Steven C. Howard, P.E.

Model Analysis of a Terminal Groin

Bald Head Island, NC

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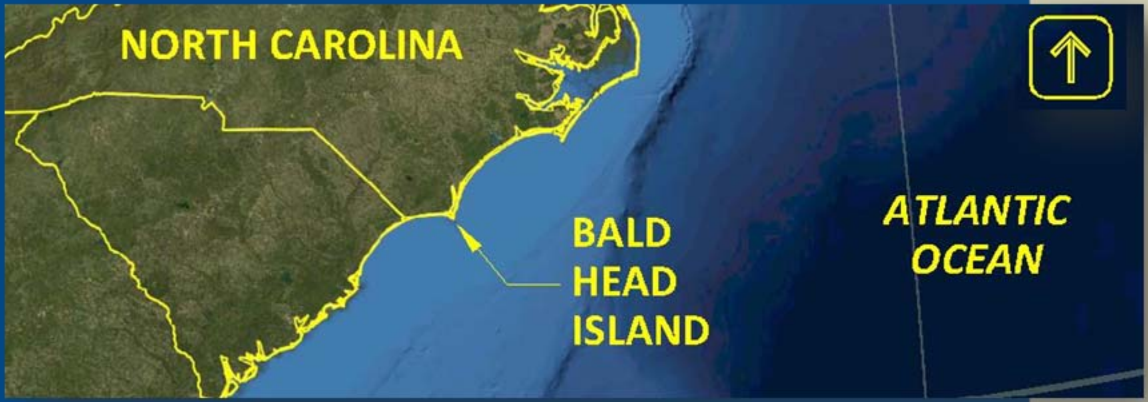
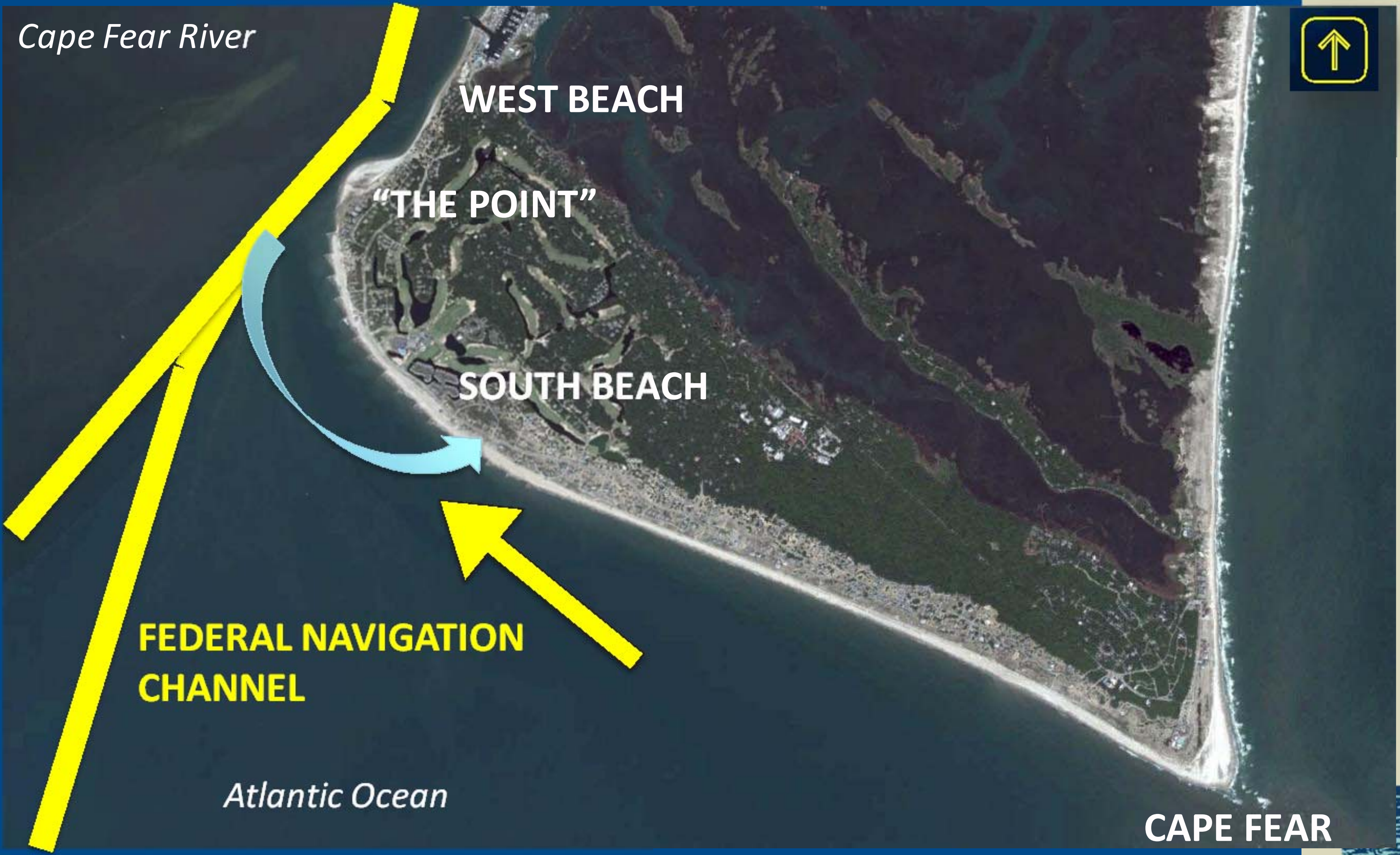
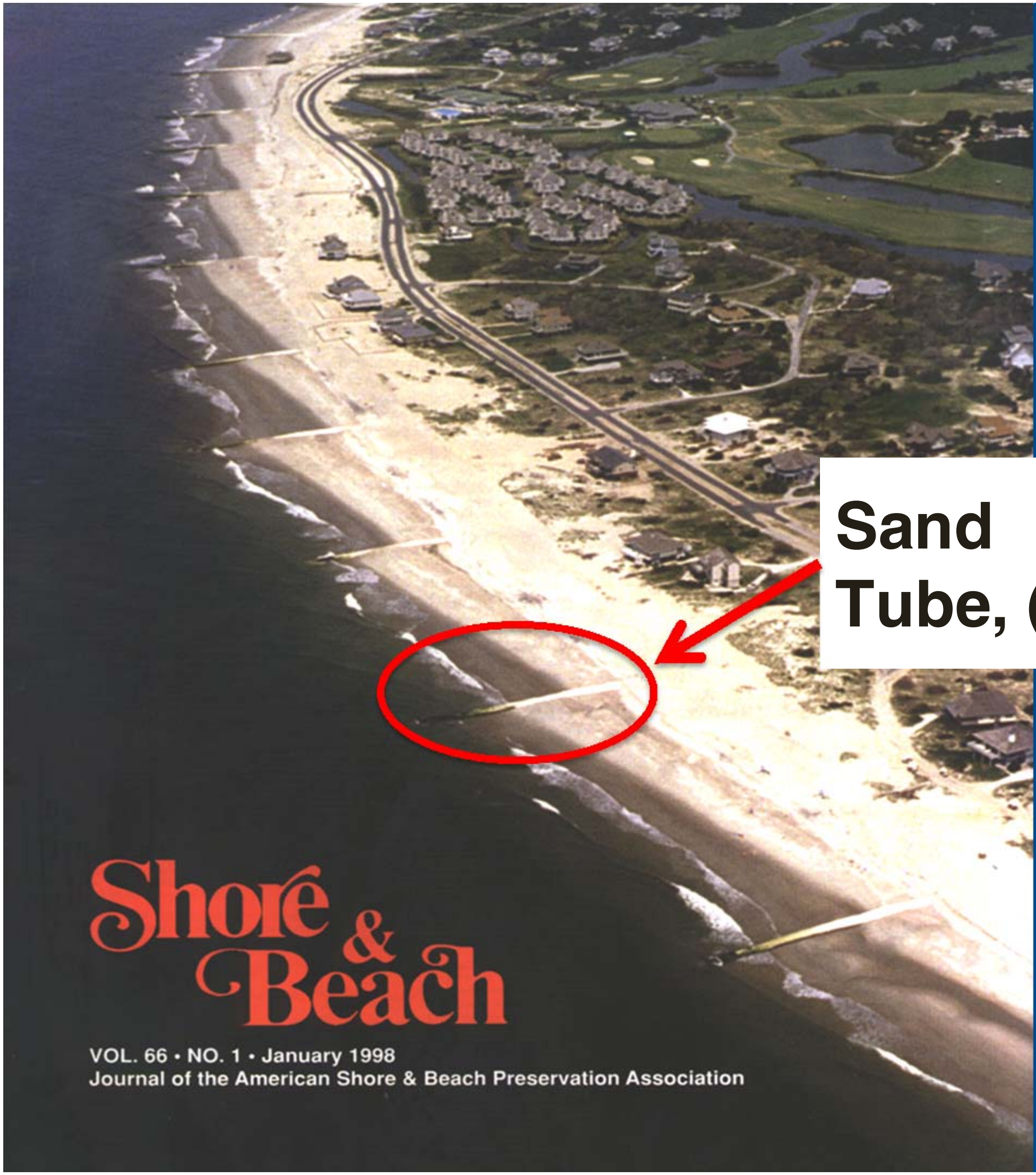
Bald Head Island, NC


NORTH CAROLINA
BALD HEAD ISLAND
ATLANTIC OCEAN

Bald Head Island, NC


Cape Fear River
WEST BEACH
"THE POINT"
SOUTH BEACH
FEDERAL NAVIGATION
CHANNEL
Atlantic Ocean
CAPE FEAR



Shore & Beach

VOL. 66 • NO. 1 • January 1998
Journal of the American Shore & Beach Preservation Association

Sand Tube, (typ)

BUILT
1995

REBUILT
2005
2010

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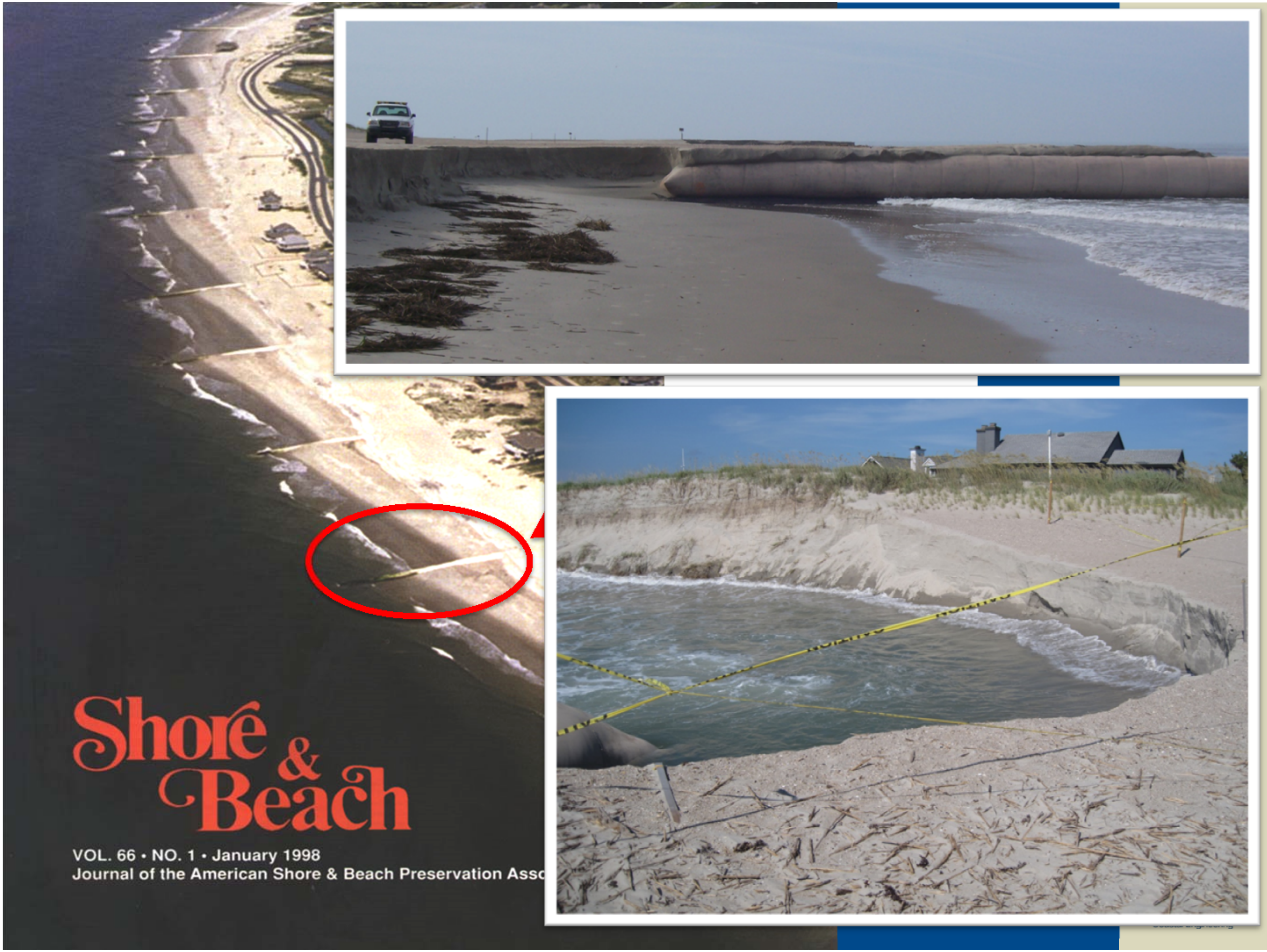
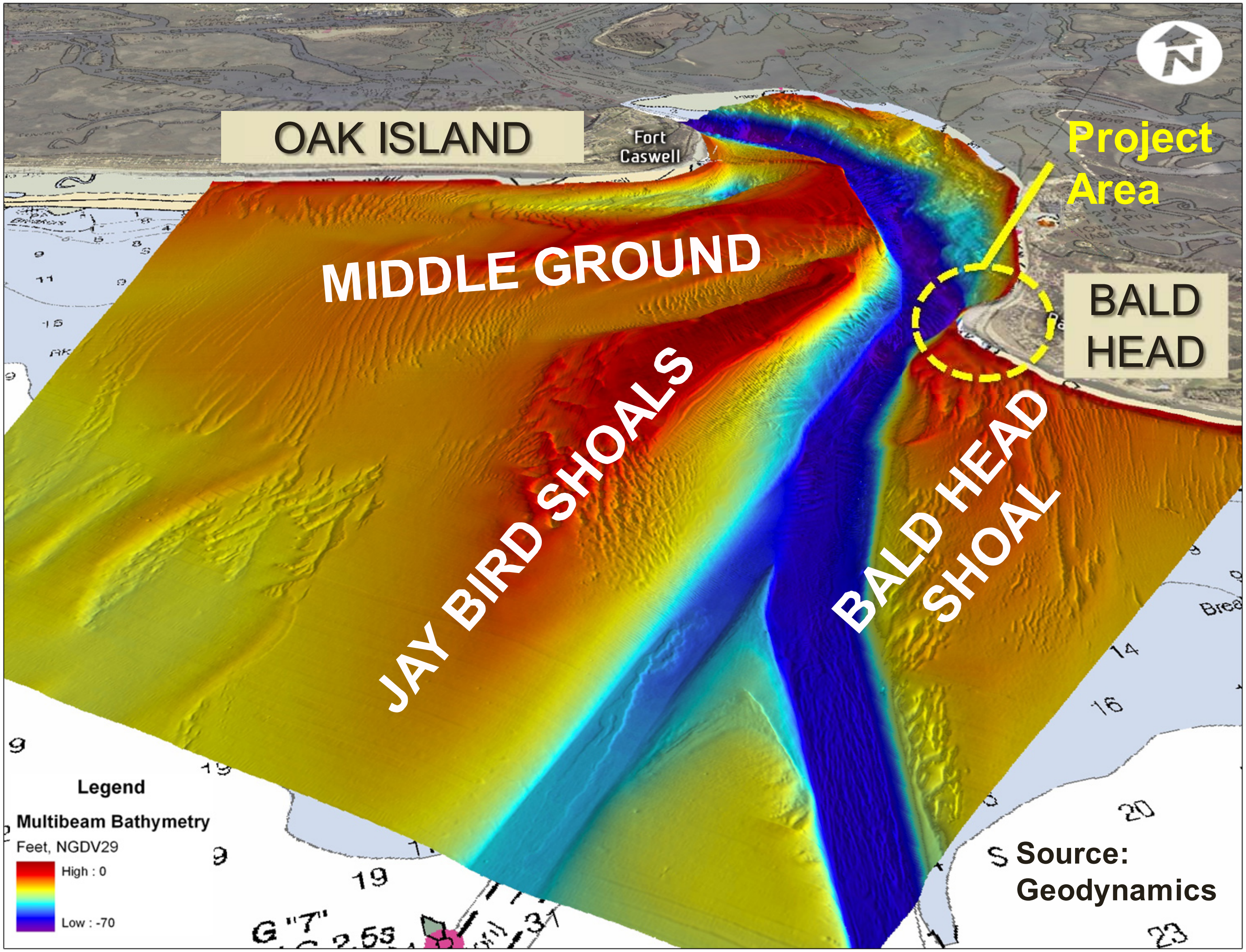


