 Mail Service Center, Raleigh, North Carolina 27699-9001.
5. As evidenced by certified mail receipts, copies of the present Request have been sent to the owners of property in and adjacent to West Beach (**Exhibit A** (list)).

B. FACTUAL BACKGROUND AND PERTINENT RULES

1. West Beach lies directly along the Cape Fear River inlet and falls within both the current and proposed inlet hazard area zones. *See Exhibit B* (map of Bald Head Island).
2. For the purposes of this Request, West Beach is defined as the area within the existing inlet hazard area between transects one (1) through forty (40), inclusive, on *Exhibit C* (map of West Beach).
3. Pursuant to 15A NCAC 07H .0310(a)(1), “[a]ll development in the inlet hazard area shall be set back from the first line of stable natural vegetation a distance *equal to the setback required in the adjacent ocean hazard area.*” (Emphasis added).
4. Pursuant to 15A NCAC 07H.0306(a)(1), the setback distance for single-family development or multi-family development of three units or less in the ocean erodible area is defined by a distance equal to the erosion rate multiplied by a factor of thirty (30). The setback distance for small-scale (less than 5,000 square feet) multi-family development greater than three units and commercial development is also a distance equal to the erosion rate multiplied by a factor of thirty (30). For large-scale (5,000 square feet and greater) multi-family development greater than three units and commercial development, the setback distance is equal to the erosion rate multiplied by a factor of sixty (60) or, for areas with an erosion rate greater than 3.5 feet per year, a distance equal to the erosion rate multiplied by a factor of thirty (30) plus 105 feet. 15A NCAC 07H .0304(1)(a) defines that “erosion rates shall be the long-term average based on available historical data” as depicted on a map updated through 1998 (the “1998 Map”).
5. Unlike the State’s other inlet shorelines, no erosion rates along West Beach or the coastline north of West Beach are depicted on the Division of Coastal Management’s 1998-era erosion rate maps.
6. An eight (8) feet annual erosion rate applies to the homes and lots along South Beach immediately adjacent to the Bald Head Island inlet hazard area. Therefore, pursuant to 15A NCAC 07H.0304(a)(1), this rate is extrapolated to all areas inside the inlet hazard area, including West Beach where the Division of Coastal Management has recently calculated site-specific erosion rates to be approximately two feet per year or less. The eight (8) feet annual erosion rate currently applied to West Beach is derived from erosion rates calculated by the Division of Coastal Management for the portion of South Beach immediately adjacent to the South Beach portion of the inlet hazard area (i.e., on the other side of the “point” from West Beach). *See Exhibit B* (map of Bald Head Island).

7. In consequence, numerous homes and lots along West Beach are being subjected to a two hundred forty (240) feet building setback (8 foot erosion rate x 30) rather than a setback of sixty (60) feet (2 foot erosion rate x 30).
8. Approximately thirty million dollars (\$30,000,000.00) worth of properties are potentially effected along West Beach by the application of a South Beach erosion rate of eight (8) feet per year. *See Exhibit D* (list of properties effected and tax valuations).
9. This effect on West Beach properties results in decreased values to the Village and Brunswick County tax bases. Approximately eight (8) property owners have obtained, and others reportedly are obtaining, tax valuation reductions based on the non-conforming or unbuildable nature of the properties based on a setback distance of 240 feet (erosion rate of 8 feet per year x 30).
10. Sayre and other individual property owners allege they are being harmed by the non-conforming and “unbuildable” nature of their properties. *See Exhibits E1 and E2* (statements by Sayre and Jack Nichols, West Beach property owners, made to Commission at February 2009 meeting).
11. Currently, the Commission is in the lengthy process of amending the inlet hazard area regulations. An intended result of such process is to amend both the inlet hazard area affecting Bald Head Island, and to amend the applicable rules therein. In their current state, the proposed rules contemplate a two (2) feet annual erosion rate along West Beach. *See Jeffrey Warren, Ph.D., CRC Memorandum 09-05: Proposed Development Policies for Expanded Inlet Hazard Area Boundaries* (January 28, 2009) (attached as **Exhibit F** and proposing two feet annual erosion rate to few areas in North Carolina, including West Beach, without assigned erosion rates on current map, Table 1, Page 3).
12. Even assuming all possible efficiency, these inlet hazard area amendments cannot reasonably be expected within the coming year. Causes of delay include: (i) budget cuts forcing the Commission to either abbreviate or altogether cancel scheduled meetings; and (ii) Senate Bill 866, which, if enacted, would prohibit the Commission from effectuating any rule change that has an economic impact (most likely encompassing the proposed amendments to the inlet hazard area regulations).
13. The Commission has the immediate authority to vary the 1998 erosion rate map through “individual contested cases, *declaratory* or interpretive rulings.” 15A NCAC 07H .0304(1)(a) (emphasis added).
14. The relief sought herein is interim and would not affect pending Commission rulemaking related to the inlet hazard area boundaries and development conditions within said boundaries.

C. PROPOSED STIPULATED FACTS

1. West Beach is defined for the purposes of this Request as the area within the existing inlet hazard area between transects one (1) through forty (40), inclusive, shown on **Exhibit C**.
2. For purposes of oceanfront setback delineation, an annual erosion rate of eight (8) feet applies by rule to the area of West Beach within the inlet hazard area.
3. The eight (8) feet annual erosion rate results in an oceanfront setback distance of 240 feet landward of the first line of stable and natural vegetation for small or non-commercial structures
4. The 240 feet building setback applies to thirteen (13) homes with a total tax value of \$25,270,985.00 and four (4) lots with a total tax value of \$4,950,000.00 (*See Exhibit D*).
5. Division of Coastal Management (“DCM”) Staff prepared, on June 8, 2009, a map of West Beach showing transects and erosion rate calculations as shown on **Exhibit C**. The erosion rates calculated from the transects depicted on this map used the same transect orientation and shoreline analysis methods as those for the 1998 maps currently applied to the rest of the State’s oceanfront shoreline. The general method is an end-point calculation that determines the shoreline distance between an early shoreline from the 1930s and 40s defined from National Ocean Service Topographic Sheet (NOS T-sheet) maps and a late shoreline generated from 1998 aerial photography. This distance is divided by the time period represented by the shorelines to develop a long-term rate (e.g., 240 feet of shoreline movement over a period of 60 years is a rate of four feet per year). Specifically, the West Beach calculation conducted by DCM for this declaratory ruling used an early shoreline from 1942 (NOS T-sheet) and a late shoreline from 2000 (aerial photography). Aerial imagery for 1998 does not exist for West Beach.
6. The Commission has the authority to declare an annual erosion rate for West Beach. 15A NCAC 07H .0304(1)(a).
7. The circumstance of West Beach and its property owners is unique among North Carolina coastal communities because transects and erosion rates have not been defined previously by the Division of Coastal Management. To better understand the shoreline history along West Beach, and in response to this petition, the Division has since defined erosion rates for this portion of the Village shoreline. The maximum erosion rate for West Beach (as defined herein) by the Division using the method described above in Section 5 is 2.4 feet per year, and the maximum accretion rate is 4.3 feet per year. Spatial smoothing of the data, similar to what was done for the current erosion rate numbers for the State’s

oceanfront erosion rate data, further reduces the maximum erosion rate to 2.2 feet per year. The Division notes that rounding of the data through a process called “blocking” would place a minimum erosion setback factor of two (2) feet per year for the entirety of West Beach (transects 1 through 40). See **Exhibit G** for the complete methods used by the Division in the most recent shoreline erosion update.

8. The Declaratory Relief granted would not affect subsequent Commission rulemaking, but would merely establish an erosion rate, subject to adjustment by lawful Commission rules and processes. The erosion rates specific to this declaratory ruling may be superseded upon the effective date of any subsequent inlet hazard area development rules promulgated by the Commission.

D. ARGUMENT

Gaps in the current erosion rate map maintained by the Coastal Resources Commission (“CRC”), in conjunction with certain regulations applicable to the Inlet Hazard Area (“IHA”), are creating unintended results and causing an incorrect eight (8) feet annual erosion rate to apply to many homes along West Beach on Bald Head Island—where the actual erosion rate is approximately two (2) feet per year. See **Exhibits B** and **C** (maps of West Beach). In consequence, numerous homes are being subjected to an incorrect and unreasonable two hundred forty (240) feet building setback (8 x 30) rather than the correct sixty (60) feet setback (2 x 30). The result is that, arbitrarily, homes are rendered non-conforming and lots are deemed unbuildable. Such unreasonable and oppressive regulation has generated tremendous uncertainty, affected tax valuations and held up property transactions. The situation requires immediate correction.

West Beach lies within both the current and proposed IHA zones. (See **Exhibit B**; see also **Exhibit F** (discussing current status of IHA amendment process)). Pursuant to 15A NCAC 07H .0310(a)(1), “[a]ll development in the inlet hazard area shall be set back from the first line of stable natural vegetation a distance equal to the setback required in the adjacent ocean hazard

area.” Further, 15A NCAC 07H .0306(a)(1) provides that the appropriate setback distance in an ocean hazard area—and therefore in the “adjacent” IHA—is the erosion rate multiplied by a factor of thirty (30). Finally, “erosion rates shall be the long-term average based on available historical data” as depicted on a map updated through 1998. 15A NCAC 07H .0304(1)(a).

To date, no erosion rate has been identified along West Beach. As a result, the staggering eight (8) feet per year erosion rate affecting the coastline on the *opposite* side of the IHA zone applies throughout the entire IHA zone. **More than thirty (30) million dollars worth of properties are harmed.** See Exhibit D (property and valuation list).

Such an unreasonable and arbitrary regulatory scheme, as applied to West Beach, contravenes CAMA’s goal to “insure that the development or preservation of the land and water resources of the coastal area proceeds in a manner consistent with the capability of the land and water for development, use, or preservation based on ecological considerations.” N.C. Gen. Stat. § 113A-102(b)(2).

A declaratory or interpretive ruling by the CRC is a speedy and available fix to the problems described above. Specifically, 15A NCAC 07H .0304(1)(a)—which addresses erosion rates in ocean hazard areas—provides that such rates may be varied by the CRC through “**declaratory or interpretive rulings.**” (Emphasis added).¹ Through either of these procedures, the Coastal Resources Commission may vary the erosion rates depicted on the 1998 map (or lack thereof). Accordingly, the CRC should declare or interpret that the erosion rate at West Beach is two (2) feet per year.

¹ A “declaratory” ruling is largely governed by statute and regulation. See N.C. GEN. STAT. § 150B-4; 15A NCAC 07J .0601 *et seq.* The procedures and scope of “interpretive” rulings, however, are not addressed by the statutes and regulations. Nonetheless, the above-cited regulation explicitly refers to the CRC’s power to make “interpretive” rulings. As such, an interpretive ruling may be an easy and efficient means of applying a reasonable setback requirement along West Beach.