Shore & Beach

VOL. 66 • NO. 1 • January 1998

Journal of the American Shore & Beach Preservation Assc


OAK ISLAND
Fort Caswell
Project Area
MIDDLE GROUND
BALD HEAD
JAY BIRD SHOALS
BALD HEAD SHOAL
N
Legend
Multibeam Bathymetry
Feet, NGDV29
High : 0
Low : -70

Source: Geodynamics

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Dredging Operations at "The Point"

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Maintenance Dredging

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NAVIGATION PROJECT LOCAL EFFECTS

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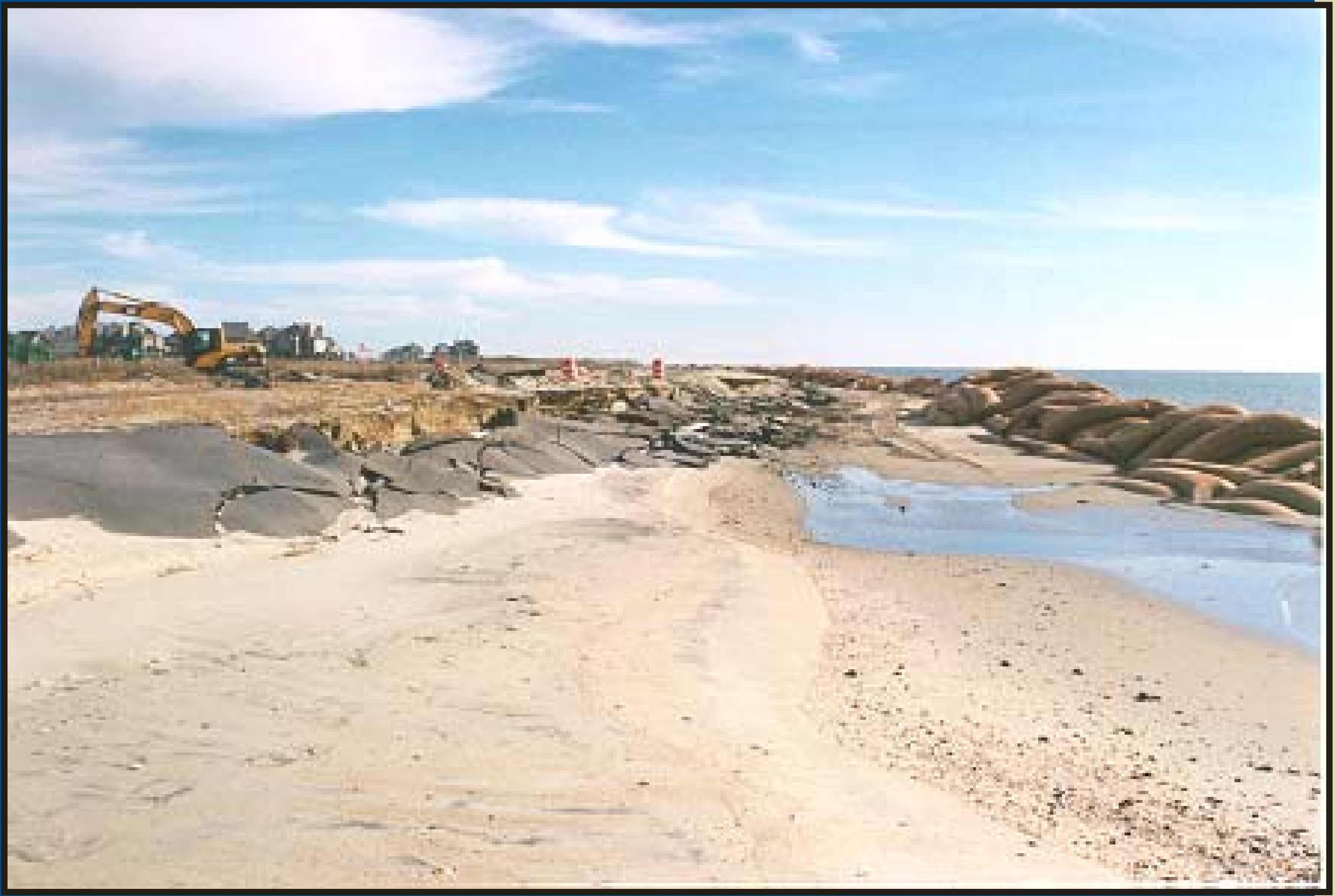
NAVIGATION PROJECT LOCAL EFFECTS



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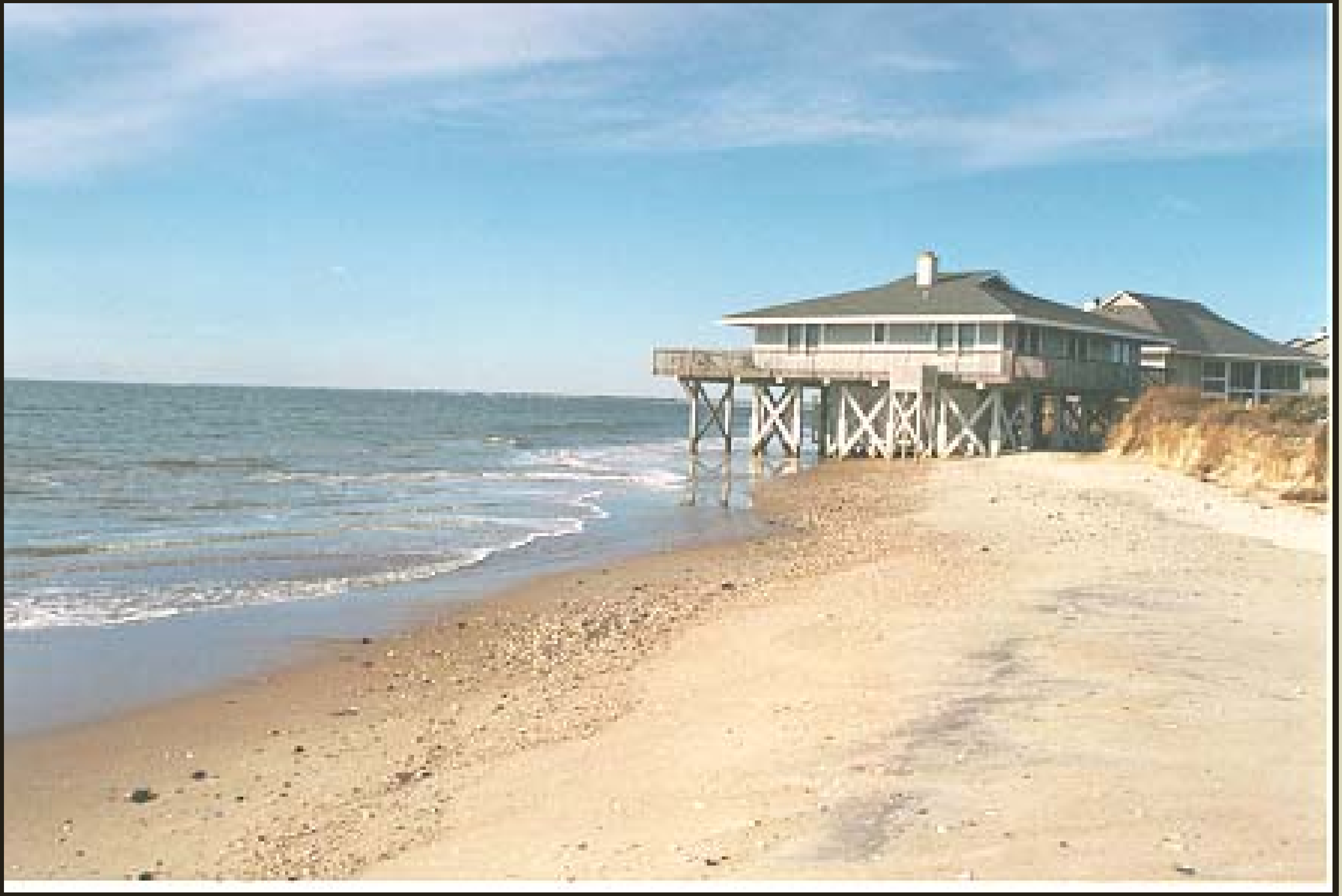
Coastal Engineering

NAVIGATION PROJECT LOCAL EFFECTS



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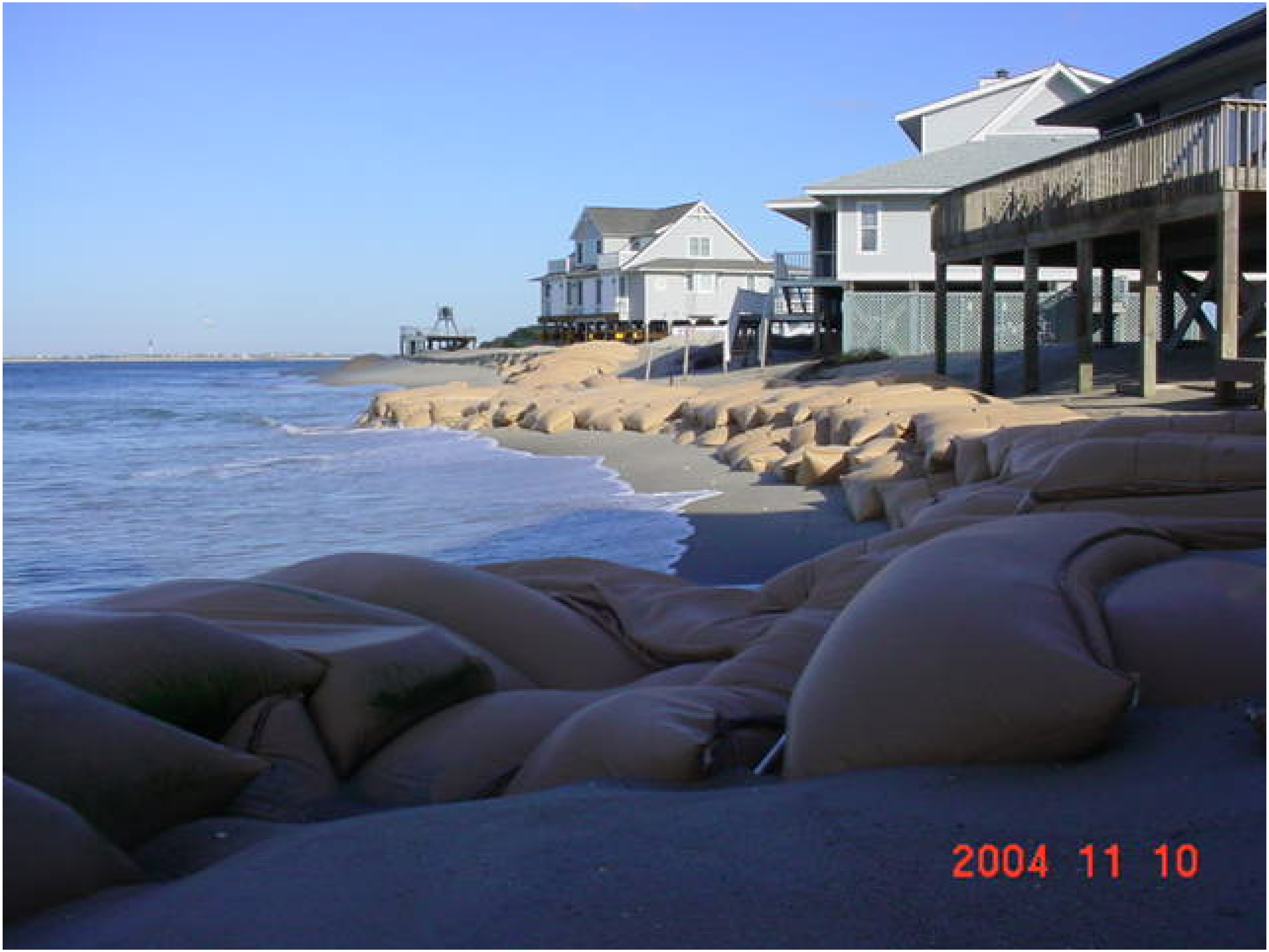
2004 11 10

Bobcat
2004 11 17

Background

- Since 2000 – 9 Mcy of sand have been placed on South Beach.
- The Village elected to pursue construction of a terminal groin.

WHAT IS A TERMINAL GROIN?

(HINT: It's not a jetty)

- Meant to stabilize the end of a littoral cell, not specifically improve an inlet.
- Structure must be "leaky" (i.e. low and permeable).
- Large uniform armor rock.
- Serve as a template for updrift shoreline.

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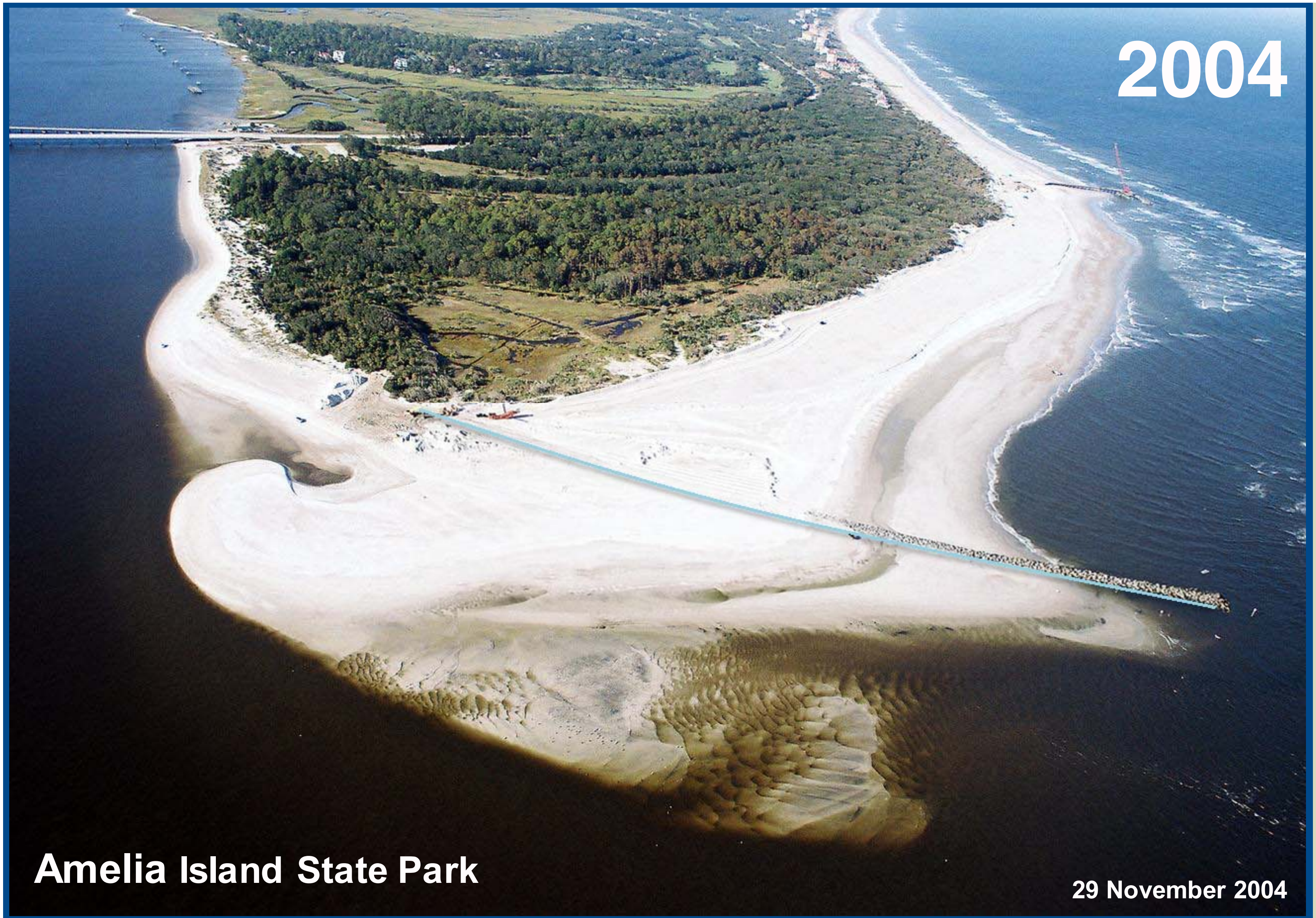

2004

Amelia Island State Park

29 November 2004

Terminal Leaky Groin & Breakwater

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“So, you want to build a *‘jetty’* in North Carolina?” – Everyone not on Bald Head

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COASTAL ARMORING IN THE TAR HEEL STATE

- **2011: SB 110 repealed decades-long ban on hard structures allowing for potential construction of up to four "test" terminal groins.**