Applying an annual erosion rate of two (2) feet to West Beach will facilitate coastal administration and application of building setbacks and zoning regulations, will provide certainty to property owners, will increase or maintain existing property values, and will permit real estate transactions to go forward, consistent with CAMA's stated goal to "insure that the development or preservation of the land and water resources of the coastal area proceeds in a manner consistent with the capability of the land and water for development, use, or preservation based on ecological considerations." N.C. Gen. Stat. § 113A-102(b)(2).

E. PROPOSED RULING

For the foregoing reasons, the Requestors respectfully move the Commission for a Declaratory Ruling awarding the following relief:

The Commission, having considered the due and lawful petition of the Requestors for a Declaratory Ruling, finds and declares:

1. No annual erosion rate or transects were previously adopted for West Beach on Bald Head Island, North Carolina, nor shown on the 1998 erosion rate map adopted in 2004.
2. DCM Staff prepared as of June 8, 2009, transects and calculated annual erosion rates for West Beach, consisting of the area within the existing inlet hazard area between transects (1) through forty (40), inclusive, as shown on **Exhibit C**.
3. Based upon the information provided by Requestors and DCM Staff, the Commission declares, pursuant to 15A NCAC 07H .0304(1)(a) and 07J .0602, that the annual erosion rate for West Beach is two (2) feet and same shall be shown henceforth on the erosion rate map maintained by the Commission.
4. This Ruling shall not prevent the Commission from modifying in the future the West Beach annual erosion rate by lawful rulemaking procedure and processes.

F. CONCLUSION

The Request for Declaratory Ruling by the Village of Bald Head Island and J. Andrew Sayre is in the best interest of coastal administration, addresses a unique regulatory circumstance

and is for the public benefit. See G.S. 113A-102(b)(2). The relief sought is authorized by law, including, but not limited to, N.C.G.S. 113A-124(c)(7), 15A NCAC 07H .0304 and 15A NCAC 07J .0602. Requestors urge the Coastal Resources Commission to consider and act upon this request in an expedited manner.

RESPECTFULLY SUBMITTED, this 9th day of June, 2009 by:

ROUNTREE, LOSEE & BALDWIN, LLP

Street: 2419 Market Street
Wilmington, North Carolina 28403

Mailing: Post Office Box 1409
Wilmington, North Carolina 28402

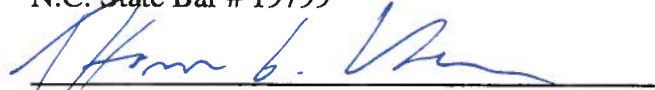
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Thomas G. Varnum

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Attorneys for Requestors

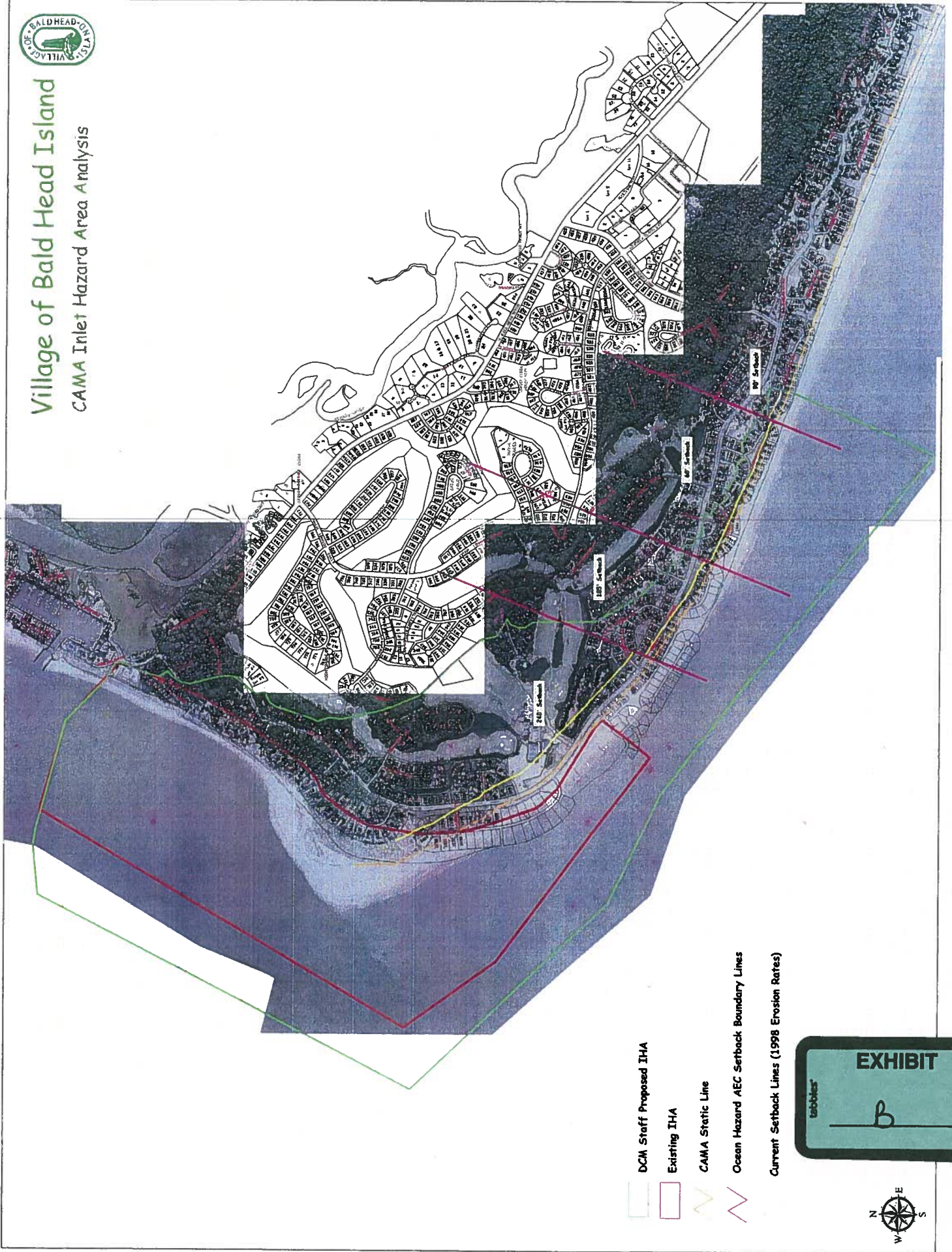
West Beach and Adjacent Property Owners

Parcel Number	Lot Number	Name	Mailing Address
2604G008	1023	Marvin & Sara Neuwirth	PO Box 3178 Bald Head Island, NC 28461
2604G009	1022	James E. Harrington	PO Box 3336 Bald Head Island, NC 28461
2604G010	1021	Cheryl Murphy	1508 East 86th Street # 163 Indianapolis, IN 46240
2604G011	1020	Fernand & Evelyn Parent	68 Hillcrest Ave. Charleror, PA 15022
2604G012	1019	Elizabeth Beam	1718 Canterbury Rd. Raleigh, NC 27608
2604G013	1018	Joseph & Leah Devlin	7016 Harps Mill Rd. Raleigh, NC 27615
2604G014	1017	John & Carol Mazuy	9 Russell Pond Rd. Kingston, MA 02364
2604G015	1016	Thomas & Eliza Lewis	1927 S. Churchill Dr. Wilmington, NC 28403
2604G017	1014 and 1015	James & Helyn Wisner	6417 Quail Run Rd. Wilmington, NC 28409
2604G018	1013	James & Catherine Berges	4 Brentmoor Park Clayton, MO 63105
2604G019	1012	John & Susan Nichols	1104 High Country Rd. Towson, MD 21204
264100103	Common Areas	Bald Head Association	PO Box 3030 Bald Head Island, NC 28461
2604G033	1234	Leslie Wheeler	32 Longcourse Lane Paoli PA 19301
2604G032	1233	Robert & Giancarla Helgesen	PO Box 3314 Bald Head Island, NC 28461
2604G031	1232	Timothy & Joan McCormick	71 Misty Pine Rd. Fairport, NY 14450
2604G030	1229	Peter & Eileen Quinn	508 Avonwood Rd. Haverford, PA 19041
2604G029	1230	Peter & Eileen Quinn	508 Avonwood Rd. Haverford, PA 19041
2604G027	1228	Michael Hartshorn	960 Checkrein Ave. Columbus OH 43229
2604G026	1227	The Berne Company, Inc.	33 Brays Island Drive Sheldon, SC 29941
2604G025	1226	Darin & Laura Hill	10045 Old Warden Rd. Raleigh, NC 27615
2604G02301	1225	Edward & Pat Johnston	PO Box 3148 Bald Head Island, NC 28461
2604G023	1224	Edward & Pat Johnston	PO Box 3148 Bald Head Island, NC 28461
2604G022	1223	Edward Harper	PO Box 10548 Southport, NC 28461
2604G021	1222	Christine Wright	232 Hempstead Pl. Charlotte, NC 28287
2604G020	1221	Thomas Watjen	PO Box 281 Lookout Mountain, TN 37350
2604F001	1216	Ronald & Margaret Cresswell	1968 Boulder Dr. Ann Arbor MI 48104
2604F002	1217	Haughton Pareddee Living Trust c/o Dr. Angela Pardee	7124 Quail Hill Rd. Charlotte, NC 28210
2604F003	1009	15 Sea Gull Trail LLC	3020 N Fairway Dr. Burlington, NC 27215
2604F004	1008	David & Mary Lewis	9315 Peshurst Trace Charlotte, NC 28210
2604F005	1007	David & Mary Lewis	9315 Peshurst Trace Charlotte, NC 28210
2604F006	1006	George & Alice Horton	4900 W. Cornwallis Rd Durham, NC 27705



Village of Bald Head Island

CAMA Inlet Hazard Area Analysis



- DCM Staff Proposed IHA
- Existing IHA
- CAMA Static Line
- Ocean Hazard AEC Setback Boundary Lines

Current Setback Lines (1998 Erosion Rates)



EXHIBIT

B

Bald Head Island

West - Beach

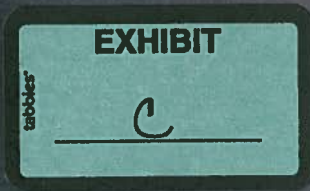


1942-Shoreline

2000-Shoreline

Legend

- - - Transects
- 1942 Shoreline (NOS T-Sheet)
- 2000 Shoreline (Wet / Dry)
- - - Proposed IHA Boundary
- ▭ Parcels



NOTE:
 This map illustrates 25-meter transects and 1942 & 2000 shorelines used to calculate long-term erosion rates on Bald Head Island's "wet-beach." These erosion data DO NOT reflect short-term erosion potentially caused by inlet dredging or storm events.