- **2013-15: Bald Head Groin was permitted and constructed.**

- **Complex analysis required for permitting and construction.**

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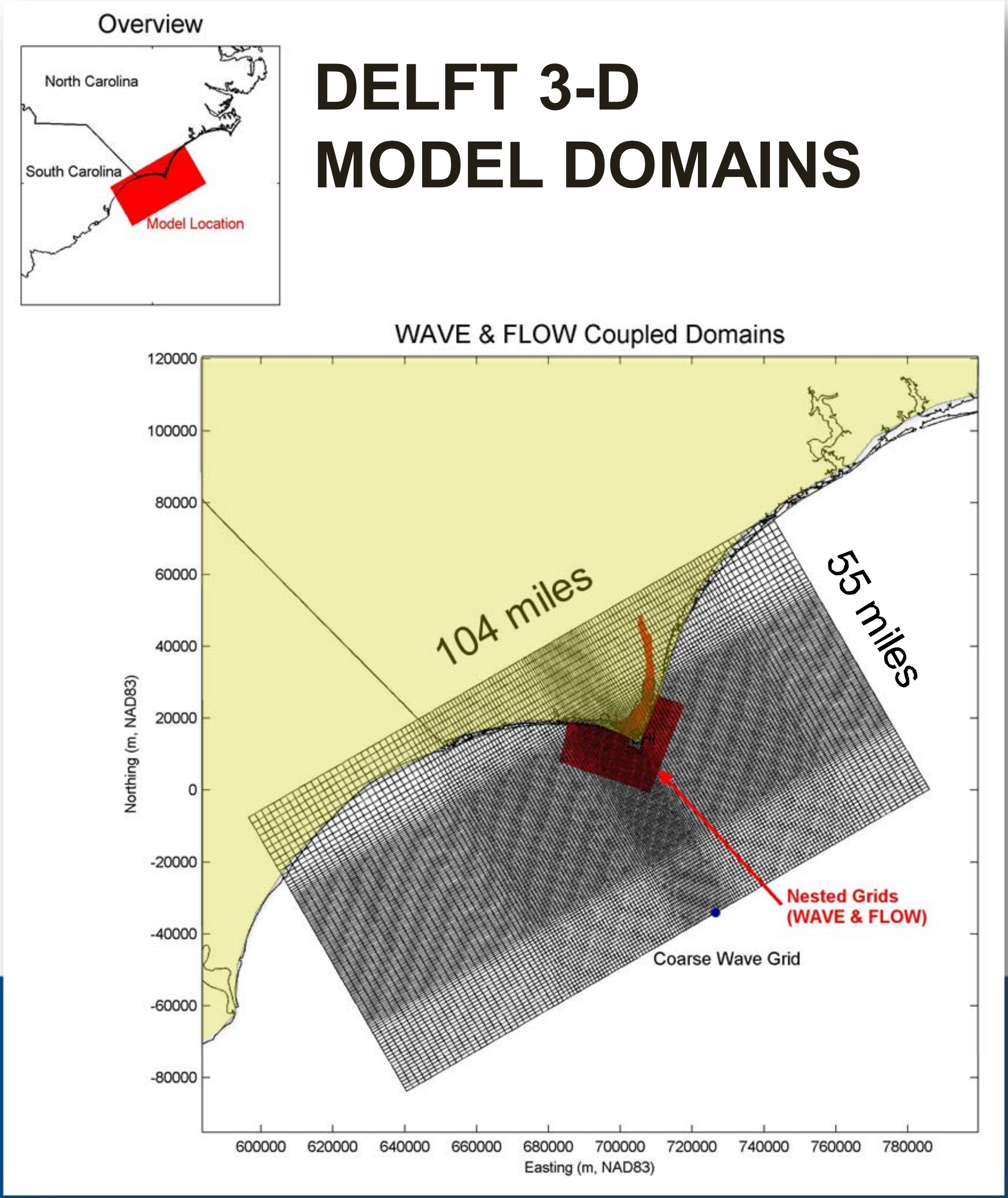
MODELING WAS REQUIRED

DELFT 3-D

Computational Domains (WAVE + FLOW)



DELFT 3-D MODEL DOMAINS

Overview
North Carolina
South Carolina
Model Location
WAVE & FLOW Coupled Domains
120000
100000
80000
60000
40000
20000
0
-20000
-40000
-60000
-80000
Northing (m, NAD83)
600000
620000
640000
660000
680000
700000
720000
740000
760000
780000
Easting (m, NAD83)
104 miles
55 miles
Nested Grids
(WAVE & FLOW)
Coarse Wave Grid

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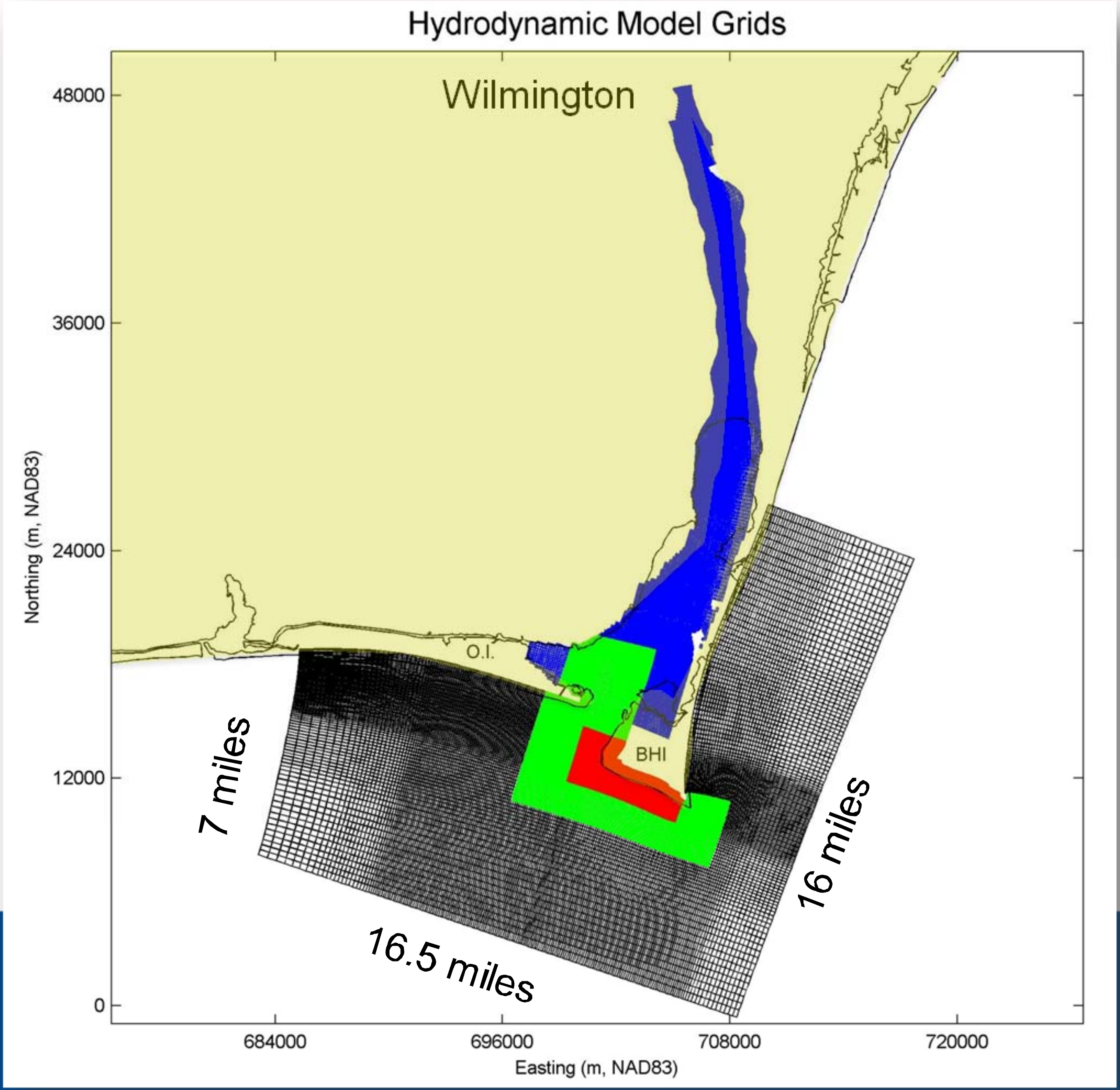
Hydrodynamic Grids (FLOW)


Hydrodynamic Model Grids
Wilmington
O.I.
BHI
7 miles
16 miles
16.5 miles
Northing (m, NAD83)
48000
36000
24000
12000
0
Easting (m, NAD83)
684000
696000
708000
720000

- 4 Domains
- Cell Size Range: 430m offshore (Black) to 17 m nearshore (Red)
- WAVE Model refined using similar grid resolution(s)

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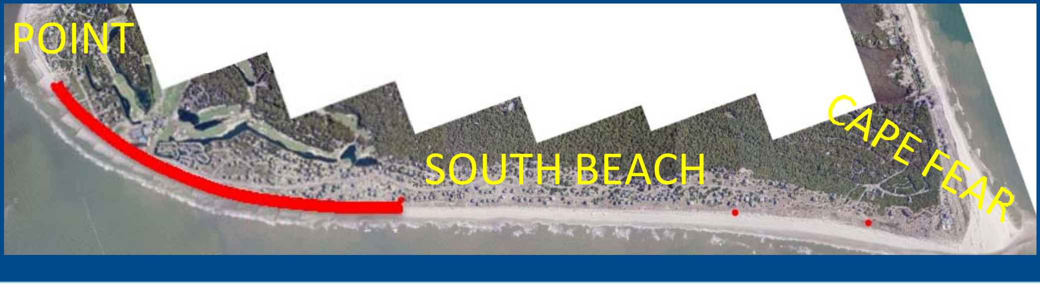
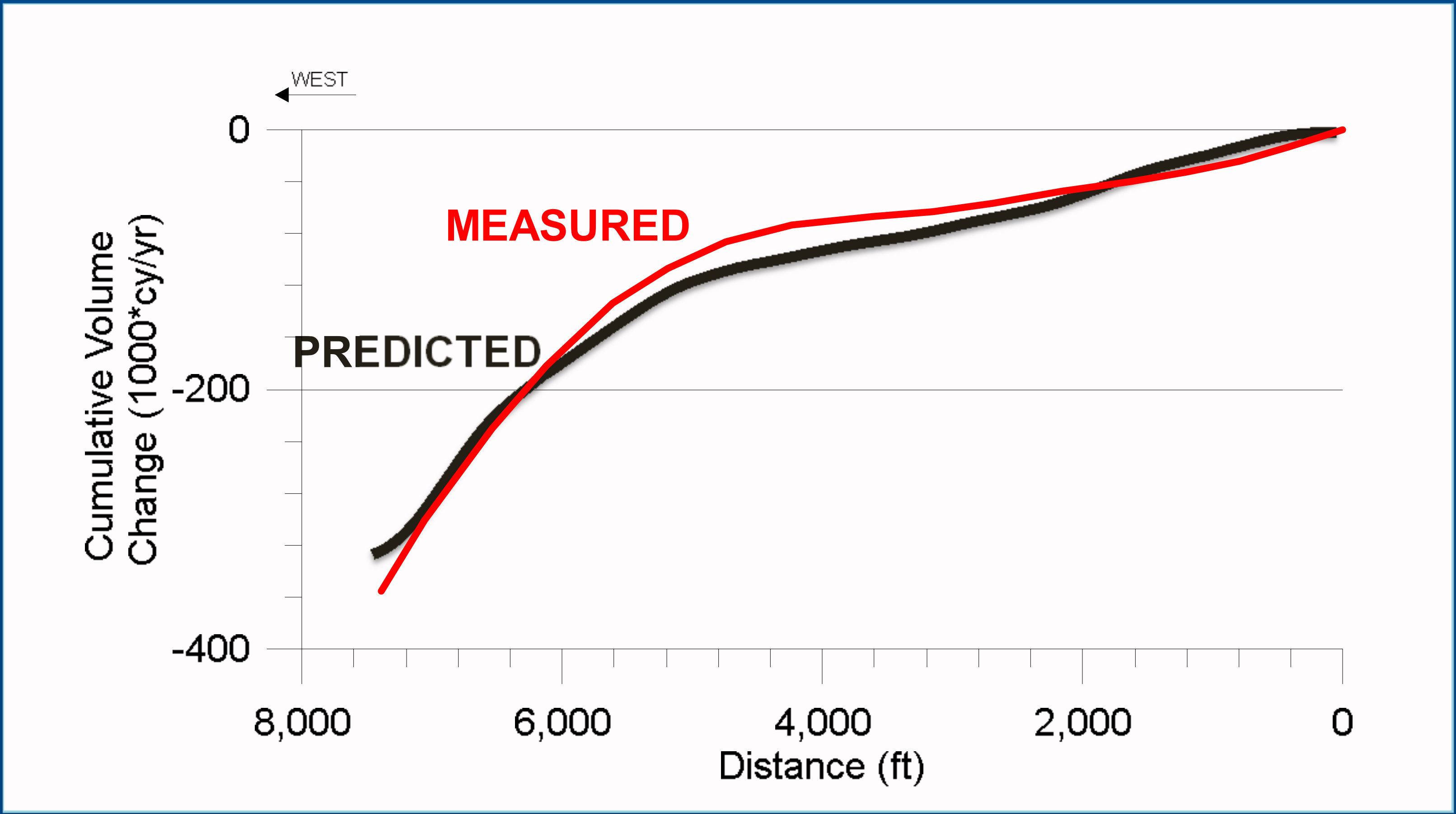
Calibrated to Volume Change on Bald Head Island


POINT
SOUTH BEACH
CAPE FEAR



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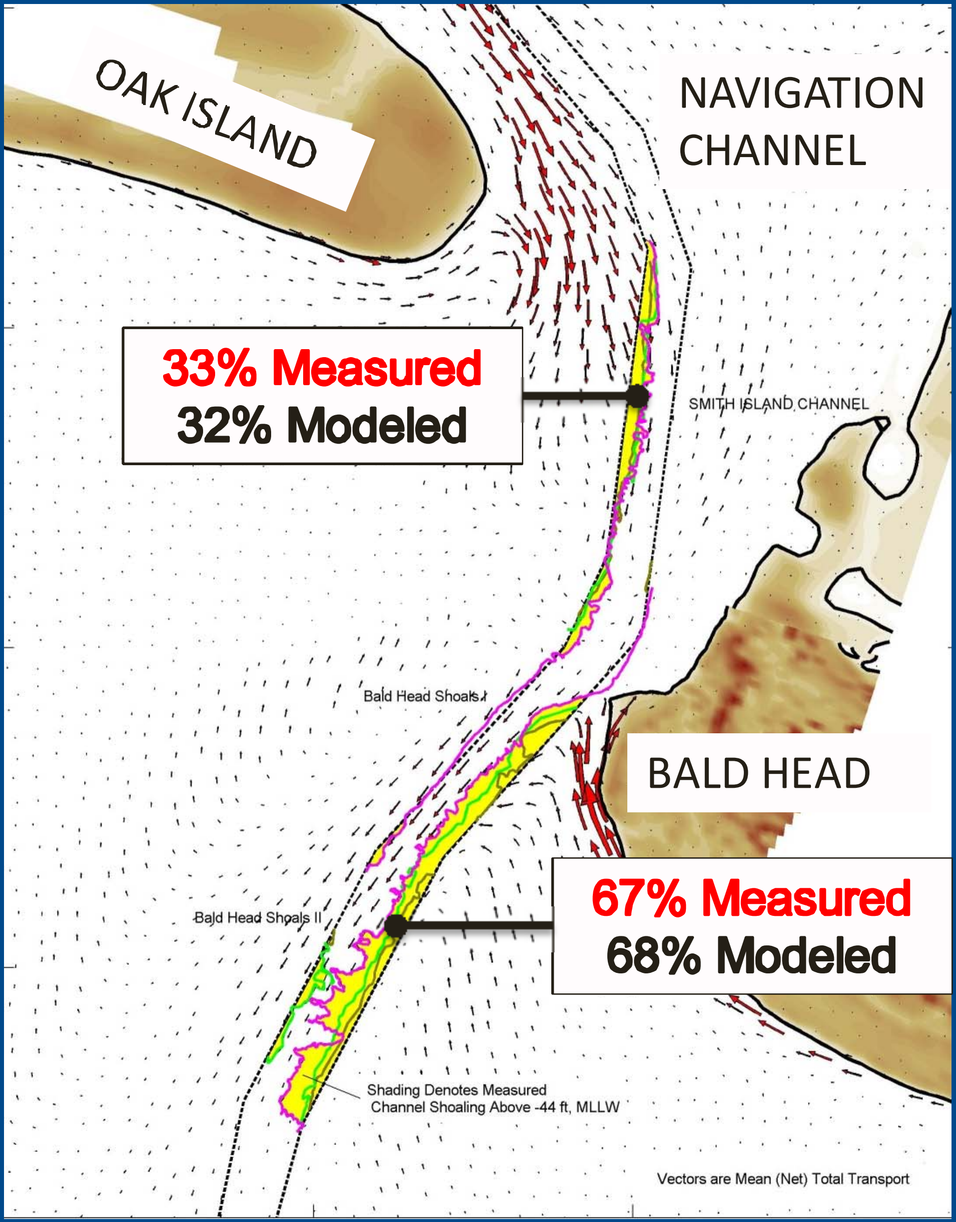
Transport Patterns & Rates


OAK ISLAND
NAVIGATION CHANNEL
SMITH ISLAND CHANNEL
Bald Head Shoals I
Bald Head Shoals II
BALD HEAD

33% Measured
32% Modeled

67% Measured
68% Modeled

Shading Denotes Measured Channel Shoaling Above -44 ft, MLLW

Vectors are Mean (Net) Total Transport

Typical 2-Year Cycle:

- **Measured Shoaling 1,176,000 cy**
- **Computed Shoaling 963,500 cy**

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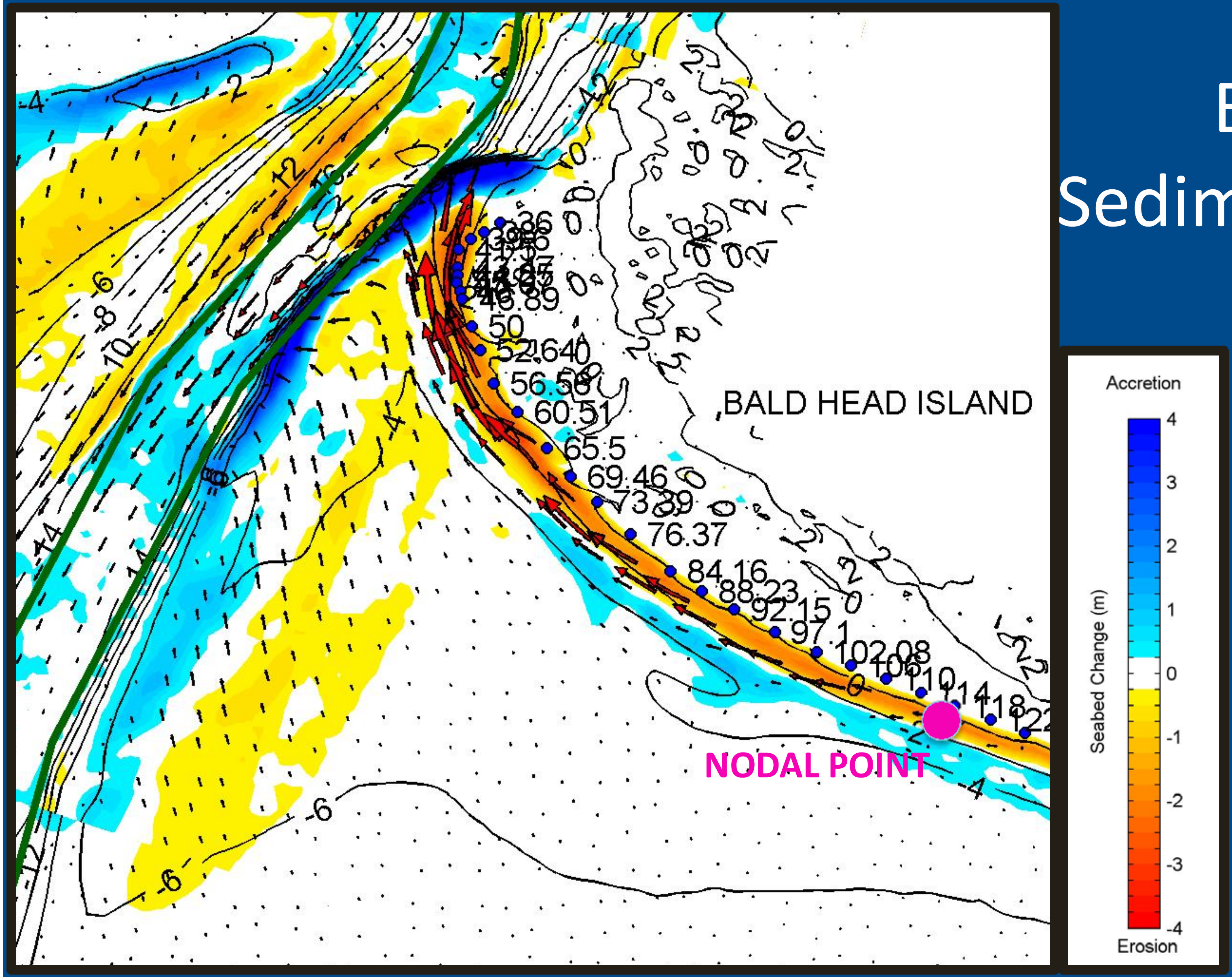
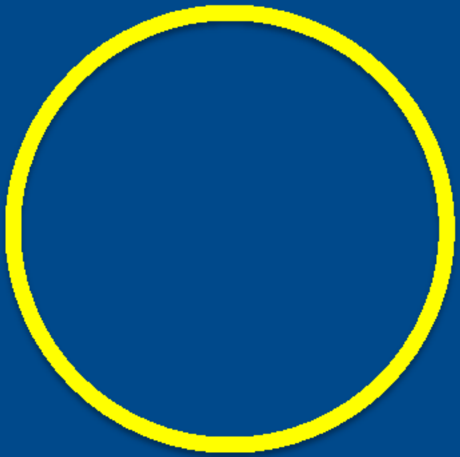
Average Annual Erosion & Sedimentation


BALD HEAD ISLAND
NODAL POINT
36
39
50
52.64
56.58
60.51
65.5
69.46
73.39
76.37
84.16
88.23
92.15
97.1
102.08
106
110
114
118
122
-2
-4
-6
-8
-10
-12
-14
-16
0
2
Accretion
Seabed Change (m)
4
3
2
1
0
-1
-2
-3
-4
Erosion

Modeling Difficulties



Nobody's perfect!

Relevant Delft3D Limitations

While powerful, Delft3D could not:

- account for repose of a slope due to “avalanching”.
  - Could not model immediate response to dredging.

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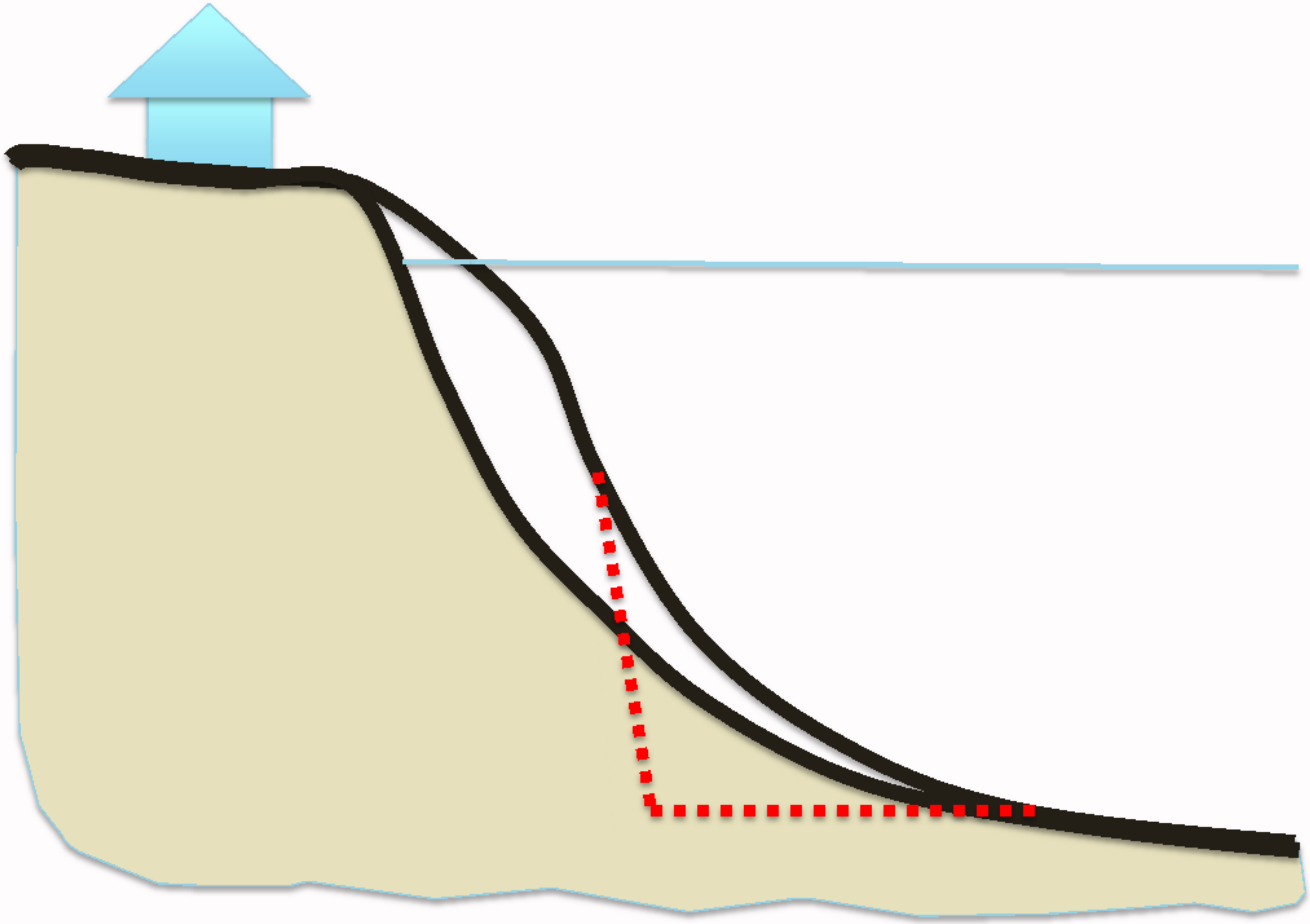
Relevant Delft3D Limitations

Slope avalanche



Relevant Delft3D Limitations

While powerful, Delft3D could not:

- account for repose of a slope due to “avalanching”.
  - Could not model immediate response to dredging.

- precisely describe the permeability of a structure.
  - Requires sensitivity testing

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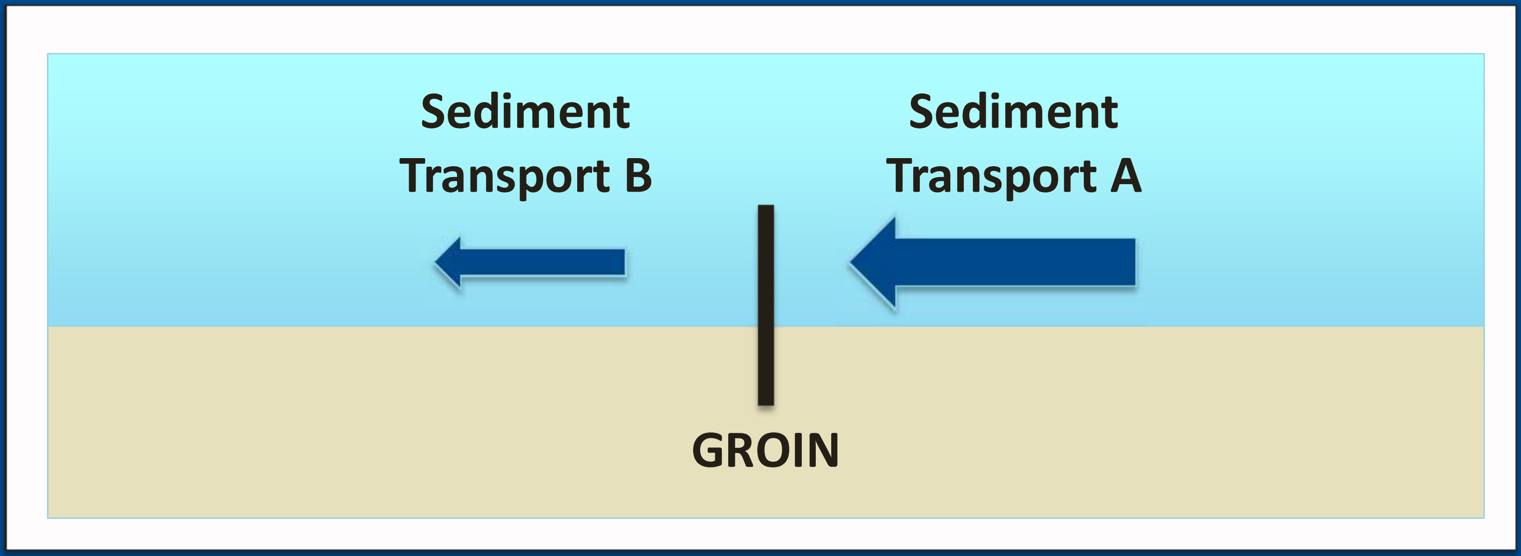
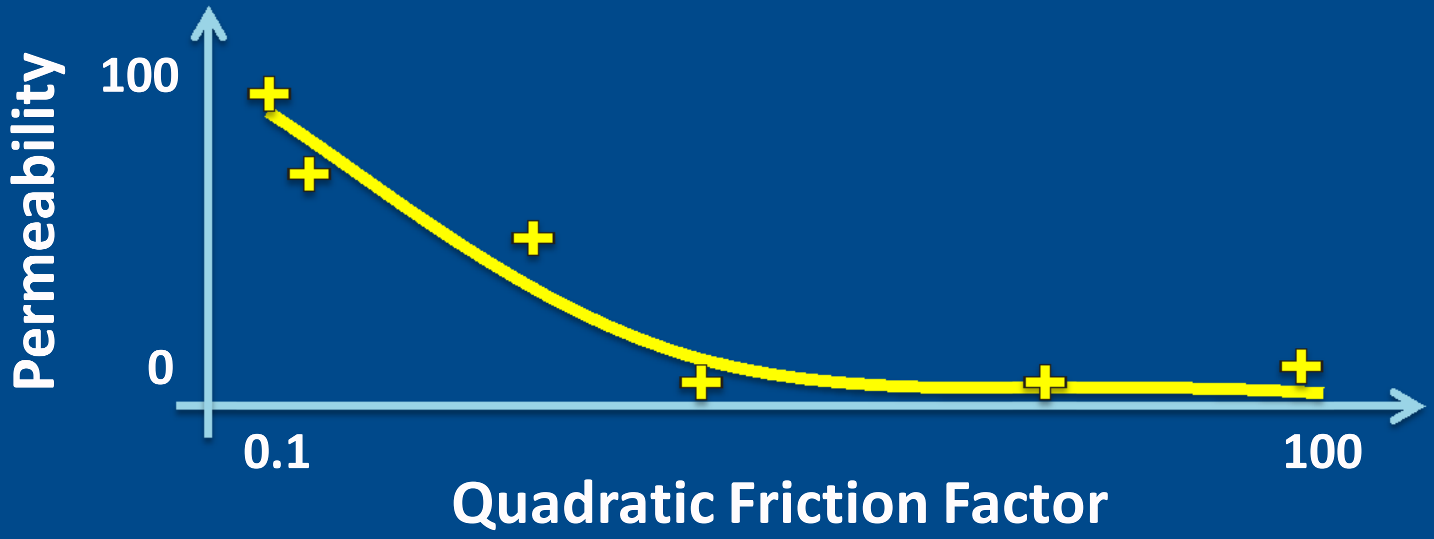
Relevant Delft3D Limitations


Sediment Transport B
Sediment Transport A
GROIN



Relevant Delft3D Limitations

Relevant Delft3D Limitations

While powerful, Delft3D could not:

- account for repose of a slope due to “avalanching”.
  - Could not model immediate response to dredging.
- precisely describe the permeability of a structure.
  - Requires sensitivity testing
- predict MHW shoreline position.
  - Can predict submerged shorelines (MLLW).
- fully describe inlet shoreline physics (ship wake, wind waves, etc.)

So, how was Delft3D applied?