NCDCM_ID	End-Point (Meters)	End-Point (Feet)	5-pt average
1	0	0.0	
2	0	0.0	
3	0	0.0	0.1
4	0.12	0.4	0.1
5	0.03	0.1	0.0
6	-0.05	-0.2	-0.1
7	-0.12	-0.4	-0.2
8	-0.1	-0.3	-0.3
9	-0.03	-0.1	-0.4
10	-0.1	-0.3	-0.5
11	-0.24	-0.8	-0.7
12	-0.33	-1.1	-1.0
13	-0.43	-1.4	-1.3
14	-0.48	-1.6	-1.6
15	-0.54	-1.8	-1.8
16	-0.6	-2.0	-1.9
17	-0.64	-2.1	-2.1
18	-0.69	-2.3	-2.2
19	-0.73	-2.4	-2.2
20	-0.69	-2.3	-2.2
21	-0.64	-2.1	-2.1
22	-0.59	-1.9	-2.0
23	-0.56	-1.8	-1.8
24	-0.52	-1.7	-1.7
25	-0.49	-1.6	-1.5
26	-0.42	-1.4	-1.1
27	-0.28	-0.9	-0.6
28	-0.03	-0.1	0.0
29	0.25	0.8	0.6
30	0.44	1.4	1.2
31	0.53	1.7	1.5
32	0.57	1.9	1.7
33	0.54	1.8	1.8
34	0.54	1.8	1.9
35	0.57	1.9	2.1
36	0.68	2.2	2.4
37	0.86	2.8	2.8
38	1.01	3.3	3.3
39	1.16	3.8	3.8
40	1.31	4.3	4.2
41	1.43	4.7	4.7
42	1.56	5.1	5.1
43	1.68	5.5	5.5
44	1.82	6.0	6.1
45	1.96	6.4	6.7
46	2.23	7.3	
47	2.48	8.1	

Negative values=erosion
Positive values=Accretion

IHA Information

Structures That Can't Meet The Current Setback of 240' In Existing IHA

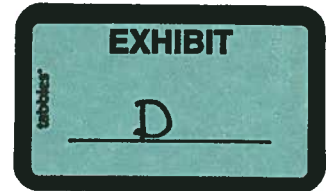
Name	Lot #	Address	B.C Tax Value	Tax Parcel #
Coupland	1001	15 Green Teal	\$1,357,030	2604F031
Gutman	1002	13 Green Teal	\$1,397,280	2604F032
Anderson	1003	11 Green Teal	\$1,503,530	2604F033
Faber	1004	9 Green Teal	\$1,526,820	2604F034
Horton	1006	21 Sea Gull	\$2,718,480	2604F006
Lewis	1008	17 Sea Gull	\$2,631,290	2604F004
Seagull LLC	1009	15 Sea Gull	\$1,391,830	2604F003
Nichols	1012	41 Cape Fear Trail	\$1,635,580	2604G019
Berges	1013	39 Cape Fear Trail	\$2,240,200	2604G018
Wisner	1014&15	35 Cape Fear Trail	\$3,675,740	2604G017
Lewis	1016	33 Cape Fear Trail	\$1,358,560	2604G015
Mazuy	1017	31 Cape Fear Trail	\$1,774,120	2604G014
Devlin	1018	29 Cape Fear Trail	\$2,060,520	2604G013

Unimproved Lots That Can't Meet The Current Setback of 240' In Existing IHA

Sayre	Estate Lot 1	5 Green Teal	\$2,200,000	2604F023
Lewis	1007	19 Sea Gull	\$1,000,000	2604F005
Parent	1020	25 Cape Fear Trail	\$1,000,000	2604G011
Washburn	1029	36 Sandpiper	\$750,000	2641D017

TOTAL

\$30,220,980





①

I APPEAR BEFORE YOU TODAY WEARING

FOUR HATS:

FIRST I HAVE BEEN ON THE BALO
HEAD ISLAND VILLAGE COUNCIL FOR ALMOST

12 YEARS. I WOULD LIKE TO THINK

THAT I AM WELL INFORMED. HOWEVER

OVER THE PAST SIX MONTHS OR SO I

HAVE BEEN SURPRISED AND INCREASINGLY
ALARMED BY THE ^{potentially broad and uncertain} ~~DANGER THAT THE~~

^{implications of the} PRESENT AND PROPOSED IHA RULES ~~ARE~~

~~THE~~ THE WELL BEING OF INDIVIDUAL PROPERTY

OWNERS AND THE VILLAGE'S TAX BASE _{is}
depend on clear rules

IT APPEARS THAT THE REGULATIONS HAVE

NOT BEEN LOGICAL, WELL COMMUNICATED

②

NOR UNIFORMLY ADMINISTERED. THE VILLAGES OF BALD HEAD ISLAND IS A RELATIVELY NEW ~~AND~~ ~~FRAGILE~~ ENTITY. VERY MUCH IN A FORMATIVE STATE. PLEASE ENSURE THAT ANY IHA REGULATIONS DON'T THREATEN THE DESIRABILITY OF BALD HEAD NOR ITS FINANCIAL STABILITY.

SECONDLY, I AM THE OWNER OF A PROPERTY WITHIN THE IHA. IT IS A LARGE LOT OF ABOUT 1.5 ACRES WITH GOOD ELEVATION, BEING THE TERMINUS OF THE PRIMARY DUNE AT THE EDGE OF THE CAPE FEAR RIVER. WE BOUGHT IT AS ~~AN~~ A RETIREMENT INVESTMENT IN 1996 AND IT SEEMINGLY APPRECIATED WELL OVER THE

③

YEARS. AT LEAST THE BRUNSWICK COUNTY TAX DEPT. THOUGHT SO. AS RECENTLY AS JUNE 2008 I HAD AN MAI APPRAISAL DONE IN ORDER TO REFINANCE. THIS APPRAISAL AGREED WITH BRUNSWICK COUNTY'S VALUATION

I RECENTLY REQUESTED FROM THE LOCAL CAMA OFFICER INFORMATION ON WHAT BUILDING RESTRICTIONS MIGHT APPLY. HE INFORMED ME THAT THE SETBACK FROM THE RIVER IS 240 FEET WHICH MAKES THE LOT UNBUILDABLE.

EXCEPT FOR POSSIBLY A COUPLE OF FEET OF EROSION THAT OCCURRED AFTER THE COE REALIGNED AND DEEPENED THE NAVIGATION CHANNEL, THE LOT LOOKS EXACTLY AS IT

④

DID WHEN WE BOUGHT IT.

I CANNOT AFFORD TO LOSE THE VALUE OF THIS LOT. I AM APPEALING BOTH THE 2008 AND 2009 PROPERTY TAXES, AND I AM ALSO CONCERNED THAT I MAY BE IN DEFAULT FOR BREACH OF A ~~technical~~ COVENANT OF MY LOAN. THIS IS AN UNACCEPTABLE SITUATION. I CONTINUE TO PAY THE BANK ~~AND~~ ^{BUT} DOUBT THE BANK WOULD BE SYMPATHETIC IF THE LOT WERE WORTHLESS.

THIRDS I AM IN THE BUILDING BUSINESS AND MY WIFE OWNS A REAL ESTATE COMPANY CONCENTRATING SOLELY ON BALD HORN PROPERTY, INCLUDING SEVERAL LOCATED IN THE IHA.

IN AN ALREADY DIFFICULT MARKET, OTHERWISE VIABLE TRANSACTIONS IN THE IHA HAVE COME TO A COMPLETE HALT. IN OUR

⑤

NEW COMMUNITY THE HEALTH OF THE REAL ESTATE MARKET IN LARGE PART TRANSLATES TO THE OVERALL HEALTH OF THE COMMUNITY.

FINALLY I AM A PAST BOARD MEMBER OF THE BHI CLUB. I WAS INTEGRALLY INVOLVED IN THE RECENT MULTI-MILLION DOLLAR RENOVATION OF THE CLUBHOUSE.

BEFORE COMMITTING THESE SUBSTANTIAL DOLLARS, WE EVALUATED ALTERNATE LOCATIONS FOR A TOTALLY NEW BUILDING.

WE WERE UNABLE TO IDENTIFY ANY VIABLE ALTERNATE SITES. WHEN THE TIME COMES TO REPLACE THIS BUILDING, IT SIMPLY HAS TO REMAIN ON ITS PRESENT SITE.

⑥

THANK YOU ALL FOR YOUR CONSIDERATION.

Subject: The Inlet Hazard Area Changes

My name is Jack Nichols. I have a home in Baltimore, Maryland and on BHI, N.C. I appreciate the opportunity you have given me to speak briefly about my concerns on the present practices and policies relating to erosion rates and setbacks in the Inlet Hazard Area on BHI; and an even greater concern over the future regulations for property owners in the Inlet Hazard Area.

My wife and I have owned two homes on BHI since May of 1987, first owning a Villa on South Beach next to the BHI Club; and then moving to 41 Cape Fear Trail in 1991, which is on West Beach, on the Cape Fear River. One reason for our move was to get away from the problems created by the high rate of erosion and the frequent storm surges from the ocean. When we moved into our Villa in 1987 there were numerous homes and a large Inn and restaurant on the beach. In four years the Inn, and all the homes were gone. The Villas had now become ocean front property.

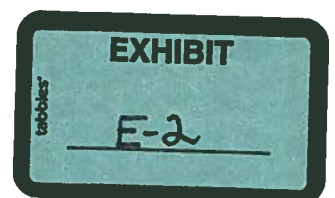
The home on Cape Fear Trail which was built in 1989 was issued a permit using 60 feet as the minimum setback from the First Line of Stable Vegetation. Our home was actually built over 120 feet from the FLSV. Our lot is just over 200 feet deep; over 200 feet across the waterfront and it narrows at the entrance to about 50 feet, the home is 2000 sq. feet.

We sold our Cape Fear Trail home two years ago to a BHI neighbor, subject to the sale of his home. About six months ago this purchaser checked with the CAMA Officials locally and was told that our home was in the Inlet Hazard Area and was in violation of the 240 feet setback restriction and therefore was not rebuildable if it was destroyed. The prospective purchaser then put this transaction on hold until this issue could be resolved. We are still in this position.

In October of last year we had a meeting with the local CAMA Official. He told us that the original minimum setback for our home was 60 feet but should have been 180 feet based on a six foot erosion rate for the Inlet Hazard Area. He said the erosion rate for the entire Inlet Hazard Area was based on the 1988 erosion rate from South Beach. He went on to say that the erosion rates for West Beach did not exist. He then added that the 1998 erosion rate for the Inlet Hazard Area was 8 feet and our setback requirement had increased to 240 feet. Our lot is 200 feet deep; which means our lot was not buildable in ~~1989~~1998.

In further conversations and e-mails I was told that our property was in violation of the setback requirements of the IHA at the time of construction; therefore any previous variance or grandfathering would not be reinstated.