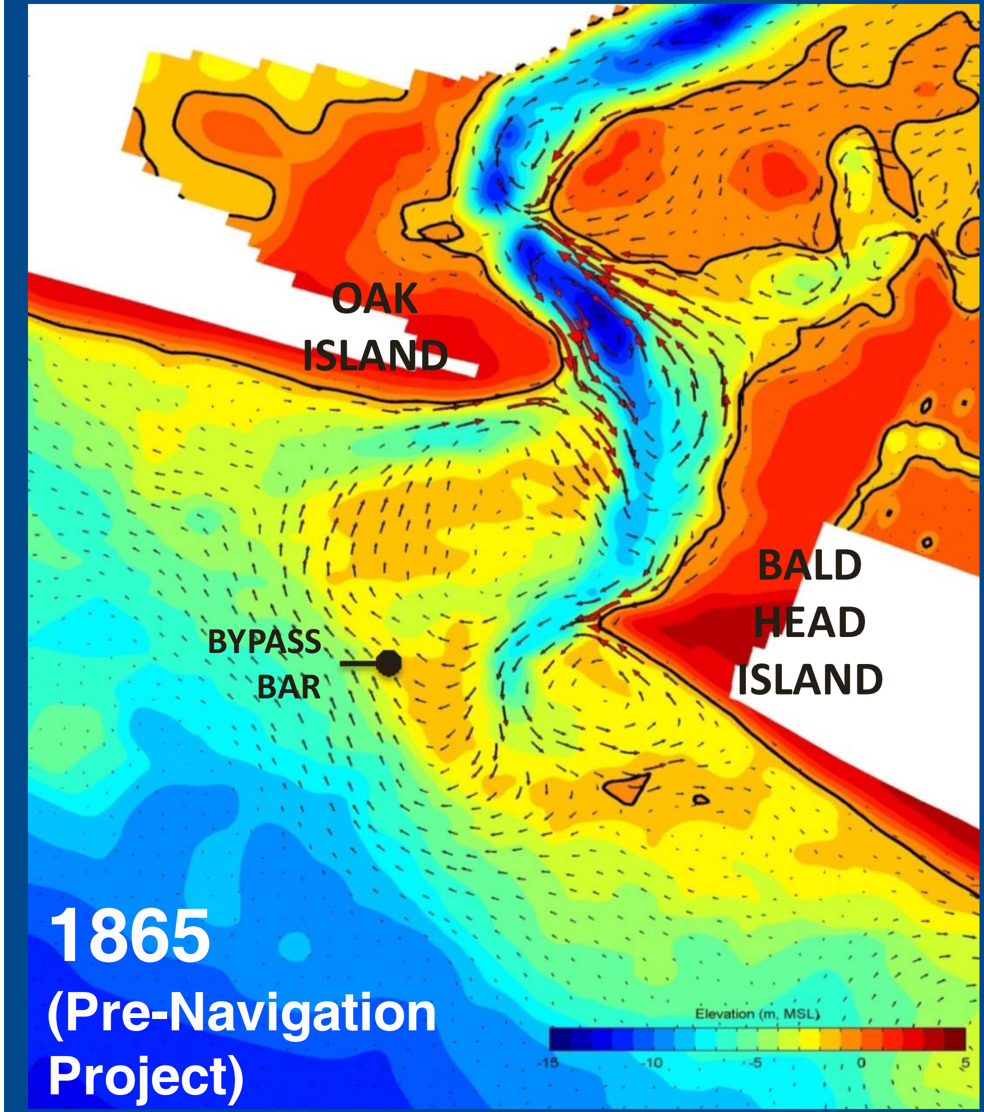
Evaluate E.I.S. alternative actions

- Performance predictions

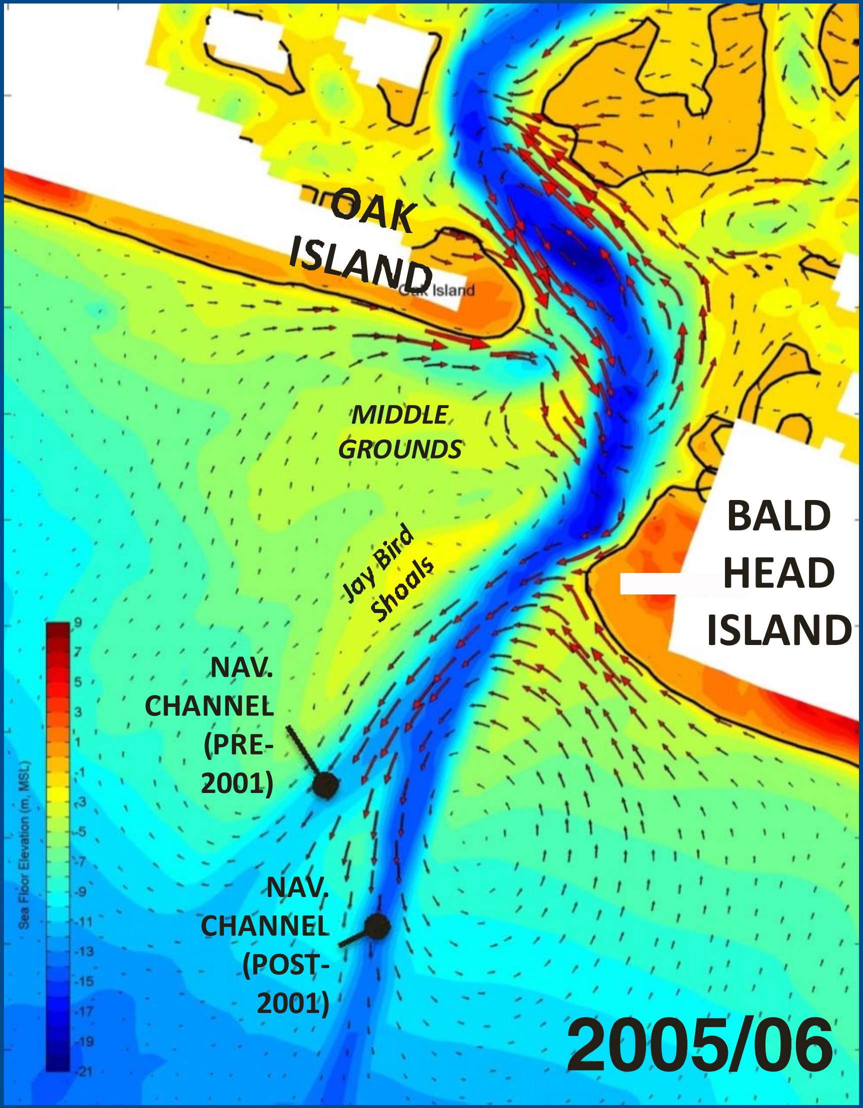
Also modeled:

- Multiple channel orientations
- Multiple dredge scenarios
- Multiple shoreline alignments
- Tube groin field alterations
- Sediment Budget
- Historical inlet configurations

Historical Perspective


OAK ISLAND
BALD HEAD ISLAND
BYPASS BAR
Elevation (m, MSL)
-15
-10
-5
0
5

1865
(Pre-Navigation Project)


OAK ISLAND
Oak Island
MIDDLE GROUNDS
Jay Bird Shoals
BALD HEAD ISLAND
NAV. CHANNEL (PRE-2001)
NAV. CHANNEL (POST-2001)
Sea Floor Elevation (m, MSL)
9
7
5
3
1
-1
-3
-5
-7
-9
-11
-13
-15
-17
-19
-21

2005/06

Analytical Design: Shoreline Orientation & Erosion

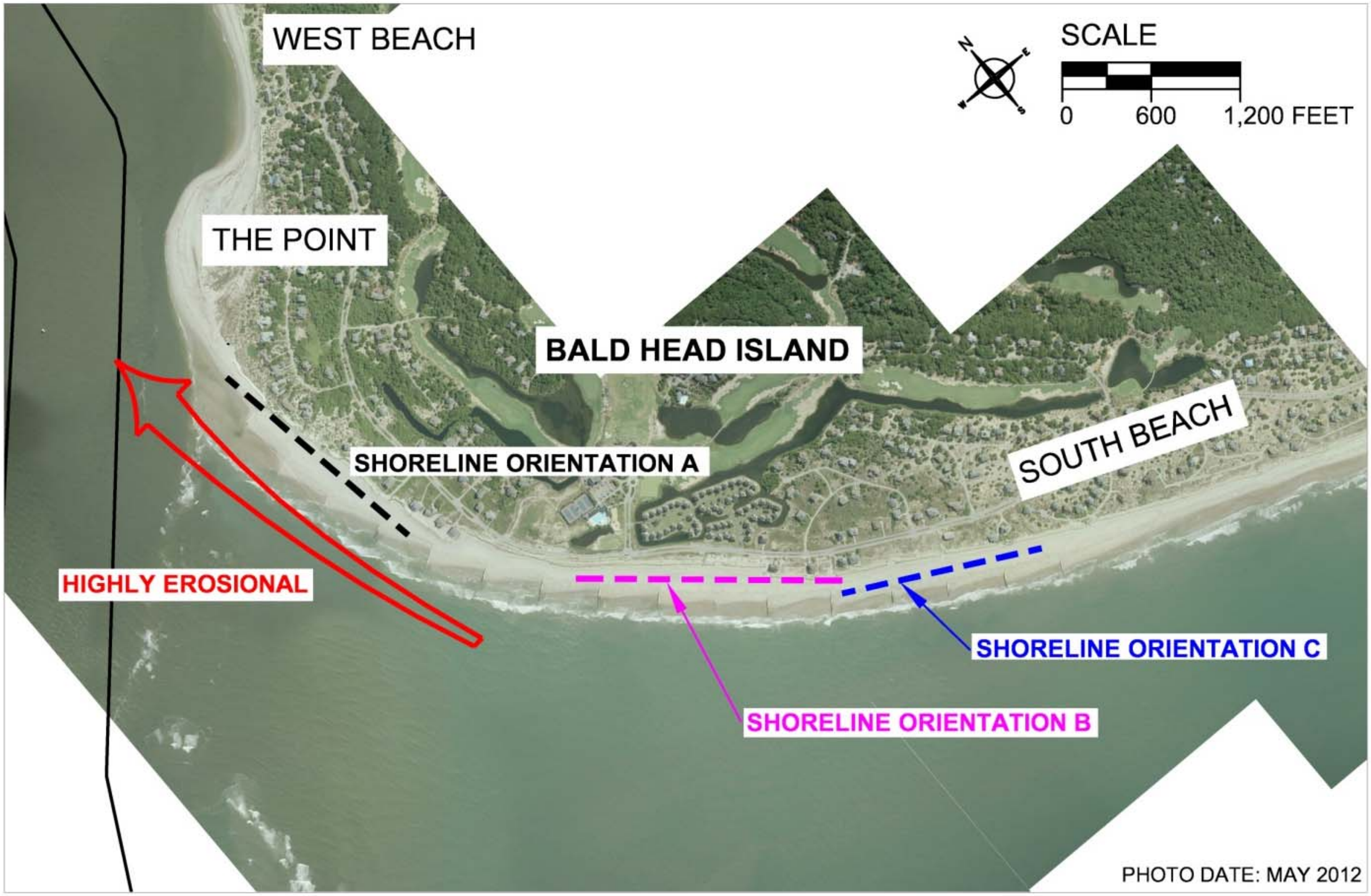
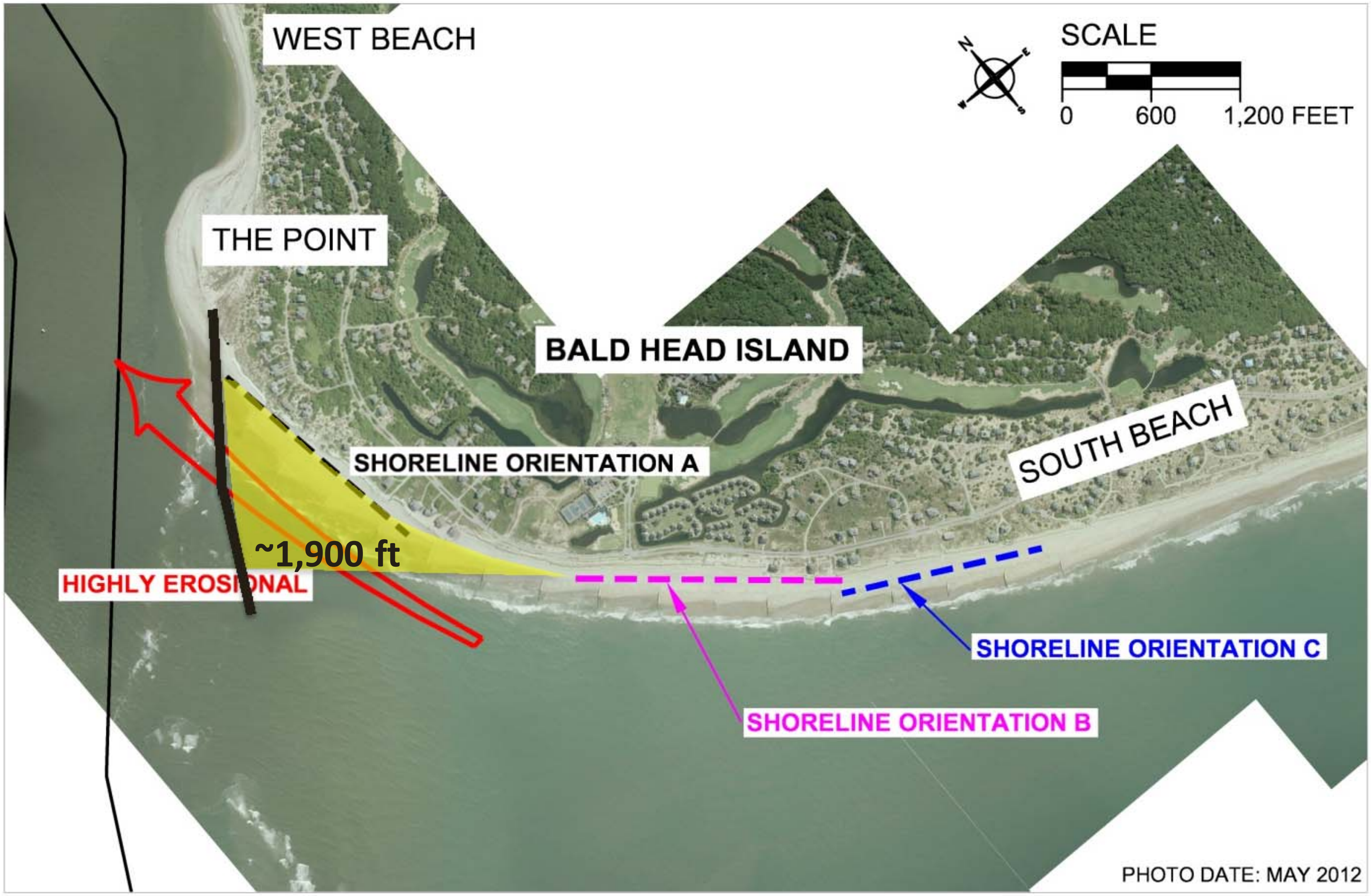

WEST BEACH
SCALE
0
600
1,200 FEET
N
E
S
W
THE POINT
BALD HEAD ISLAND
SOUTH BEACH
SHORELINE ORIENTATION A
HIGHLY EROSIONAL
SHORELINE ORIENTATION B
SHORELINE ORIENTATION C

PHOTO DATE: MAY 2012

olsen associates, inc. Coastal Engineering

Analytical Design: Shoreline Orientation & Erosion


WEST BEACH
SCALE
0
600
1,200 FEET
N
E
S
W
THE POINT
BALD HEAD ISLAND
SHORELINE ORIENTATION A
SOUTH BEACH
~1,900 ft
HIGHLY EROSIONAL
SHORELINE ORIENTATION C
SHORELINE ORIENTATION B
PHOTO DATE: MAY 2012

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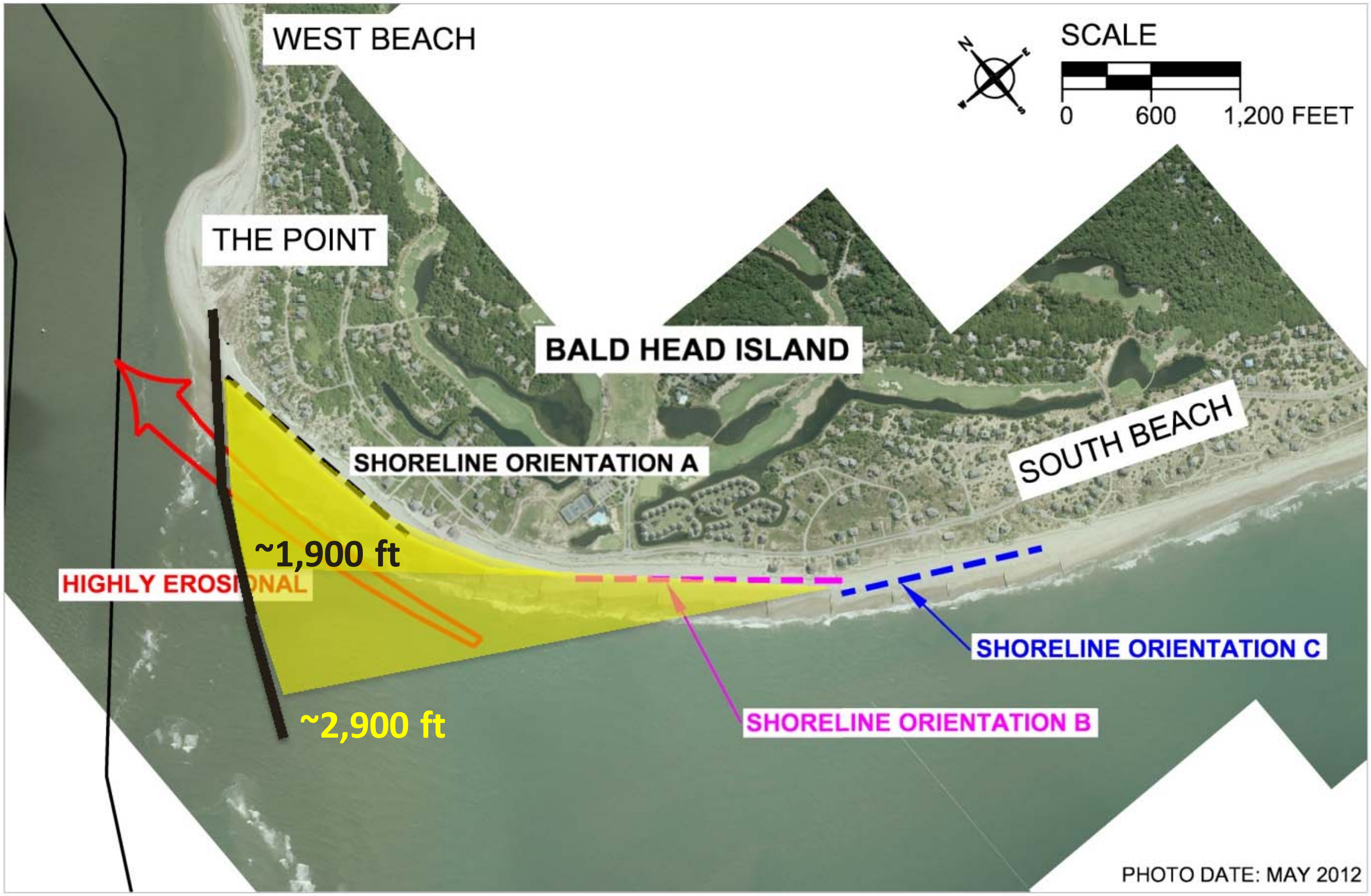
Analytical Design: Shoreline Orientation & Erosion