I asked ~~asked~~ when it was decided by CAMA to use erosion rates from South Beach to establish setback rates for West Beach. He said that to his knowledge that was first discussed in



2003 when issues arose concerning other properties. He agreed that up to then, the setbacks on the River property were inconsistent and the 60 foot rate was probably used because there wasn't any erosion rates established on West Beach. He then said that the Ocean Erosion Rates were applied to the entire Inlet Hazard Area. I pointed out to him that this decision was made more than 15 years after our house was permitted in 1989 with a 60 foot setback. I added that in 2002 a CAMA permit was issued confirming our 60 foot setback when we added a screened porch to our home.

In my 18 years living on the West Beach there has been minor erosion balanced by frequent accretion resulting in little if any change in the vegetation line; until ~~two to three~~ five or six years ago, when major changes were made to the Shipping Channel in the river. The Channel was widened to 500 feet; deepened to 42 feet and moved closer to the Island. We are now experiencing greater erosion and the Village Government has taken the combined action of re-nourishment and vegetation planting to stabilize the West Beach. The Village also has an agreement with the Corps of Engineers to monitor the South and West Beaches and furnish sand for re-nourishment.

The Village also has additional plans to use other sources of sand if needed to protect the beaches on BHI.

The following major issues concerning the Inlet Hazard Area on Bald Head Island should be taken into consideration before these areas and rules are established.

1. Evaluate the ongoing damages caused by "other than natural reasons" like the shipping channel changes ; the proposed new port in Southport; and ways of protecting the BHI Beaches
2. Evaluate the effect of the extension of the jetty at the entrance to the Marina and other types of groins along the River.
3. Evaluate the effect of regular replacement of sand along South and West Beach.
4. Adopt clear, sensible rules so that property owners are not left to wonder if lots are buildable or marketable.

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In summary: I feel that on BHI it is unreasonable and arbitrary to use erosion rates for South Beach (Ocean) to establish setback requirements on West Beach (River). This issue should be resolved now and not wait until the new regulations are established; and these new policies should take into consideration the history and facts concerning the situation on BHI.



North Carolina Department of Environment and Natural Resources
Division of Coastal Management

Beverly Eaves Perdue, Governor

James H. Gregson, Director

Dee Freeman, Secretary

January 28, 2009

MEMORANDUM

CRC 09-05

TO: Coastal Resources Commission

FROM: Jeffrey Warren, PhD, CPG
Coastal Hazards Specialist

SUBJECT: Proposed Development Policies for Expanded Inlet Hazard Area
Boundaries

At the May 2008 Coastal Resources Commission (CRC) meeting, Division of Coastal Management (DCM) staff presented draft rule language for development within the updated Inlet Hazard Area (IHA) boundaries as well as a boundary for the Bald Head Island (BHI) IHA that was a revision of the CRC Science Panel on Coastal Hazards initial recommendation. Spencer Rogers, a member of the CRC Science Panel, addressed issues that the Panel had with some of the concepts of the draft rule language, specifically those relating to how the oceanfront setback was determined adjacent to an inlet and, in particular, the calculation of erosion rates and the use of the vegetation line as a reference point for measuring setbacks. The CRC requested that the issues addressed by Rogers, as well as the revised IHA boundary developed by DCM staff, be taken back to the Science Panel.

Since the May 2008 CRC meeting, the Science Panel has met three times to discuss the issue. At the November CRC meeting, DCM staff presented an IHA boundary for BHI based on Science Panel input and additional DCM consideration. Although the Science Panel continues to support their initial IHA boundary recommendation presented in September 2007, staff presented the rationale that DCM staff used to justify the November 2008 IHA boundary revision. Spencer Rogers offered additional comments on the issue. In response, the CRC voted to adopt the boundary as presented by staff. All of the proposed IHAs (including the November revisions to BHI) can be reviewed online:

http://www.nccoastalmanagement.net/Hazards/proposed_IHA.htm

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At the November 2008 meeting, DCM staff noted that draft development policies and data germane to how these policies might affect development in both the existing and proposed IHA boundaries would be provided for the Commission's consideration in February 2009. Attached is a comparison (Table 1) of the proposed development policies for the revised IHA boundaries to the existing IHA policies (for development currently in the IHA) and the existing Ocean Erodeable Area or OEA policies (for development currently not in the IHA but slated to be included in the proposed boundary revisions).

Dr. Margery Overton, CRC Science Panel chair, is scheduled to speak to the CRC at the February meeting and outline the Panel's concerns with managing development adjacent to the State's 12 developed inlets. Based on comments from the most recent Science Panel meeting (January 14th), the issues appear to be fourfold: 1) application of newly calculated oceanfront shoreline erosion rate data adjacent to inlets (versus existing data based on 1998 shoreline), 2) consideration of short-term variability of shoreline (and vegetation line) when determining setbacks, 3) consideration of multiple setback criteria at each inlet (and potentially using the most restrictive), and 4) consideration of inlet-specific (i.e., unique to each inlet) policies for placement of development. DCM continues to consider the Panel's input as inlet-related development policies are developed. Although the application of a new erosion rate will be accomplished as a separate project through a phased approach, DCM feels it has developed a policy framework for addressing most, if not all, of the Panel's concerns.

At the upcoming meeting recommendations for revised IHA development criteria as outlined in Table 1 will be presented along with relevant support data (e.g., size and number of affected structures, erosion rates, etc.). Simply stated, the general concept of these IHA development criteria is twofold: 1) keep it small (<5,000 square feet) and 2) keep it from moving oceanward of existing development. CRC approval of this policy, including any amendments they feel are appropriate, can be distributed to the appropriate stakeholder groups following the meeting (including the Science Panel, which is scheduled to meet again in Raleigh on February 25th). Comments and concerns identified by stakeholders will be considered by DCM and incorporated into draft rules that can be presented to the CRC at their April meeting. Note that the two relevant rules are 15A NCAC 07H.0304 (which defines the IHA boundaries) and 07H.0310 (which defines the development requirements within the IHA boundaries). Although the Coastal Area Management Act requires any changes to an Area of Environmental Concern (AEC) to be subject to hearings in each affected county (in this case, there are five – Brunswick, New Hanover, Pender, Onslow, and Carteret), DCM staff recommends that both rules (07H.0304 and 07H.0310) be subject to the same level of public input. If the CRC chooses to send the proposed rules to public hearing in April, it is likely that regional public hearings can occur during early to mid August with a final hearing in front of the full CRC in Raleigh (August 27th).

Table 1. Applicable development policies established by the Coastal Resources Commission in both the Inlet Hazard Area (IHA) and Ocean Erodible Area (OEA) compared to the proposed development standards proposed by the Division of Coastal Management staff. The OEA data are tabulated here because they are the current rules applicable for oceanfront development in areas that are included in the proposed IHA expansion (but not currently in an IHA).

POLICY	Existing IHA	Existing OEA	Proposed IHA
Size limits	No commercial or multi-family (4 units or greater) greater than 5,000 sq ft	No size limits as long as setback can be met	No structures greater than 5,000 sq ft (excluding development related to public access such as parking lots)
Grandfathering for existing structures >5,000 sq ft	No	No	Yes (can be replaced to pre-rule change size as long as current setbacks are met)
Parking	Not greater than 5,000 sq ft	Setback based on size	All parking >5,000 sq ft shall be gravel or packed clay
Density Limits	No more than 1 unit per 15,000 sq ft	None	None
Setback exception for lots platted prior to 1979	No	Yes	Yes
Static Line Exception*	Yes (although not addressed in current IHA rules, nothing in current rules would exclude its application)	Yes	Yes
Erosion Rates Applied to Setback Determinations	Adjacent OEA	As defined in 07H.0304	As defined in 07H.0304 (plus a 2 ft-per-yr rate assigned to a few areas on current maps without assigned erosion rates; DCM plans a coast-wide update to current erosion rates)
Vintage of Erosion Rates Applied	Primarily current rates with some exceptions dependant on lot plat date	Primarily current rates with some exceptions dependant on lot plat date	Rates in place at time of permit decision
Setback Reference Point	Vegetation line	Vegetation line	Vegetation line AND landward most adjacent structure AND as far back on lot as feasible (with provision for unique lot and shoreline geometries on a case-by-case basis)
Setback Factor	30	30 or 60 (plus potential graduated setback factor between 60 and 90 based on pending setback rules)*	30 (no greater setback needed since total floor area limited to 5,000 sq ft; size exception for public access facilities which will need to meet relevant setback*)
Sandbag Frequency**	Once	Once	Multiple times**
Sandbag Time Limits**	Max of 5 years	Max of 5 years	Max of 8 years** (with planned inlet relocation project)

* Static line exception and setback rules (15A NCAC 07H.0306) approved by CRC in September and RRC in November 2008 being sent to General Assembly for review.

** Although proposed sandbag rules are provided here for comparison, they are not part of the proposed IHA development policy and rules. The public hearing for proposed amendments to the sandbag rules (15A NCAC 07H.0308(a)(2)) that would allow the conditions described in the above table is scheduled to occur at the February CRC meeting.

NC CRC - Information Item
04/28/04

**North Carolina
1998 Long-Term Average Annual Erosion Rate Update:
Methods Report**

March 18, 2004

Stephen B. Benton
Caroline J. Bellis
Julia M. Knisel

*North Carolina Department of
Environment and Natural Resources,
Division of Coastal Management*

Margery F. Overton
John S. Fisher

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ACKNOWLEDGEMENTS

A number of people contributed to this erosion rate update. Contributions from staff of the NC Division of Coastal Management (DCM), including John Buie, Sean McGuire, Chase Bernard, Pat Hughes, Ken Richardson, Guy Stefanski, and Steve Underwood, ranged from design, grant management, and quality control, to production of maps for public use. Charlie Brown and Keith Johnston, with the NC Department of Transportation (DOT), provided valuable assistance with acquisition of the 1998 aerial photographs, development of the orthophotograph and digital terrain model (DTM) contracts, and quality control of these products. Jason Fink and Allyson Jason, formerly with the Kenan Natural Hazards Mapping Program at the NC State University (NCSU), assisted with photo rectification and quality control. Sheppard Moore and Dr. Gavin Smith, with the NC Division of Emergency Management (DEM), provided critical funding through the Federal Emergency Management Agency. Lynn Jack, with the Wilmington District of the US Army Corps of Engineers (USACE), located historical aerial photographs in the USACE archives, which were scanned and rectified to produce an early shoreline. Mike Rink, with the National Oceanic and Atmospheric Administration (NOAA) at the Coastal Services Center (CSC), provided the digital topographic-sheet (T-sheet) shorelines that were used as the other early shorelines. Finally, Michael Brown of SURDEX Corporation provided valuable coordination between his company and DCM staff.

ACRONYMS

CSC	Coastal Services Center
CRC	Coastal Resources Commission
DCM	Division of Coastal Management
DEM	Department of Emergency Management
DOT	Department of Transportation
DTM	Digital Terrain Model
GIS	Geographic Information System
GPS	Global Positioning System
NCSU	North Carolina State University
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration
OGMS	Orthogonal Grid Mapping System
T-sheet	Topographic-sheet
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey

HISTORY OF NC EROSION STUDY AND UPDATES

In late 1978 and early 1979, the NC Coastal Resources Commission (CRC) undertook a comprehensive review and revision of the oceanfront regulations adopted in September 1977. One major new management strategy that came out of this revision was the use of an oceanfront development setback based in part on the average annual long-term rate of shoreline change. These setbacks create an undeveloped buffer zone along the oceanfront shoreline to protect houses and other buildings from storm scour and long-term erosion.

1979 Study

Since a setback program based on long-term shoreline erosion rates requires accurate, up-to-date shoreline erosion rate information, a study contract was made with Dr. Aziz Tayfun, Spencer Rogers, and Dr. Jay Langfelder of NCSU in February 1979. This study accomplished the following tasks:

- Analysis of the short-term erosion associated with a 100-year storm event; and
- Analysis of the long-term oceanfront shoreline changes.

The procedure used in this study to determine average annual long-term erosion rates was based on a series of earlier studies that used methods developed by Stafford (1968). Using several sets of aerial photographs, Stafford manually measured the perpendicular distance from fixed reference features to the high water line at a series of points. The low spatial resolution and variable accuracy of this work limited its usefulness. However, it provided the conceptual framework for subsequent studies. Averaging the shoreline change distance over the time interval between an early shoreline date and a recent shoreline date has come to be called the “end point method.”

In April 1979, DCM staff saw a presentation by Dr. Robert Dolan of the University of Virginia on his recently developed shoreline erosion study methodology, Orthogonal Grid Mapping System (OGMS). Using a projecting light enlarger in combination with a zoom transfer scope, Dolan’s technique corrected some of the scale variations and other distortions of aerial photographs. This methodology increased the number of shoreline transects and improved spatial resolution. Dolan provided the NC Office of Coastal Management with a copy of his data, which was only available for the northern portion of NC, and it was used where available in the study contract with NCSU.

The study report was completed (Tayfun, *et al.*, 1979) and shoreline change rates were approved for use in establishing setbacks by the CRC in July 1979. DCM staff determined that erosion factor segments provided in the report were relatively long. Staff felt that shortening them would provide a more realistic picture of shoreline changes. Based on an evaluation of the accuracy of the Dolan data, it was determined that the erosion factor segments could be shortened along the northern half of the state. Here, the original erosion factor segments were longest, and shoreline change data most dense (1 measurement every 100 m for the Dolan data set in the northern half of the state versus 1

measurement every ± 300 m for the southern half). The revision was done in house and the new erosion factor segment maps became effective June 1, 1980.

1980 Update

In June 1981, the first erosion rate update, which utilized Dolan's data for the entire state and current through late 1980, was completed through a contract with Dolan. A detailed description of the Dolan OGMS methodology is found in Dolan, *et al.*, 1978 and Dolan, *et al.*, 1980.

Since the shoreline erosion study was strictly a historical snapshot of the shoreline changes that took place over the time interval studied, and physical conditions along the coast change over time leading to potential changes in erosion conditions, staff proposed that the study be updated approximately every five years. A five-year time interval is about the minimum necessary, considering the sensitivity of the study methods, to accurately portray erosion rate changes and insure that erosion rates used by DCM reflect current erosion conditions. Also, in order to keep the erosion rates used for management consistent with current erosion conditions, DCM proposed that the time interval used for the study be limited to the most recent approximately 50 year time interval. A detailed description of methods and update results are found in Benton, 1983.

1986 Update

The shoreline change study was updated through 1986 through another contract with Dolan. Though other methods were considered, DCM staff ranked Dolan's OGMS method as the most accurate and practical for NC's coastal management needs. Major enhancements to the method included the reduction of transect spacing from 100 m to 50 m, and the provision of a personal computer version of the shoreline change analysis program, COASTS for DCM staff use. This allowed access to the data for in-house research, education, contested cases, and other purposes. A detailed description of methods used and update results are found in McCullough, and Benton, 1988.

1992 Update

For the 1992 shoreline change update, a contract was developed with Dr. Margery Overton and Dr. John Fisher of the Civil Engineering Department of NCSU. The original Dolan data set was used again for the early date except for an approximately 10-mile section of coast in southern Currituck County between Duck and Corolla. This segment of shoreline was rectified and digitized by Overton and Fisher due to comments received during the public hearings on the proposed 1992 erosion rate update study results.

Though the study continued to use the end point method, a number of enhancements were incorporated into the update. For the first time, a geographic information system (GIS) was utilized in the process for 1992 and portions of the early date aerial photo rectification process. A set of large-scale (1:4,800) stable mylar prints were produced from a set of vertical aerial photographs taken by the Photogrammetry Unit of the NC

DOT for the project. These were rectified using 1:24,000 scale US Geological Survey (USGS) topoquad maps utilizing a mathematical algorithm called “rubber-sheeting” to correct scale differences and distortions inherent to aerial photography. Shorelines were digitized by Dolan on the 1:4,800 scale mylar prints to insure consistency with earlier studies. Discontinuities between line segments from photo to photo were corrected by “snapping” the segments together.

Since the early date for most of the shoreline was not in GIS format, the newly mapped shoreline was transformed into a numerical format to perform shoreline change rate calculations. The calculations were performed by a computer program called ECOAST developed by Dolan. ECOAST is an enhancement of Dolan’s earlier COAST program. A detailed description of methods used and update results are found in Overton, and Fisher, 1996a, and Benton, *et al.*, 1997.

1998 UPDATE

The 1998 shoreline erosion study update was developed through contracts with the following:

- NC DOT for establishing ground control, providing vertical aerial photographs of the oceanfront shoreline, and providing quality control for digital orthophoto products;
- SURDEX Corporation for scanning and rectifying the vertical aerial photographs and providing DTM data for the coast; and
- Overton and Fisher for calculating the shoreline erosion rates used for the 1998 update.

The 1998 update data provided is consistent with earlier studies used by DCM for the long-term average annual erosion rate setback program. First, the wet/dry line was used to delineate the shoreline position from aerial photography. This same shoreline indicator was used for all the earlier updates. Second, the end point method was used to calculate rates. The original transect locations and nomenclature established using the OGMS was also used. These consistencies allow DCM to evaluate shoreline change at the same locations as those used in earlier studies.

Several modifications were adopted in the 1998 study to utilize current aerial photogrammetric technology, improve the accuracy of the results, and provide a GIS-compatible product. Many of these improvements were recommended by the Coastal Hazards Science Panel of the CRC and were enabled by the coordinated efforts of DCM, DEM, DOT, and the Kenan Natural Hazards Mapping Program at NCSU.

The modifications are listed below.

- The 1998 photo base is a set of digital orthophotos, which improved the accuracy of the shoreline position and provided GIS-compatible data.
- The shoreline was delineated digitally in GIS format with geographic coordinates.
- Digital T-sheets were used for the early date required by the end point method. T-sheets provided a cost effective early date, and are used by other researchers including the USGS for their recent shoreline erosion studies. T-sheets eliminated the problems introduced by the variable error in the early date established during the first erosion rate study (Benton, 1983). This error is discussed in the supplementary report to the 1992 Methods Report (Benton, *et al.*, 1997).
- T-sheets do not exist for approximately 30 miles of shoreline north of Oregon Inlet. For approximately 20 miles of this shoreline, the early date was established by rectification of October 21, 1940 photographs using ERDAS IMAGINE with the OrthoBASE module. The rectification process produced a digital mosaic with continuous coverage over the project area.
- Coordinates are archived for the 1998 shoreline and the early date shoreline so that rate data associated with specific transects can be geo-referenced directly to shoreline position in a GIS.

This study provided DCM with a statewide database of shoreline position and erosion rate data in GIS format that represents up to date technology with respect to the use of aerial photography for shoreline change analysis. As an example, the worst case displacement error associated with identifying the wet/dry line from the 1998 orthophotos is estimated to be +/- 10 ft (Overton, and Fisher, 2003), an improvement over the +/- 50 ft displacement error estimated for the shoreline position used in the previous erosion rate studies (Dolan et al. 1980).

DATA SOURCES

1998 Vertical Aerial Photograph

The contract with DOT provided approximately 1,100 black and white prints from the NC/VA boundary to the NC/SC boundary flown between June and August 1998. The aerial photographs were taken at a scale of 1:7,200 and incorporated an extensive (approximately 675) array of surveyed ground control panels. These ground control panels consisted of 10' x 10' sheets of black plastic with a 1' x 8' white chevron (V). The control point is at the exterior point of the chevron. Control points were surveyed using fast static global positioning system (GPS) procedures tied to the HARN. Elevation values are accurate to 0.2 ft. The photos covered the entire ocean shoreline of

NC, approximately 320 miles. Work products from this contract included film diapositives, 9" x 9" contact prints, index sheets, and ground control data (as ASCII text).

1998 Digital Orthophotographs

Approximately 1,010 of the 1998 vertical aerial photographs were selected for conversion to digital orthophotos and production of DTMs. The photos were selected to optimize coverage of the oceanfront shoreline, but eliminated unnecessary overlap and duplication. Under a contract with SURDEX Corporation, the photos were scanned, differentially rectified using control point data and a digital elevation model, and registered to known ground coordinates. The orthophotos were tiled into 2,500' x 2,500' ground distance tiles, butt-matched and staggered North-South and East-West to maximize the coverage and efficiency of each tile. Ground pixel resolution was 6" and all image pixels were squared North-South and East-West in orientation to the NC State Plane Coordinate System Zone 4901 referenced to the North American Datum of 1983. The accuracy standards required under this contract exceed the America Society of Photogrammetry and Remote Sensing Accuracy Standards for Large-Scale Maps for Class 1 Maps and well-defined points at the 1:1,200 scale or 1.0 ft limiting root mean square (RMS) error. The RMS error is the cumulative result of all mapping errors and well-defined points pertain to features that can be sharply identified as discrete points. The orthophotos were delivered in geoTiff format.

While the orthophotos are of excellent quality in general, the contrast on the beach face was, in some areas, not sufficient to identify the wet/dry line. For these orthophotos, NCSU increased the contrast of the images to identify the wet/dry line on the beach. This processing was done using ERDAS IMAGINE and Adobe Photoshop to produce the best possible results.

T-sheets

Digital T-sheets as ArcInfo coverages were obtained from the CSC. Table 1 provides information about the original files. T-sheets were grouped together by the CSC into the same file as indicated by the folder name and spatial coverage (Table 1). The various T-sheets within a folder were potentially representative of different dates, thus the range of dates presented in Table 1. ArcInfo coverages were converted to ArcView shapefiles and evaluated for use in the erosion rate project with the assistance of metadata provided by the CSC. This metadata details accuracy estimates relative to the digitization procedures used by NOAA for their project as well as basic information about the T-sheets themselves. In addition, descriptive reports for various T-sheets needed to verify photo dates for certain shoreline segments were obtained from the staff of the National Geodetic Survey (NGS).