WEST BEACH
SCALE
0
600
1,200 FEET
THE POINT
BALD HEAD ISLAND
SHORELINE ORIENTATION A
SOUTH BEACH
~1,900 ft
HIGHLY EROSIONAL
SHORELINE ORIENTATION C
SHORELINE ORIENTATION B
~2,900 ft
PHOTO DATE: MAY 2012

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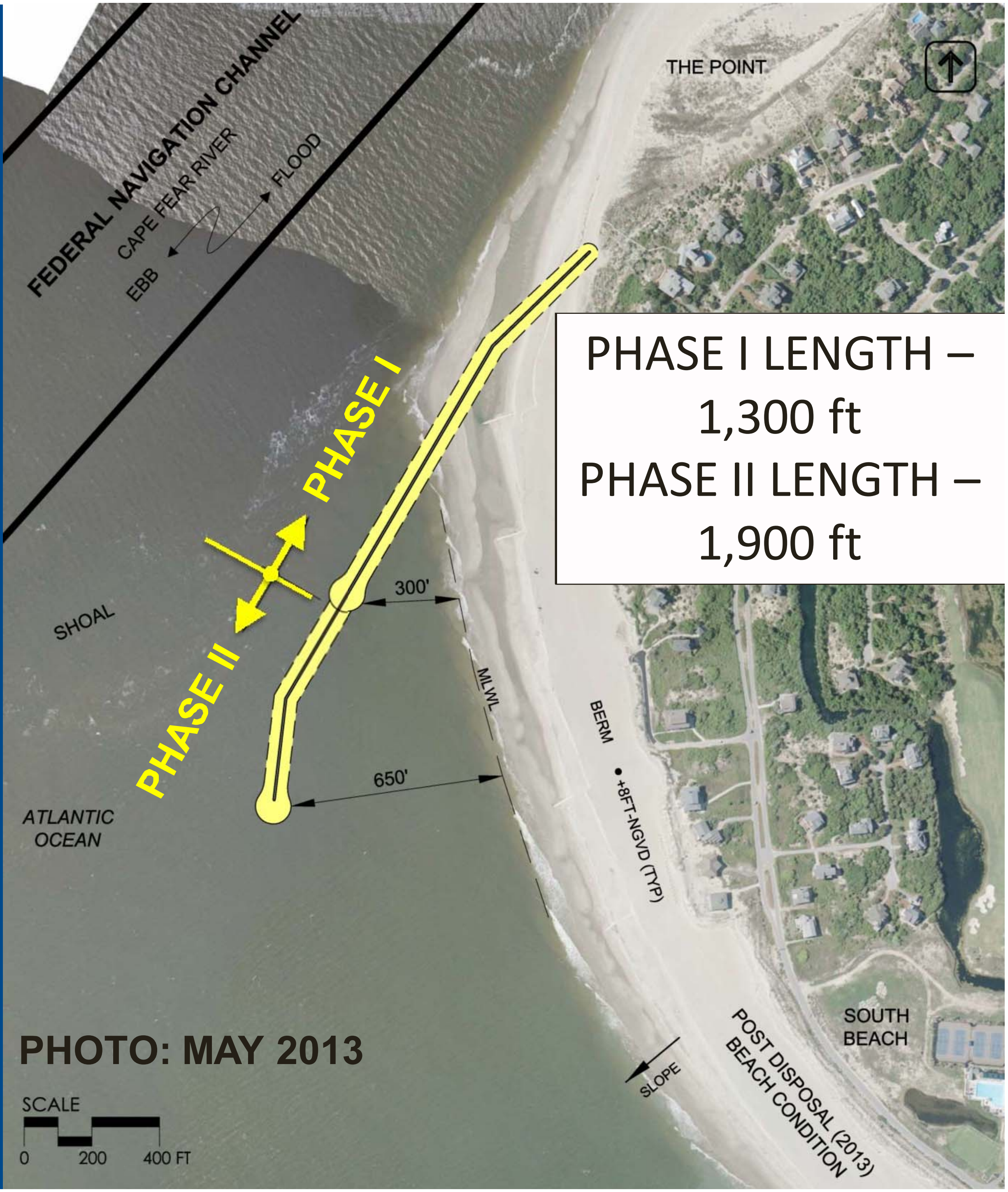
Groin Length

- Modeling suggested a 1,900 ft groin would meet project goals.
- Engineering judgement elected to construct in two Phases.



PHASE I LENGTH – 1,300 ft
PHASE II LENGTH – 1,900 ft

PHOTO: MAY 2013

FEDERAL NAVIGATION CHANNEL
CAPE FEAR RIVER
EBB
FLOOD
THE POINT
PHASE I
PHASE II
SHOAL
300'
650'
MLWL
BERM
+8FT-NGVD (TYP)
ATLANTIC OCEAN
SLOPE
POST DISPOSAL (2013) BEACH CONDITION
SOUTH BEACH
SCALE
0
200
400 FT

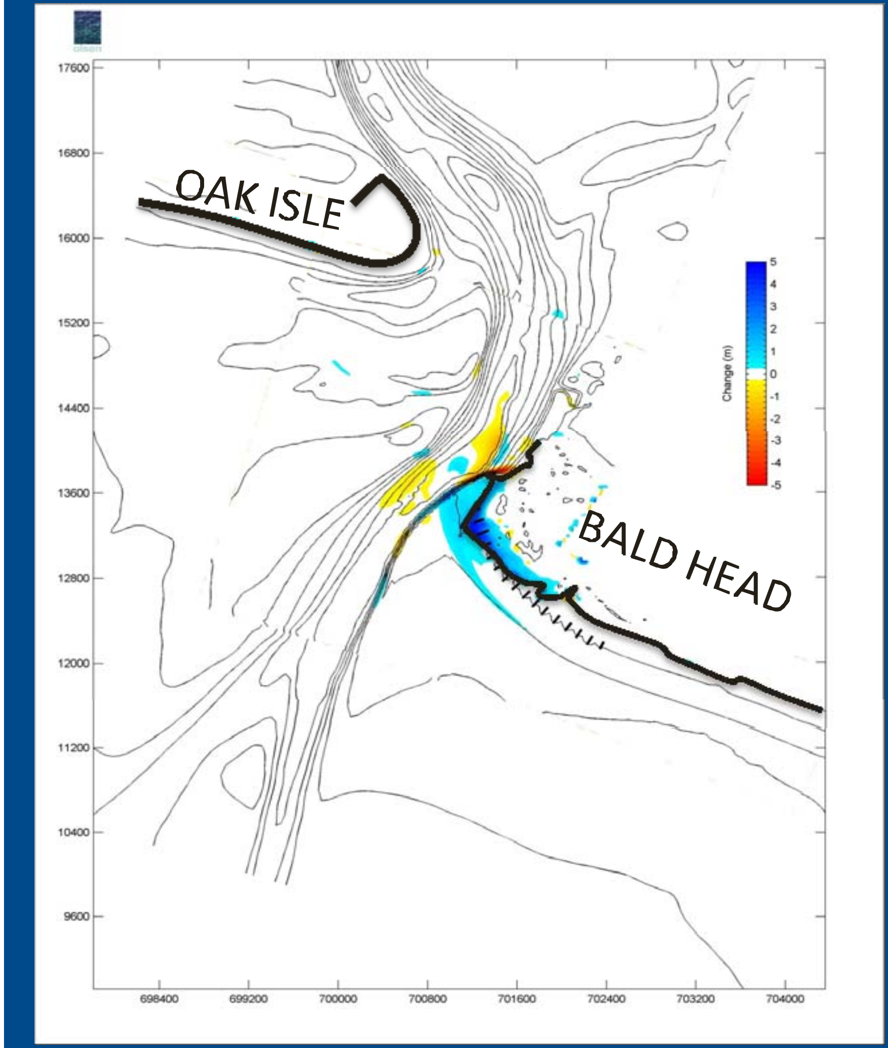
E.I.S. / PERMIT EVALUATION ISSUES

- **EXPECTED –**
  - Alternatives Analysis
  - Federal Navigation Project
  - Far-field effects (Oak Island)

Project effects on Federal Channel

- Waves (no significant change),
- Tidal Currents (no significant change),
- Cross-currents (no significant change),
- Shoaling (moderate reduction).

IMPACTS TO OAK ISLAND


17600
16800
16000
15200
14400
13600
12800
12000
11200
10400
9600
698400
699200
700000
700800
701600
702400
703200
704000
OAK ISLE
BALD HEAD
Change (m)
5
4
3
2
1
0
-1
-2
-3
-4
-5

No far-field hydrodynamic effects predicted.

MODELED GROIN PERFORMANCE

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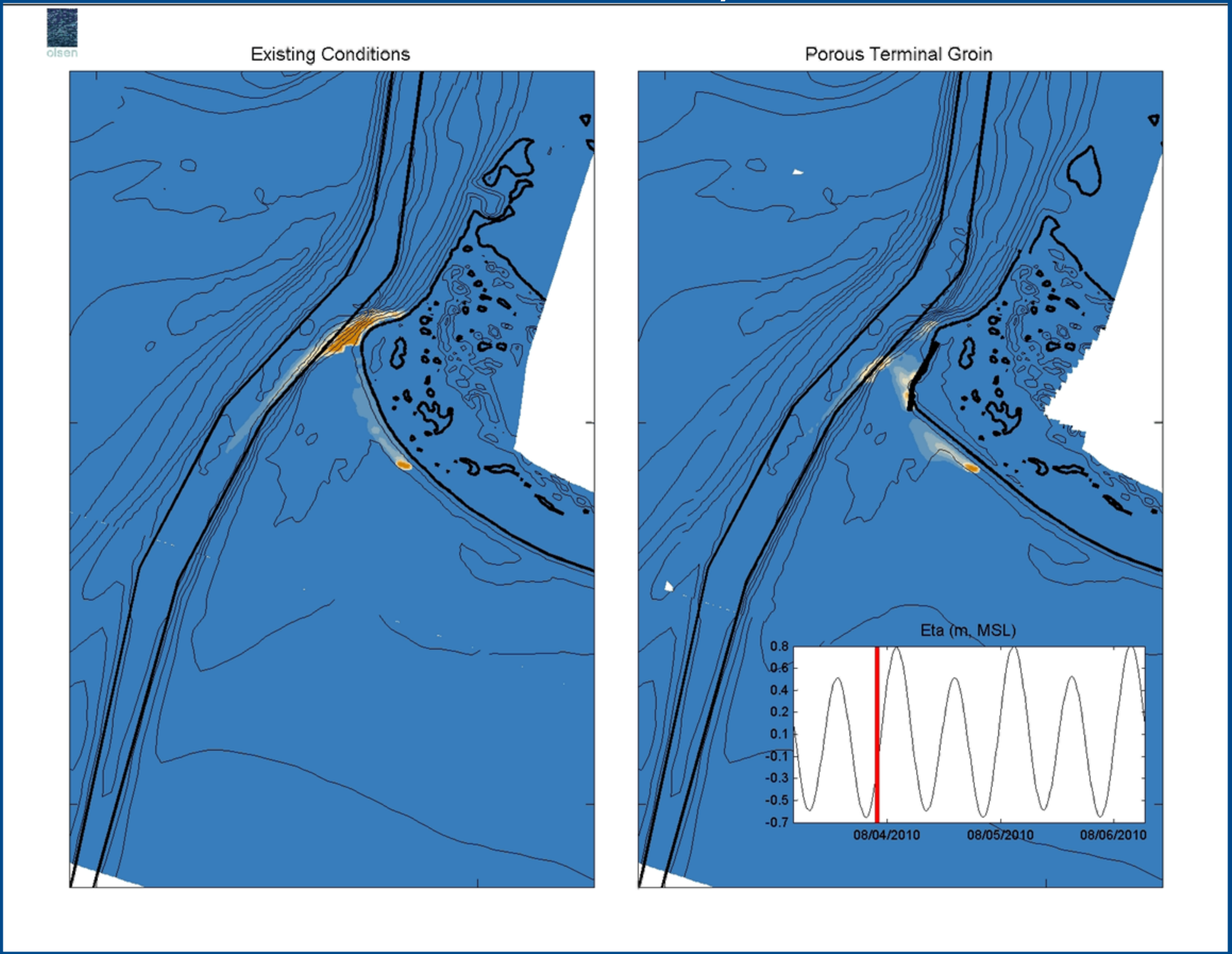
Transport Pathway

SSW wave: 3.5m, 9 sec.



Existing Conditions

Porous Terminal Groin

olsen
Eta (m, MSL)
0.8
0.6
0.4
0.2
0.1
-0.1
-0.3
-0.5
-0.7
08/04/2010
08/05/2010
08/06/2010

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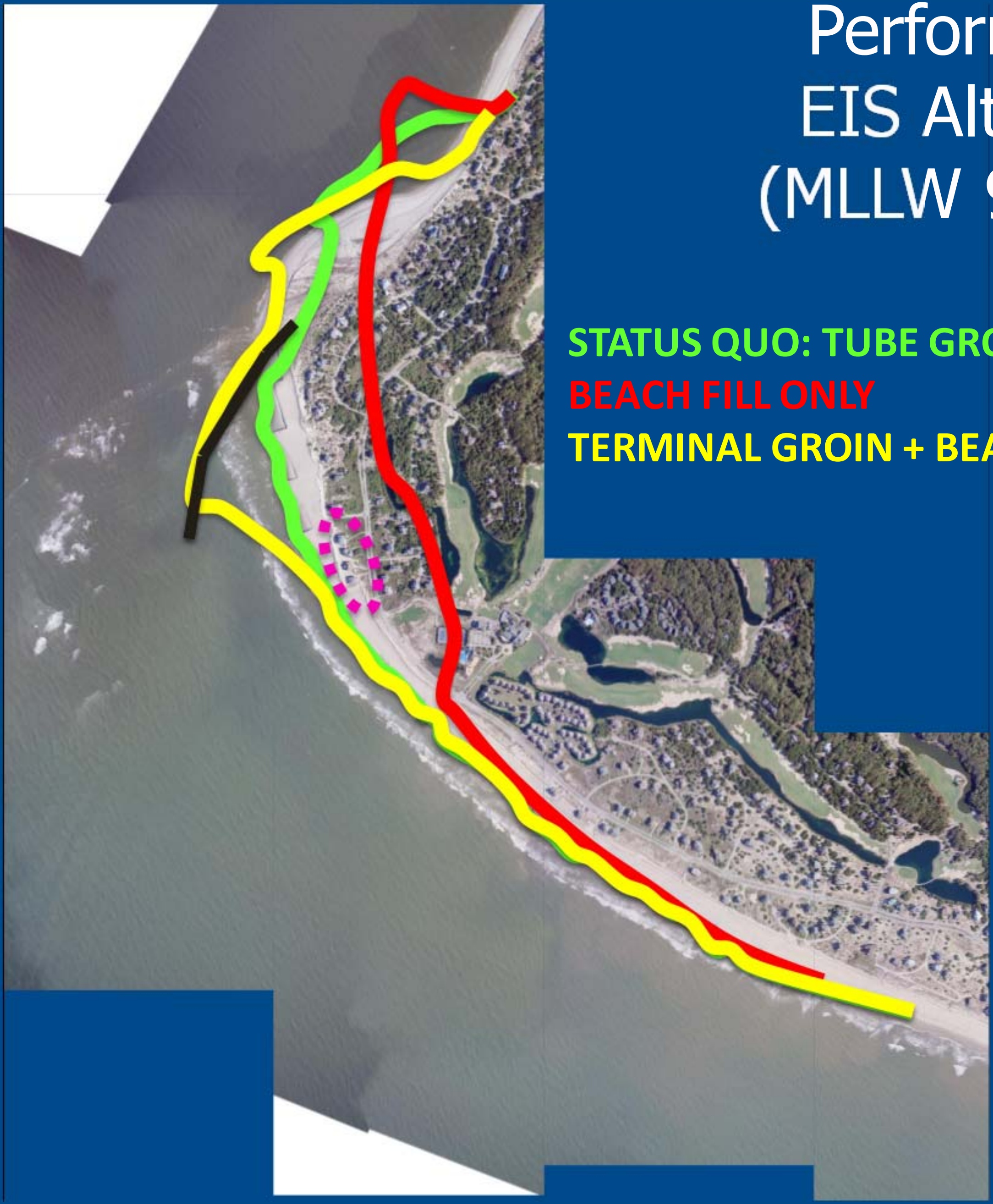

Performance of EIS Alternatives (MLLW 9-Yr POST)