The 1940s shorelines were chosen to keep the desired approximate 50-year time frame for the long-term erosion rate calculation. Table 2 provides information on the T-sheet shapefiles used in this study. The name of the shapefile was taken from the original folder name provided by the CSC in order to associate the file with its source file.

Table 1. T-sheets obtained from the CSC as ArcInfo coverages.

File Name	Shoreline Dates	Approximate Spatial Coverage	Scale
idx126f	Jan 1933	South Carolina line through Bald Head Island	1:20K
idx134k	Jan 1933-Jan 1944	Bald Head Island to Emerald Isle	1:20K
idx134l	Unknown	South of Ocracoke through Cape Lookout	1:20K
cs275	Jan 1942-Jan 1944	South Carolina line through Bald Head Island	1:20K
ph5	Jan 1946-Jul 1947	2 miles south of Oregon Inlet to Emerald Isle	1:10K
ph20	Jan 1948-Mar 1949	Pamlico Sound (no ocean front coverage)	NA
ph45	Jan 1949-Mar 1951	Nags Head to 2 miles south of Oregon Inlet	1:20K
ph58	Nov 1949-Jul 1952	Emerald Isle to mid-Topsail	1:10K
cm7219	Jan 1973-Nov 1973	3 small areas around Bald Head Island, Carolina Beach, and Atlantic Beach	1:20K
cm7305	Apr 1974	Most of Cape Hatteras to Cape Lookout (2 disjoint areas)	1:20K

Table 2. T-sheet shapefiles used in the erosion rate study.

File Name	Approximate Location
cs275	South Carolina line through Kure Beach
idx134k	Carolina Beach through mid-Topsail Island
ph58	Mid-Topsail Island through mid-Bogue Banks
ph5	Mid-Bogue Banks through Oregon Inlet
ph45	Oregon Inlet to Kitty Hawk

Historical Photography

The 1949 T-sheets used north of Oregon Inlet terminated about eight miles north of the inlet in South Nags Head. North of this area to the Virginia border, T-sheets of this time period are not available. Suitable photography, defined as originating in the 1940s, having a shore parallel flight line, having a minimum of 30 percent overlap, having less than 1:24,000 scale, providing coverage of the appropriate area and not being associated with a storm, was provided by the USACE, Wilmington District on a loan basis. The photo coverage did not extend along the entire section of coast not covered by the T-sheets, however. The northern most approximately 10 miles, just south of the Virginia border, was not covered.

COAST Database

A set of aerial photographs taken after the Ash Wednesday Storm in March 1962 and covering the northernmost 10 miles of shoreline was evaluated for possible use in this area. However, an examination of the rectified images confirmed that the post-storm shoreline was not suitable for the long-term shoreline erosion rate update. Since no other suitable photographic coverage was readily available, the “early date” established for this area in previous erosion rate studies (Benton, 1983) and archived in the COAST database was utilized for this northernmost 10-mile stretch of oceanfront shoreline. These data were extracted and geometrically converted to NC State Plane 83 coordinates. The date of the historical aerial photographs used to establish the “early date” in this area was March 29, 1955.

PROCEDURES

Photo Rectification

1998 Recent Shoreline Photography

The 1998 aerial photographs were rectified through a contract with SURDEX Corporation, a commercial photogrammetry company, as previously described.

Historical Shoreline Photography

The historical photography (1940 and 1962) used for the early shoreline for the study area north of Oregon Inlet where no T-sheet shoreline data is available was done through a contract with the Kenan Natural Hazards Mapping Program at NCSU. Rectification was done using ERDAS IMAGINE with the OrthoBASE module, photogrammetric software capable of fully orthorectifying vertical aerial photographs. The photographs were corrected for scale variation, airplane tilt, and radial lens distortion. Since the study area is relatively flat, relief displacement was determined to be minimal and was not corrected. Because of a lack of readily identifiable features suitable for use as control points on the 1940 photos, an intermediate set of photographs was rectified. A set of 1962 photos was used for this “step-back” procedure. Table 3 lists the photograph date, photo scale, and the equivalent ground coverage size of each of the photograph sets used

in processing the mosaics in this study. The commercially processed 1998 orthophotography, which was used as ground control for the 1962 photographs, is included for comparison.

Table 3: Photos used to create the 1940 mosaic.

Photo Date	Photo Scale	Ground Pixel Coverage
June-August 1998	1:7,200	0.5 ft
March 14, 1962	1:9,600	0.667 ft
October 21, 1940	1:24,000	1.667 ft

Each 9" x 9" aerial photograph was scanned at 1,200 dots per inch (dpi). Ground control points were determined by establishing photo-identifiable features common to both the 1998 and 1962 photography and the 1962 and 1940 photography. Suitable points for ground control included road intersections, piers, and corners of structures at ground elevation. When no other points were available, stable points on the estuarine shoreline were chosen. The digital images were then mosaiced into one continuous image and rectified. This image was then broken into smaller files for working and archival purposes.

Shoreline Identification

Historical T-sheet Shorelines

The T-sheet shorelines used for this study were all based on aerial photographs augmented by field surveys (Crowell, *et al.*, 1993). Historically, the shoreline datum used on T-sheets is the high water line. Early T-sheets were produced by plane table field surveys where the high water line could be interpreted based on visual observation of the features. Though the reported datum on T-sheets is mean high water, it is an interpolation of that datum from a measured high water line (Shalowitz, 1964; Crowell, *et al.*, 1993). McBeth (1956) reported that for mapping purposes, the differences in positions of the two shoreline datums are insignificant.

Vertical Aerial Photograph Shorelines

The 1998 shoreline was digitized in ArcView using the 1998 orthophotos. The shoreline feature mapped is the wet/dry line, a photo identifiable feature produced by the contrasting color of wet and dry sand on the beach. Use of the wet/dry line as a shoreline feature is described in Dolan, *et al.*, 1978, and Dolan, *et al.*, 1980, and is the same feature that has been used for all our erosion study updates to delineate the shoreline since the first erosion study data from Dolan was provided in 1979. Basically, the wet/dry line is a readily identifiable feature located, in the worst case, between high and low tide and thus

has less variability over a tidal cycle than the swash or water line. It is not necessarily equivalent to the “high water line” defined as, and identified by, markings left on the beach by the last high tide. While the high water line is generally the shoreline datum measurable in the field with the least variability over a tidal cycle, it is not consistently measurable on aerial photographs for a variety of reasons. The high water line may be too faint to be visible on the photos, or it may be visible but represent an earlier high storm tide or spring tide that overtopped a low berm and ponded. It is sometimes difficult to distinguish the high water line from storm wrack lines on aerial photos. In addition, erosion scarps and distinctive grain size changes can produce false high water lines on aerial photographs (Crowell, *et al.*, 1991; Pajak, and Leatherman, 2002)

Transect Locations

The OGMS was established by Dolan in his early shoreline change studies (Dolan, *et al.*, 1978) using USGS topographic quadrangles and enlarged to 1:5,000 scale to provide a series of base maps along this shoreline. A set of basemaps and transects were developed for NC under contract with Dolan in the 1980 long-term erosion rate study. The locations of the basemaps were recorded by digitizing the corners of the basemaps, however, transect location and shoreline position was not recorded in a coordinate-based database. In order to provide data consistent with these earlier studies, transect locations have been established using information provided from earlier erosion rate update studies and coordinate geometry. Because these transects did not exist in a coordinate database prior to this study, absolute verification of location is not possible. However, the transect locations used in this study are consistent with those used in 1992 study contracted with NCSU because similar methodologies were used to compute locations.

The OGMS has served NC well through the last four erosion rate updates. The OGMS system was developed with shore parallel basemaps and shore perpendicular transects. Each basemap is 3,600 m in length with 72 transects spaced 50 m apart. Each basemap overlaps its adjacent basemaps so that there are no gaps in the representation of shoreline position. At the time of the 1980 study, Dolan established “good” and “bad” transects to delineate which transects should be used in the overlap area of each basemap. Further, data from transects near inlets or capes where the shoreline orientation deviates significantly from parallel to the baseline was rejected and not used for shoreline erosion rate calculations.

Shoreline Change Rate Calculations

Shoreline change rate calculations include three steps. Step one is the calculation of the end point rate at each transect. The second step is to spatially smooth the data using a running average algorithm. The third step “blocks” these data into spatially uniform values where appropriate.

End Point Method

The end point method was used to compute the long-term erosion rate. The distance along a given transect between the “early date” and the 1998 shoreline is computed from

the coordinates of the intersections of the respective shorelines with that transect. This distance is divided by the time interval between the date associated with the “early date” shoreline and the date of the photograph associated with the 1998 shoreline. Details of the procedures used to compute the erosion rate are documented in Appendix A.

Smoothing

The procedure for spatially smoothing the shoreline change rate data is a simple moving average or running mean technique described by Davis, 1973. For shoreline segments consisting of at least 17 transects (approximately 0.5 miles), an average is calculated for the 17 transects and centered on the ninth transect. This spatially averaged value is the “smoothed” rate. In the vicinity of inlets, the number of transects used in the average is decreased by two (dropping one from each side of the centered calculation) until the end transect is reached. The last value is calculated by taking the weighted average using the last two transects $(2 \cdot T1 + T2) / 3$ where T1 is the last transect before the inlet and the T2 is its neighbor.

Smoothing effectively filters short-term dynamic shoreline phenomena such as beach cusps, smaller sand waves, and the attachment of landward migrating portions of offshore bar systems. Cusps and similar features range in size from 1.5 meters to 1,500 meters and have a life span ranging from days (smaller features) to seasons or years (larger sand waves) (Dolan, and Ferm, 1968; Davis, 1978). Bars generally range around 100 meters in length with migration and attachment rates ranging from seasons to years (Davis, 1978). Variation associated with larger, longer-lived features such as secondary capes and capes are not filtered by the smoothing process.

Figure 1 below illustrates the impact of the smoothing procedure on the raw rates. The largest differences between the smoothed and raw rates are in the regions of rapidly changing rates, e.g., near Ocracoke Inlet. For the more gradually varying rates, the difference between raw and smooth is about +/- 1 ft/yr.

The need for spatial blocking was established in the first erosion rate study (Benton, 1983). Blocking creates spatially uniform rate segments from the smoothed data. This allows for management of like sections of shoreline with the same shoreline change rate. In addition, it minimizes the number of neighboring shoreline segments that have different shoreline change rates.

Blocking

Blocking procedures, itemized below represent refinements and clarifications of procedures established and used in all the previous studies. These refinements and clarifications are the result of improved accuracy of the data brought about by improvements in the shoreline delineation methodology and quantitative requirements that allow for increased repeatability of results.