STATUS QUO: TUBE GROINS + BEACH FILL

BEACH FILL ONLY

TERMINAL GROIN + BEACH FILL + TUBE GROINS

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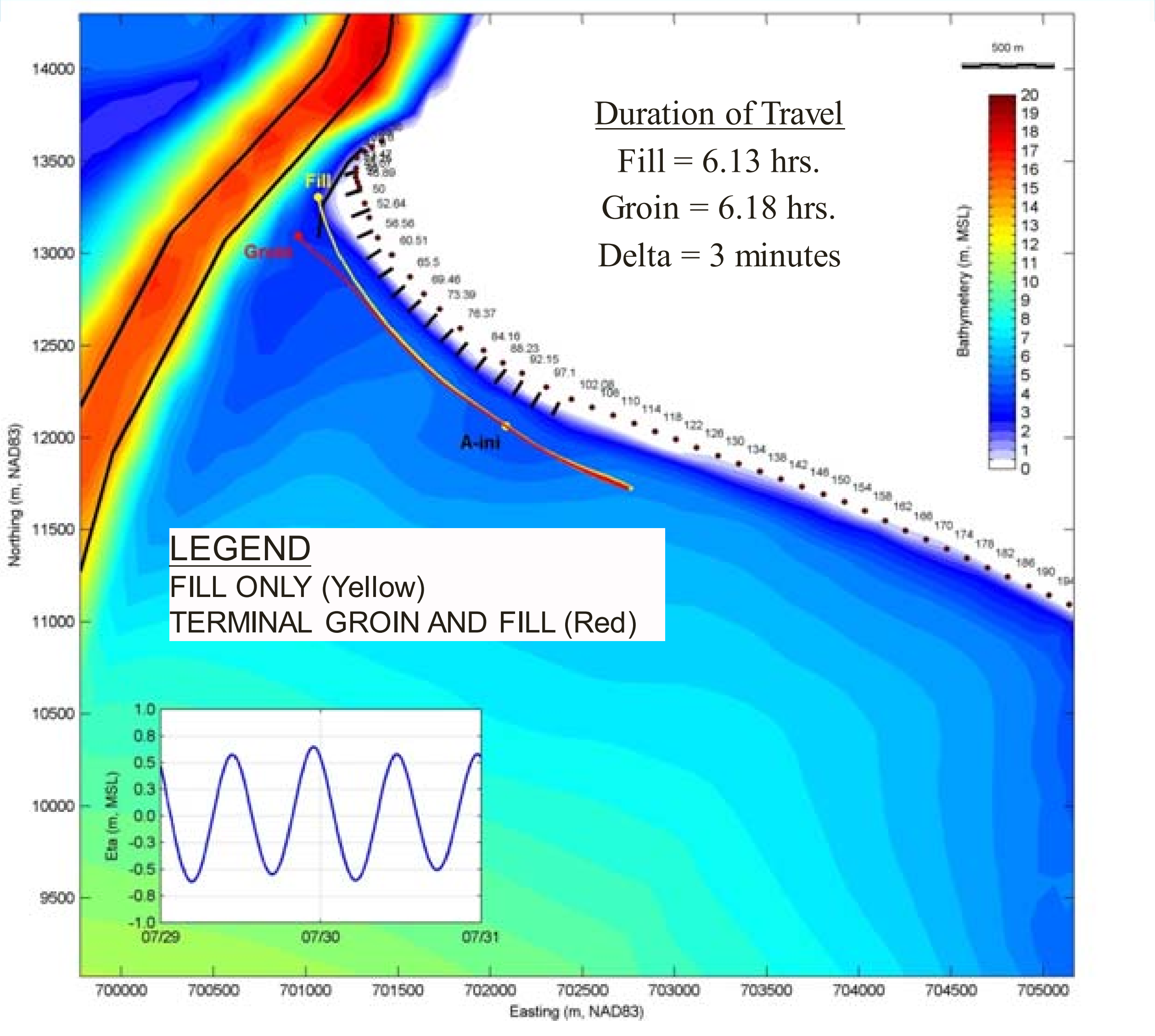
E.I.S. / PERMIT EVALUATION ISSUES

- **EXPECTED –**
  - Alternatives Analysis
  - Federal Navigation Project (i.e. Section 408 Analysis)
  - Far-field effects (Oak Island)
- **UNEXPECTED –**
  - Fish Larvae?

Assessment of Impacts to the Transport of Fish Larva

Drogue Tracking (Multiple input locations and tidal phases)


Fill
Groin
A-ini
500 m
Bathymetery (m, MSL)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Northing (m, NAD83)
14000
13500
13000
12500
12000
11500
11000
10500
10000
9500
Easting (m, NAD83)
700000
700500
701000
701500
702000
702500
703000
703500
704000
704500
705000
Eta (m, MSL)
1.0
0.8
0.5
0.3
0.0
-0.3
-0.5
-0.8
-1.0
07/29
07/30
07/31

Duration of Travel

Fill = 6.13 hrs.

Groin = 6.18 hrs.

Delta = 3 minutes

LEGEND

FILL ONLY (Yellow)

TERMINAL GROIN AND FILL (Red)

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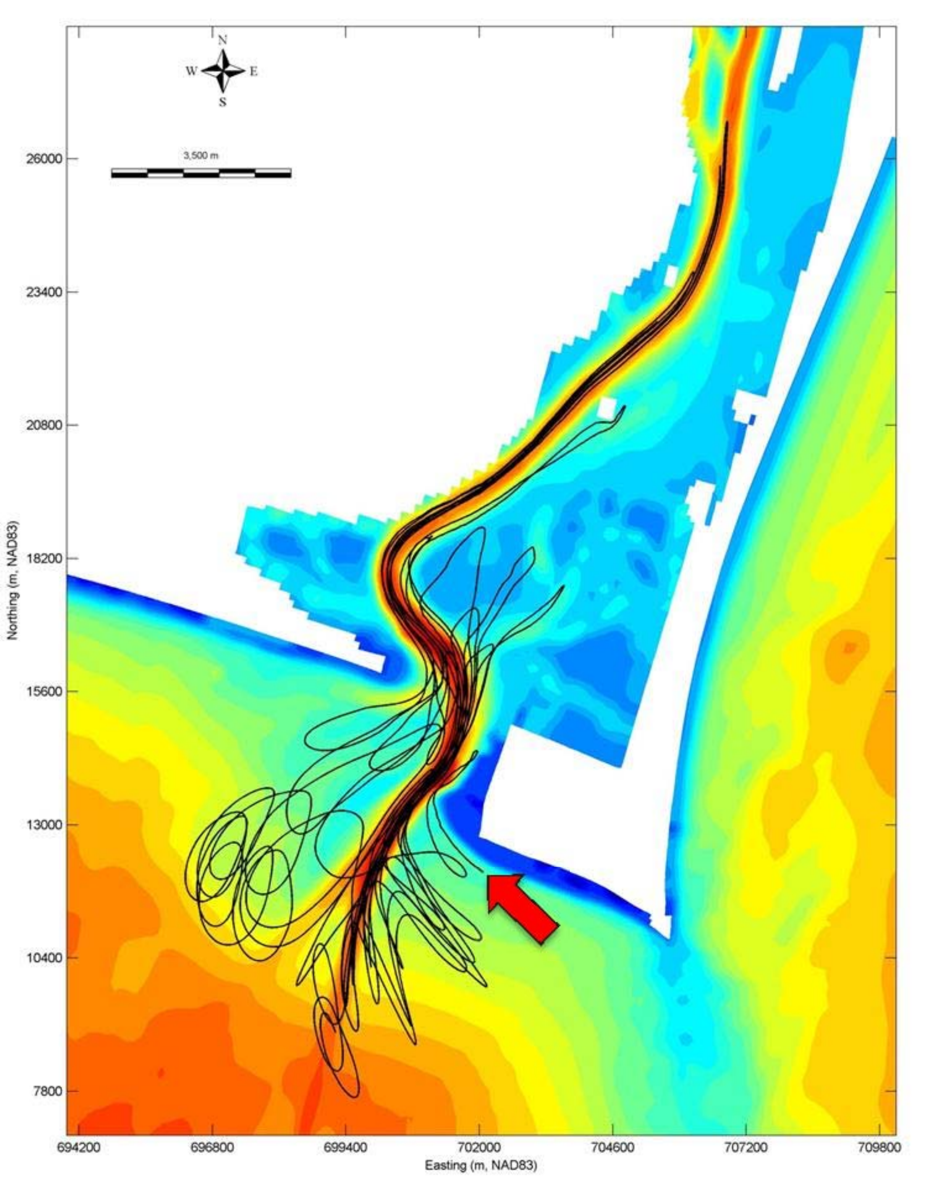
Assessment of Impacts to the Transport of Fish Larva

Drogue Tracking
(20 Days)


N
W
E
S
3,500 m
26000
23400
20800
18200
15600
13000
10400
7800
Northing (m, NAD83)
694200
696800
699400
702000
704600
707200
709800
Easting (m, NAD83)

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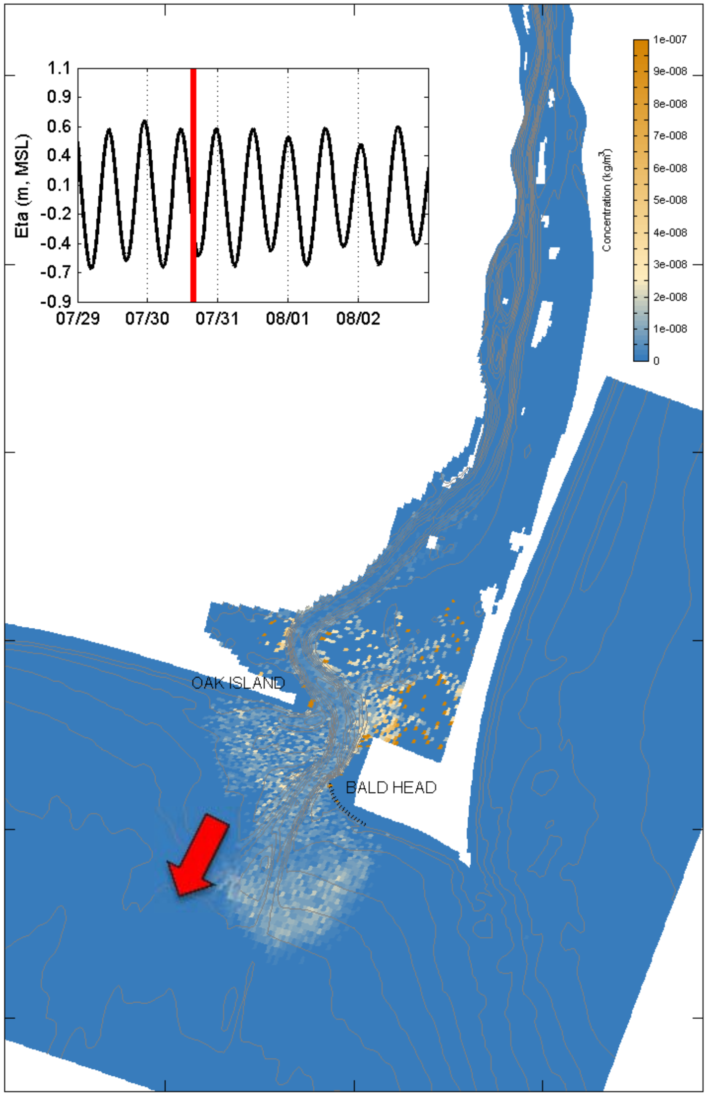
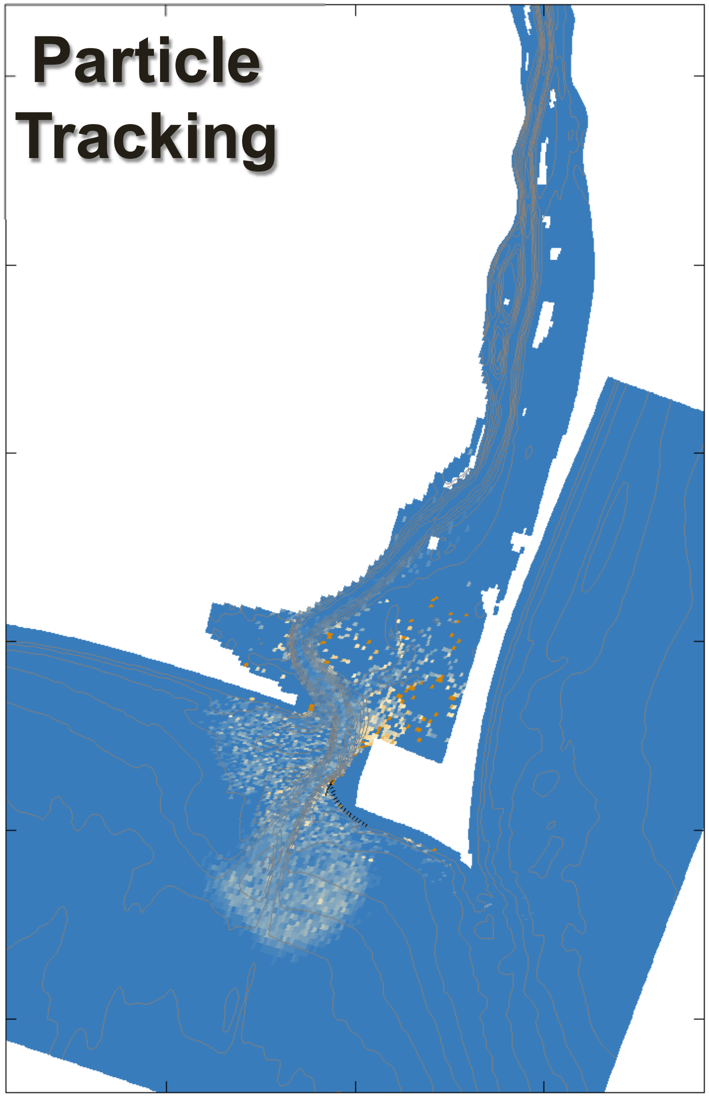
Assessment of Impacts to the Transport of Fish Larva

WITHOUT PROJECT


1.1
0.9
0.6
0.4
0.1
-0.2
-0.4
-0.7
-0.9
Eta (m, MSL)
07/29
07/30
07/31
08/01
08/02
1e-007
9e-008
8e-008
7e-008
6e-008
5e-008
4e-008
3e-008
2e-008
1e-008
0
Concentration (kg/m³)
OAK ISLAND
BALD HEAD

WITH PROJECT



Particle Tracking

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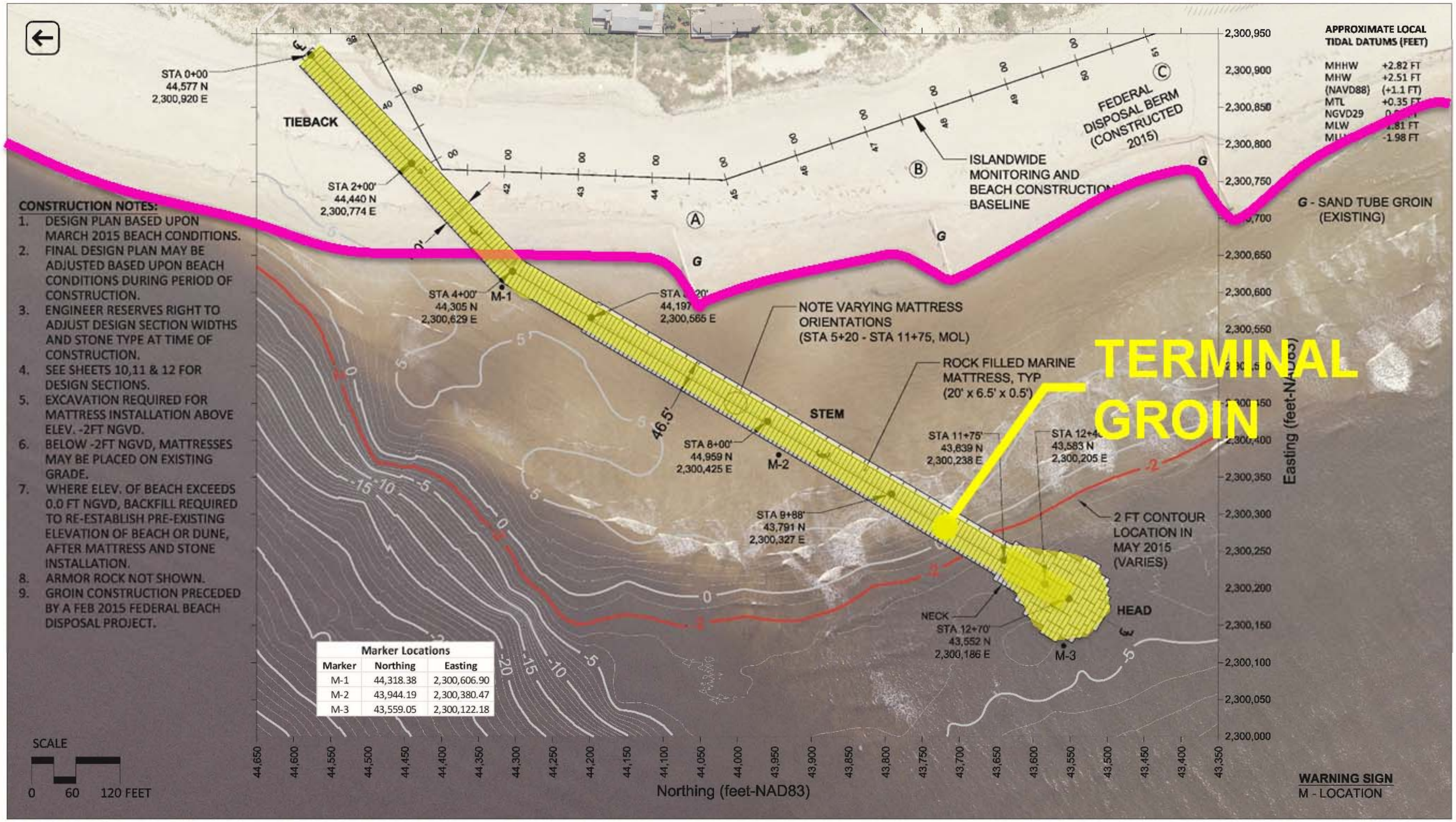