1. Erosion rate segments must be at least eight transects long (approximately one-quarter mile). Blocking is always done along the shoreline from low rates to higher rates.

2. One-foot intervals are preferred for rate block boundaries. Fractional rates are rounded to the nearest foot. $\frac{1}{2}$ foot intervals are appropriate for segments dominated by a $\frac{1}{2}$ foot value and do not have values greater than the next highest 1 foot interval.
3. Erosion factor rates for segments or groups of segments transitional between adjacent segments with larger than 1 foot differences in erosion factor rates are determined by finding the mean value of the transects within the segment rounded to the nearest $\frac{1}{2}$ foot.
4. The actual rate boundaries fall at an unknown location between transects spaced every 50 meters along the oceanfront shoreline. In determining the transect to use for a rate boundary, always slide the lower blocked rate toward the transect with the higher erosion rate value
5. When delineating a rate boundary on large-scale photo base maps, always slide the boundary toward an apparent property boundary in a direction that the lower rate is expanded toward the higher rate (give the property owner the benefit of the doubt).
6. Segments that have accreted or have erosion rates less than 2 ft/yr are assigned a value of 2 ft/yr for the erosion factor.

Figure 2 below illustrates the use of these blocking procedures on the Ocracoke data. The blocking procedure captures the variation in rate while meeting the management goal of having common rates among property owners within specified distances. In addition, this figure illustrates the portion of the island that has a less than 2 ft/yr erosion rate, but that is blocked at 2 ft/yr. Finally, the application of the blocked rate into the Inlet Hazard Area is also illustrated.

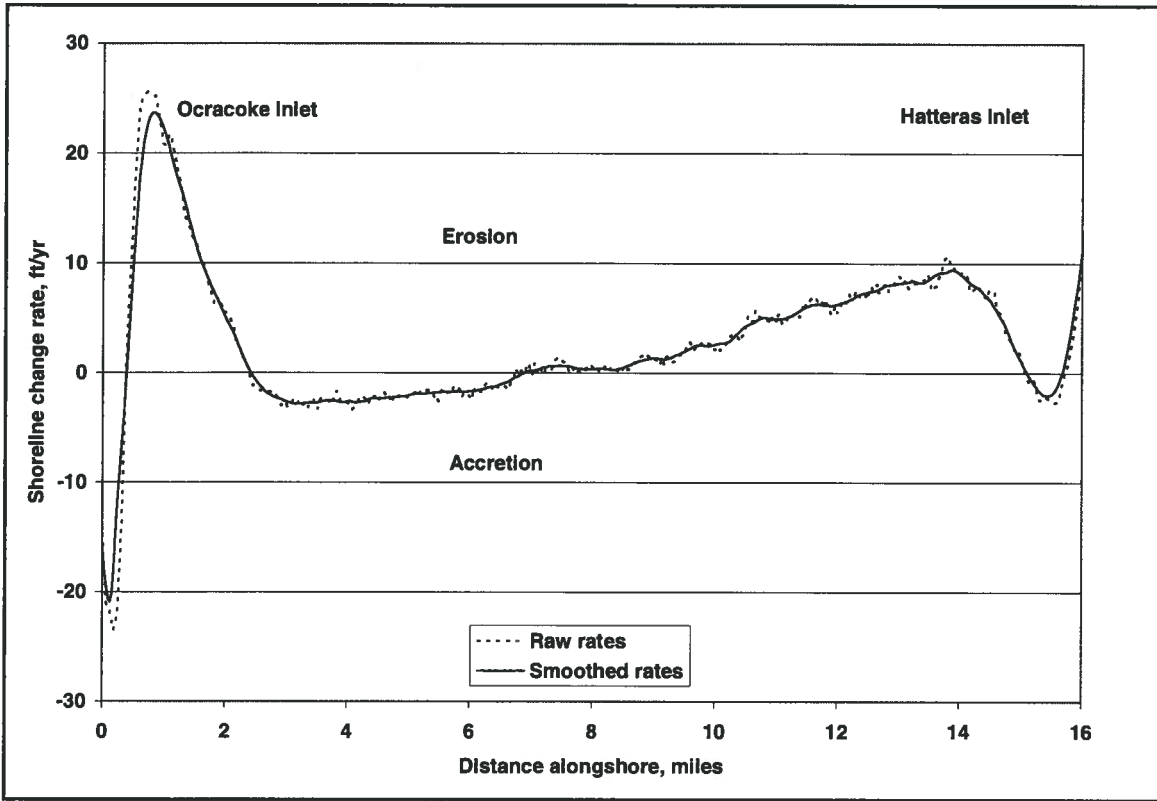


Figure 1. Raw and smoothed shoreline change rates on Ocracoke Island.

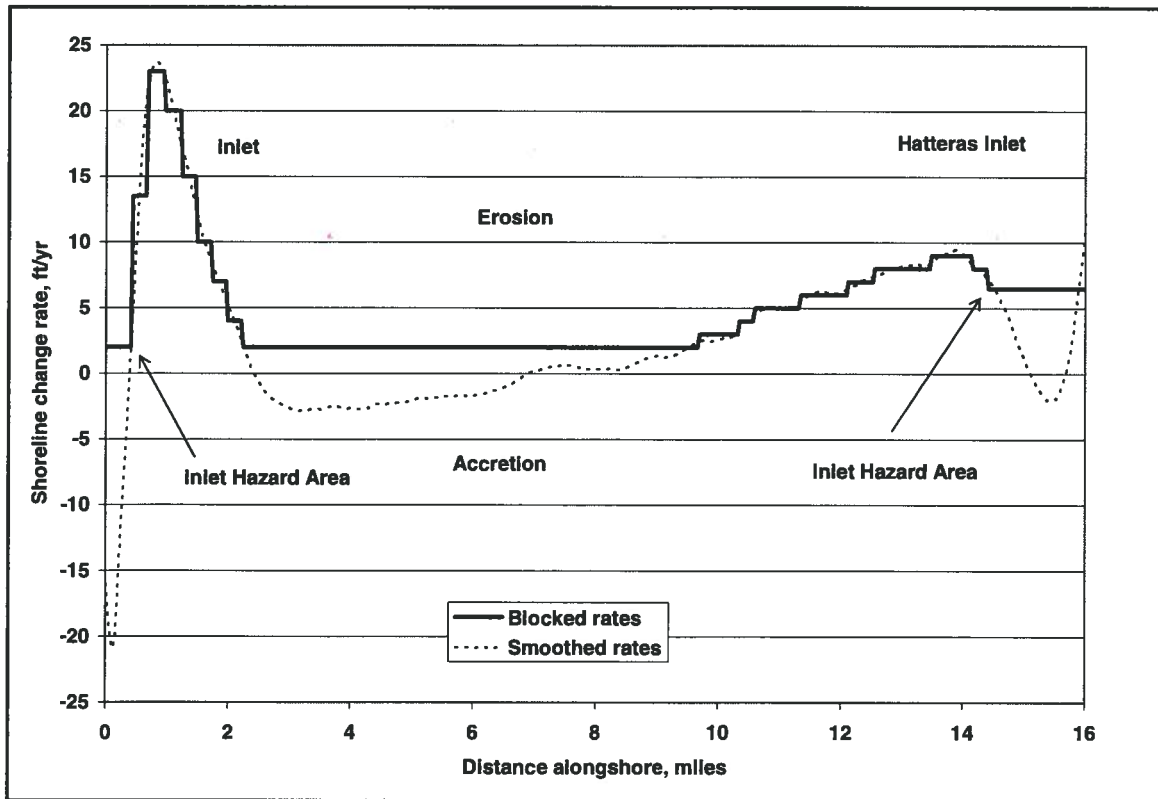


Figure 2. Blocked and smoothed shoreline change rates on Ocracoke Island.

RESULTS

The statistics of the blocked rates as computed in the earlier studies were computed for the 1998 study. These data are presented in Table 4 below. The percentages provided in the parenthesis are computed by dividing the number of miles of shoreline in a given category (e.g., accretion) by the total number of miles of shoreline in a category (e.g., South facing) and multiplying by 100.

These data can be compared to the data presented in the 1992 Methods Report (Benton, *et al.*, 1997) (Table 5). However, these should be used for rough qualitative comparison only. They cannot be compared directly because (1) there is a difference in the miles of shoreline in each study (probably due to approximations made near inlets and capes), (2) the early date is not the same in the two studies and (3) refinements have been made in the blocking methodologies that may impact the statistics below. Better comparison can be made if these factors are taken into account.

A preliminary analysis of the data showed remarkable consistency with earlier updates. The miles of shoreline eroding 2 feet/year or less increased by 1 to 6% over earlier updates. The miles of shoreline eroding at more than 8 feet/year decreased from 11% to 9% of the shoreline. A survey of erosion hot spots (defined as segments eroding more than 4.5 feet/year) was compared to the 1992 erosion hot spots. Of the 34 hot spots found in the 1998 update, nearly all were in the same location and had similar erosion rates to hotspots surveyed in the 1992 update. Three were new to the 1998 study, four were reduced to non-hot spot status. Thirteen hot spots increased in length, 16 got smaller, and six stayed the same. Eleven of the hot spots had increases in the maximum erosion rates, 12 had decreases, and 11 stayed the same.

Table 4. Summary of 1998 blocked shoreline change rates.

	South Facing	East Facing	Total
Total Shoreline (miles)	96	216	312
Accreting Shoreline (miles)	37 39%	62 29%	99 32%
Shoreline (including accretion) with Rate < 2 ft/yr (miles)	69 72%	124 58%	193 62%
Shoreline with Rate = 2-5 ft/yr (miles)	14 14%	50 23%	64 20%
Shoreline with Rate = 5-8 ft/yr (miles)	9 9%	19 9%	28 9%
Shoreline with Rate >8 ft/yr (miles)	5 5%	22 10%	27 9%
Maximum Rate (ft/yr)	23.0	30.0	30.0
Mean Rate (ft/yr)	3.9	4.4	4.3

Table 5. Comparison of the 1992 and 1998 blocked shoreline change rates.

	1992 Total	1998 Total
Total Shoreline (miles)	281	312
Accreting Shoreline (miles)	79 26%	99 32%
Shoreline (including accreting) with Rate <2 ft/yr (miles)	165 59%	193 62%
Shoreline with Rate = 2-5 ft/yr (miles)	54 19%	64 20%
Shoreline with Rate = 5-8 ft/yr (miles)	30 11%	28 9%
Shoreline with Rate >8 ft/yr (miles)	32 11%	27 9%
Maximum Rate (ft/yr)	16.0	30.0
Mean Rate (ft/yr)	3.8	4.3

COMMENTS AND RECOMMENDATIONS

The 1998 long-term average annual erosion rate update is once again surprisingly consistent with earlier updates. These, in turn, have been consistent in terms of regional trends with a review of other erosion studies (Benton, 1983) utilizing several other methodologies and involving time scales ranging up to thousands of years. However, there is a need to continue to evaluate alternative methodologies and incorporate enhancements to the study data at every opportunity. As recommended in the first Methods Report (Benton, 1983) and echoed by the CRC's Science Panel on Coastal Hazards, a probabilistic model approach should be considered when the funding and data are available. There are a number of these that have been developed over the past several years, including linear regression models, average of rates (Foster, and Savage, 1989), and jackknifing (Dolan, *et al.*, 1991). Other techniques are described in Douglas, *et al.*, 1998, Douglas, and Crowell, 2000, Fenster, *et al.* 2001, and Honeycutt, *et al.*, 2001. As part of this effort, the possibility of publication of shorter-time period erosion data should be evaluated to supplement the long-term shoreline data and storm erosion data already developed and utilized in management of the NC oceanfront.

The first steps in developing a GIS based shoreline management program have been taken with this 1998 long-term erosion update. These steps need to be followed up with broadly ranging data types and studies. As recommended by the NC Science Panel, additional digital GIS shoreline dates from historical aerial photographs and other sources, and studies of the underlying geology that so dramatically affect shoreline patterns both long-term and short-term need to be incorporated into the GIS shoreline management program database when the GIS data from these studies is completed. Similarly, as recommended in the first Methods Report, detailed wave energy analysis and wave orthogonal studies, weather data, sediment budget studies, and detailed nearshore bathymetric information should be developed for comparison with the long-term erosion data. These data should be put into a GIS format data layer and incorporated into the GIS shoreline management program database.

The wet/dry line as a delineation of the shoreline represents a best estimate of shoreline position when the data source for shoreline interpretation are limited to aerial photographs. Photo-identifiable features are often argued to represent the high water line (HWL) or the mean high water (MHW) (Pajak, and Leatherman, 2002). However, these interpretations are highly dependent on variations in photo scale, quality of image contrast, mineralogy, sedimentology, geomorphology, tide and wind/wave conditions at the time of the photograph (Fisher, and Overton, 1994). In addition, coastal engineers and scientists are escalating the debate of "what is the shoreline?" as remote sensing technologies and three dimensional visualization techniques have greatly improved our ability to map the coastal environment (Overton, and Fisher, 1996b; Stockdon, *et al.*, 2002). We should monitor these discussions and consider the possibility of using these alternative technologies in future updates. Datum-based shorelines are rapidly becoming the standard in defining shoreline position (though which datum to use is still being debated). While issues of merging two-dimensional (wet/dry line) and three-dimensional (MHW) data sets exist, the problems posed are not insurmountable (Judge, *et al.*, 2001).

REFERENCES

- Benton, S. B., 1983. "Average Annual Long-Term Erosion Rate Update Methods Report", NC Office of Coastal Management, CRC-247, Raleigh, NC, 67 pp.
- Benton, S. B., C. J. Bellis, M. F. Overton, J. S. Fisher, and J. L. Hench, 1997. "North Carolina Long Term Average Annual Rate of Shoreline Change: Methods Report", NC Department of Environment, Health, and Natural Resources, Raleigh, NC.
- Crowell, M., S. P. Leatherman, and M. K. Buckley, 1991. "Historical Shoreline Change: Error Analysis and Mapping Accuracy", *Journal of Coastal Research*, V. 7(3), p. 839-852.
- Crowell, M., S. P. Leatherman, and M. K. Buckley, 1993. "Shoreline Change Rate Analysis: Long Term Versus Short Term Data", *Shore and Beach*, April 1993, p. 13-20.
- Davis, J. C., 1973. Statistics and Data Analysis in Geology, John Wiley and Sons, Inc., New York, NY.
- Davis, R. A., 1978. Coastal Sedimentary Environments, Springer-Verlag: New York, NY, 420 pp.
- Dolan, R., and J. C. Ferm, 1968. "Crescentic Landforms along the Atlantic Coast of the US", *Science*, V. 159, p. 627-629.
- Dolan, R., B. P. Hayden, and J. Heywood, 1978. "A New Photogrammetric Method for Determining Shoreline Erosion", *Coastal Engineering*, V. 2, p. 21-39.
- Dolan, R., B. P. Hayden, P. May, and S. May, 1980. "The Reliability of Shoreline Change Measurements from Aerial Photographs", *Shore and Beach*, V. 48, No. 4, p. 22-29.
- Dolan, R., M. S. Fenster, and S. J. Holme, 1991. "Temporal Analysis of Shoreline Recession and Accretion", *Journal of Coastal Research*, V. 7(3), p. 723-744.
- Douglas, B. C., M. Crowell, and S. Leatherman, 1998. "Considerations for Shoreline Position Prediction", *Journal of Coastal Research*, V.14(3), p. 1025-1033.
- Douglas, B. C., and M. Crowell, 2000. "Long-term Shoreline Position Prediction and Error Propagation", *Journal of Coastal Research*, V.16(1), p. 145-152.

- Douglas, B. C., M. Crowell, and M. G. Honeycutt, 2002. "Discussion of Fenster, M.S; Dolan, R. and Morton, R.A., 2001. Coastal Storms and Shoreline Change: Signal or Noise?", *Journal of Coastal Research*, V. 17(3), p. 714-720, *Journal of Coastal Research*, 18(2), p. 388-390.
- Fenster, M. S., R. Dolan, and R. A. Morton, 2001. "Coastal Storms and Shoreline Change: Signal or Noise?" *Journal of Coastal Research*, V. 17(3), p. 714-720.
- Fisher, J. S. and M. F. Overton, 1994. "Interpretation of Shoreline Position from Aerial Photographs," Proceedings of the 24th International Conference on Coastal Engineering, Kobe, Japan, p. 1998 - 2003, October 1994.
- Honeycutt, M. G., M. Crowell, B. C. Douglas, 2001. "Shoreline-Position Forecasting: Impact of Storms, Rate-calculation Methodologies and Temporal Scales", *Journal of Coastal Research*, V. 17(2), p. 721-730.
- Foster, E. R., and R. J. Savage, 1989. "Methods of Historical Shoreline Analysis" in Magoon, O. T., H. Converse, D. Miner, L. T. Tobin, and D. Clark, *eds.*, Coastal Zone '89, American Society of Civil Engineers, V. 5, p. 4434-4448.
- Judge, E. K., M. F. Overton, J. S. Fisher, 2001. "Long-term Erosion Rates and Shoreline Position Databases: Merging Two and Three Dimensional Data Sets", Coastal Zone Management 2001, Cleveland, OH, July 2001.
- McBeth, F. H., 1956. "A Method of Shoreline Delineation", *Photogrammetric Engineering*, V. 22, p. 400-405.
- McCullough, M. W., and S. B. Benton, 1988. "Average Annual Long-Term Erosion Rate Update Methods Report", NC DCM, Raleigh, NC, 8 pp. + App.
- Overton, M. F., and J. S. Fisher, 1996a. "Summary Report – Historical (1940) Shoreline Position for Currituck County and Average Annual Erosion Rate", Unpublished Manuscript, NC School of Engineering, Raleigh, NC.,
- Overton, M. F. and J. S. Fisher, 1996b. "Application of 3-D Computer Modeling Using Digital Photogrammetry to Measure Shoreline Change," Proceedings of the 25th International Conference on Coastal Engineering, ASCE, V. 3, p. 3750-3761.
- Overton, M. F., and J. S. Fisher, 2003. "The 1998 Long-Term Erosion Rate Update Study for the North Carolina Shoreline", Final Report , Contract No. S02071, for NC DCM, NCSU Department of Civil Engineering, Raleigh NC, 18 pp.

- Pajak M. J. and S. Leatherman, 2002. "The High Water Line as Shoreline Indicator", *Journal of Coastal Research*, V. 18(2), p. 329-337.
- Shalowitz, A. L., 1964. Shore and Sea Boundaries, Volume 2, U.S. Department of Commerce, Publication 10-1, US Government Printing Office, Washington, DC, 749 pp.
- Stafford, D. B., 1968. "Development and Evaluation of a Procedure for Using Aerial Photographs to Conduct a Survey of Coastal Erosion", Project ERD-238, NCSU Department of Civil Engineering, 219 pp.
- Stockdon, H. F., A. H. Sallenger, Jr., J. H. List, R. A. Holman, 2002. "Estimation of Shoreline Positions and Change Using Airborne Topographic Lidar Data", *Journal of Coastal Research*, V. 18(3), p. 502-513.
- Tayfun, M. A., S. M. Rogers, and J. Langfelder, 1979. "A Methodology Report on Delineation of an Ocean Hazard Zone for NC", Contract C-1039, NCSU Department of Marine Science and Engineering, 15 pp.
- Zink, J., 2002. "Using Modern Photogrammetric Techniques to Map Historical Shorelines and Analyze Shoreline Change Rates", NCSU Masters Thesis, Raleigh, NC.

APPENDIX A: Rate Calculations

The procedure for determining the raw shoreline change rates is listed below.

1. Open the 1998 shoreline shapefile and the transect shapefile.
2. Use the script named *polyint2pnt*, (see Table A1), to determine the coordinates of the intersection of the transect with the shoreline.
3. Use the extension named *addxy*, (see Table A1), to add coordinates to the attribute table of the intersection point shapefile.
4. Save the intersection coordinates to a *.dbf file.
5. Bring the *.dbf coordinate file into Excel.
6. Repeat steps 1 through 5 using the early date shapefile.
7. Calculate the distance between the two intersection points using the following formula:

$$\text{dist} = \sqrt{(x_{98} - x_{\text{early}})^2 + (y_{98} - y_{\text{early}})^2}$$

where x and y are the coordinates of the intersection points.

8. For each transect, determine the correct date for the 1998 orthophotos and enter data into a column in Excel.
9. For each transect, determine the correct date for the early date used and enter data into a column in Excel.
10. Calculate the change in date by subtracting the two dates in excel (the number of days will be computed) and dividing by 365.25 (to convert from days to years and to account for leap years.)
11. Compute the shoreline change rate by dividing the dist computed in step 7 by the change in time computed in step 10.
12. Compute the orientation of the shoreline and determine if the shoreline change rate is positive (erosion) or negative (accretion).
13. Multiply rate by +1 for erosion and -1 for accretion.
14. Set the format to 1 decimal place to display rate.

Table A1. ArcView scripts used to determine intersection coordinates.

Name	Type	Creator	Source
polyint2pnt	Avenue Script	Dirk Vandervoort May 12, 1999	Environmental Systems Research Institute (ESRI) ArcScripts website < http://arcscripts.esri.com/ >
AddXY	Avenue User Extension	Zachary L. Stauber May 4, 2000	Collection of ArcView Extensions < http://horta.ulb.ac.be/cours/sis/SeqTraitement/ExtensionsAV/extensionsAV.htm >