STA 0+00
44,577 N
2,300,920 E
TIEBACK
STA 2+00'
44,440 N
2,300,774 E
STA 4+00'
44,305 N
2,300,629 E
M-1
STA 5+20'
44,197
2,300,565 E
NOTE VARYING MATTRESS ORIENTATIONS (STA 5+20 - STA 11+75, MOL)
ROCK FILLED MARINE MATTRESS, TYP (20' x 6.5' x 0.5')
TERMINAL GROIN
46.5'
STEM
STA 8+00'
44,959 N
2,300,425 E
M-2
STA 9+88'
43,791 N
2,300,327 E
STA 11+75'
43,639 N
2,300,238 E
STA 12+4
43,583 N
2,300,205 E
NECK
STA 12+70'
43,552 N
2,300,186 E
M-3
HEAD
2 FT CONTOUR LOCATION IN MAY 2015 (VARIES)
ISLANDWIDE MONITORING AND BEACH CONSTRUCTION BASELINE
FEDERAL DISPOSAL BERM (CONSTRUCTED 2015)
A
B
C
G
G - SAND TUBE GROIN (EXISTING)
Easting (feet-NAD83)
Northing (feet-NAD83)
SCALE
0
60
120 FEET
WARNING SIGN
M - LOCATION
2,300,950
2,300,900
2,300,850
2,300,800
2,300,750
2,300,700
2,300,650
2,300,600
2,300,550
2,300,500
2,300,450
2,300,400
2,300,350
2,300,300
2,300,250
2,300,200
2,300,150
2,300,100
2,300,050
2,300,000
44,650
44,600
44,550
44,500
44,450
44,400
44,350
44,300
44,250
44,200
44,150
44,100
44,050
44,000
43,950
43,900
43,850
43,800
43,750
43,700
43,650
43,600
43,550
43,500
43,450
43,400
43,350

APPROXIMATE LOCAL TIDAL DATUMS (FEET)

MHHW	+2.82 FT
MHW	+2.51 FT
(NAVD88)	(+1.1 FT)
MTL	+0.35 FT
NGVD29	0.
MLW	.81 FT
ML	-1.98 FT

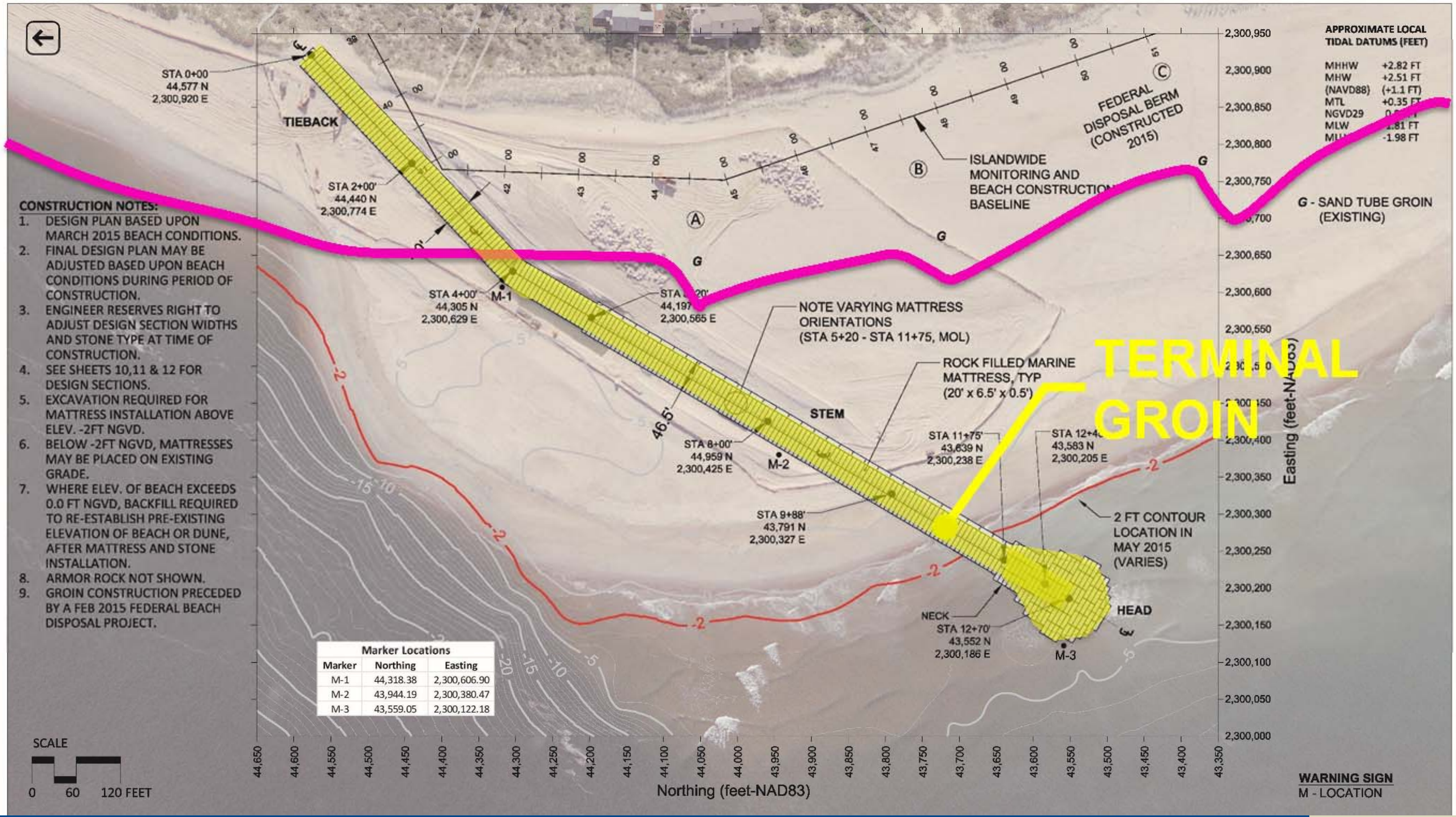
CONSTRUCTION NOTES:

1. DESIGN PLAN BASED UPON MARCH 2015 BEACH CONDITIONS.
2. FINAL DESIGN PLAN MAY BE ADJUSTED BASED UPON BEACH CONDITIONS DURING PERIOD OF CONSTRUCTION.
3. ENGINEER RESERVES RIGHT TO ADJUST DESIGN SECTION WIDTHS AND STONE TYPE AT TIME OF CONSTRUCTION.
4. SEE SHEETS 10,11 & 12 FOR DESIGN SECTIONS.
5. EXCAVATION REQUIRED FOR MATTRESS INSTALLATION ABOVE ELEV. -2FT NGVD.
6. BELOW -2FT NGVD, MATTRESSES MAY BE PLACED ON EXISTING GRADE.
7. WHERE ELEV. OF BEACH EXCEEDS 0.0 FT NGVD, BACKFILL REQUIRED TO RE-ESTABLISH PRE-EXISTING ELEVATION OF BEACH OR DUNE, AFTER MATTRESS AND STONE INSTALLATION.
8. ARMOR ROCK NOT SHOWN.
9. GROIN CONSTRUCTION PRECEDED BY A FEB 2015 FEDERAL BEACH DISPOSAL PROJECT.

Marker Locations

Marker	Northing	Easting
M-1	44,318.38	2,300,606.90
M-2	43,944.19	2,300,380.47
M-3	43,559.05	2,300,122.18

PRE-BID BEACH (May 2014)


TERMINAL GROIN
TIEBACK
STEM
NECK
HEAD
STA 0+00
44,577 N
2,300,920 E
STA 2+00'
44,440 N
2,300,774 E
STA 4+00'
44,305 N
2,300,629 E
STA 5+20'
44,197
2,300,565 E
STA 8+00'
44,959 N
2,300,425 E
STA 9+88'
43,791 N
2,300,327 E
STA 11+75'
43,639 N
2,300,238 E
STA 12+4
43,583 N
2,300,205 E
STA 12+70'
43,552 N
2,300,186 E
M-1
M-2
M-3
46.5'
NOTE VARYING MATTRESS ORIENTATIONS (STA 5+20 - STA 11+75, MOL)
ROCK FILLED MARINE MATTRESS, TYP (20' x 6.5' x 0.5')
ISLANDWIDE MONITORING AND BEACH CONSTRUCTION BASELINE
FEDERAL DISPOSAL BERM (CONSTRUCTED 2015)
A
B
C
G
2 FT CONTOUR LOCATION IN MAY 2015 (VARIES)
G - SAND TUBE GROIN (EXISTING)
WARNING SIGN
M - LOCATION
-2
-5
-10
-15
-20
Northing (feet-NAD83)
Easting (feet-NAD83)
44,650
44,600
44,550
44,500
44,450
44,400
44,350
44,300
44,250
44,200
44,150
44,100
44,050
44,000
43,950
43,900
43,850
43,800
43,750
43,700
43,650
43,600
43,550
43,500
43,450
43,400
43,350
2,300,950
2,300,900
2,300,850
2,300,800
2,300,750
2,300,700
2,300,650
2,300,600
2,300,550
2,300,500
2,300,450
2,300,400
2,300,350
2,300,300
2,300,250
2,300,200
2,300,150
2,300,100
2,300,050
2,300,000
SCALE
0
60
120 FEET

CONSTRUCTION NOTES:

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(NAVD88)	(+1.1 FT)
MTL	+0.35 FT
NGVD29	0.[illegible]
MLW	[illegible].81 FT
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Marker	Northing	Easting
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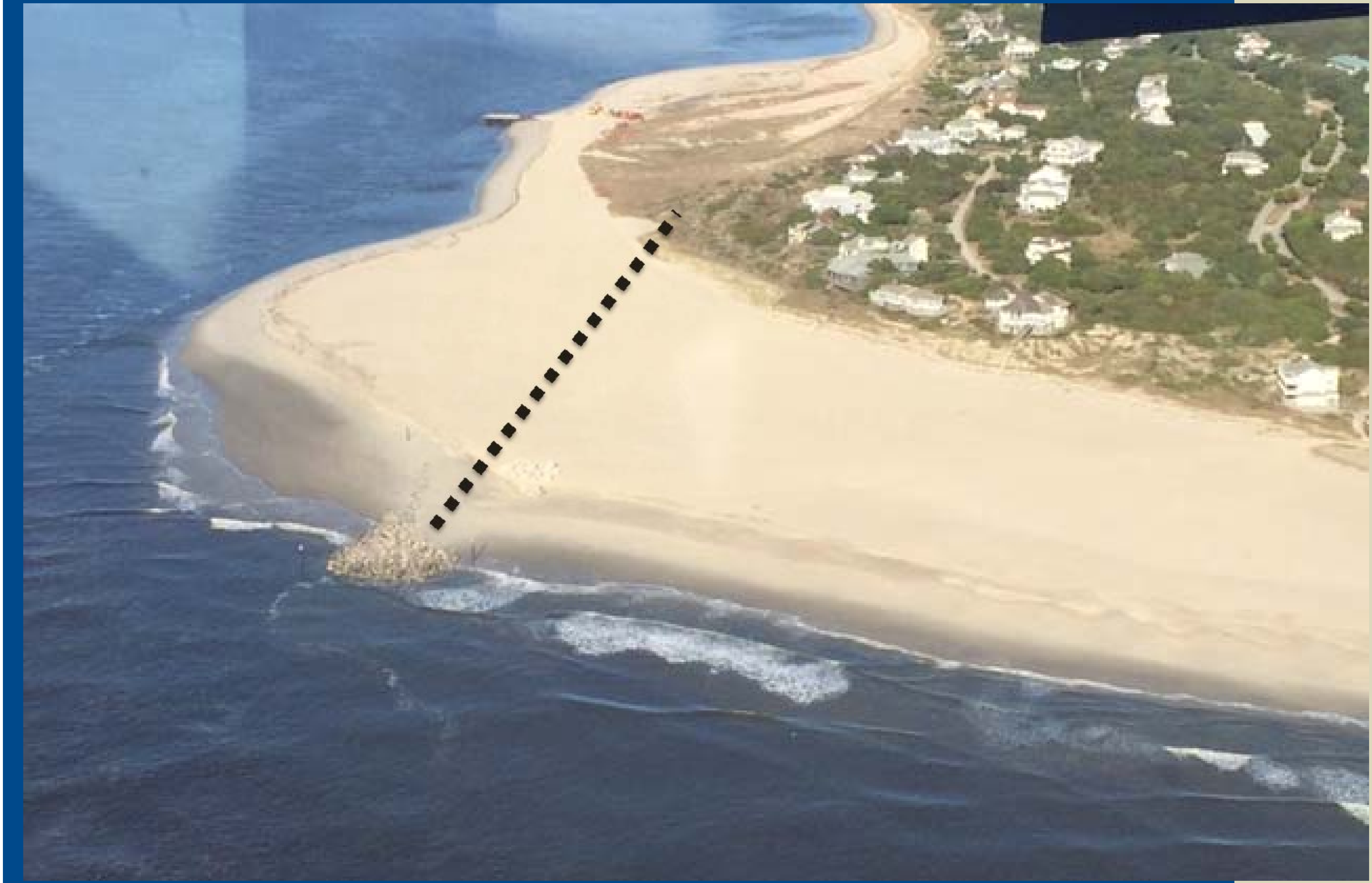
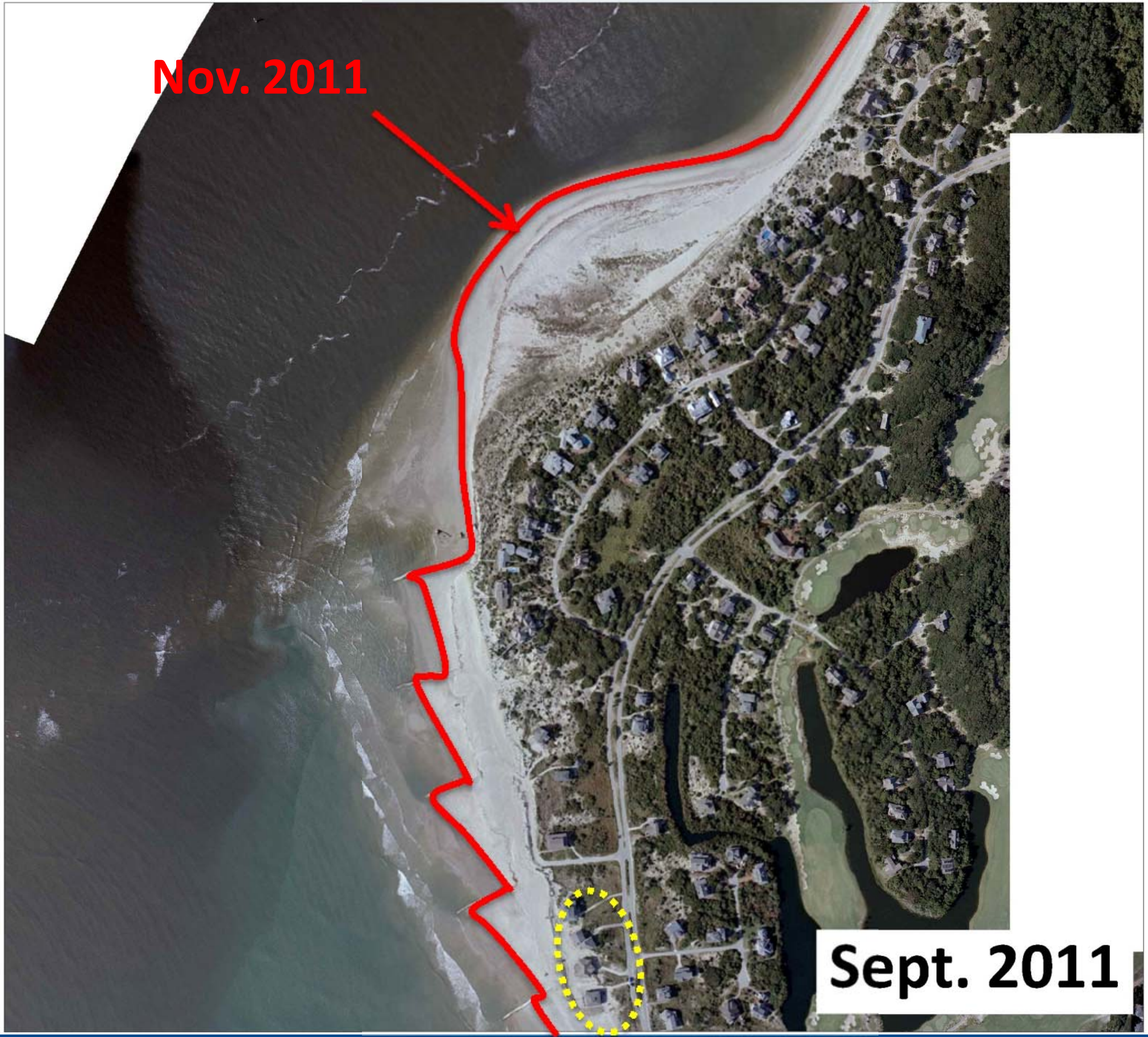
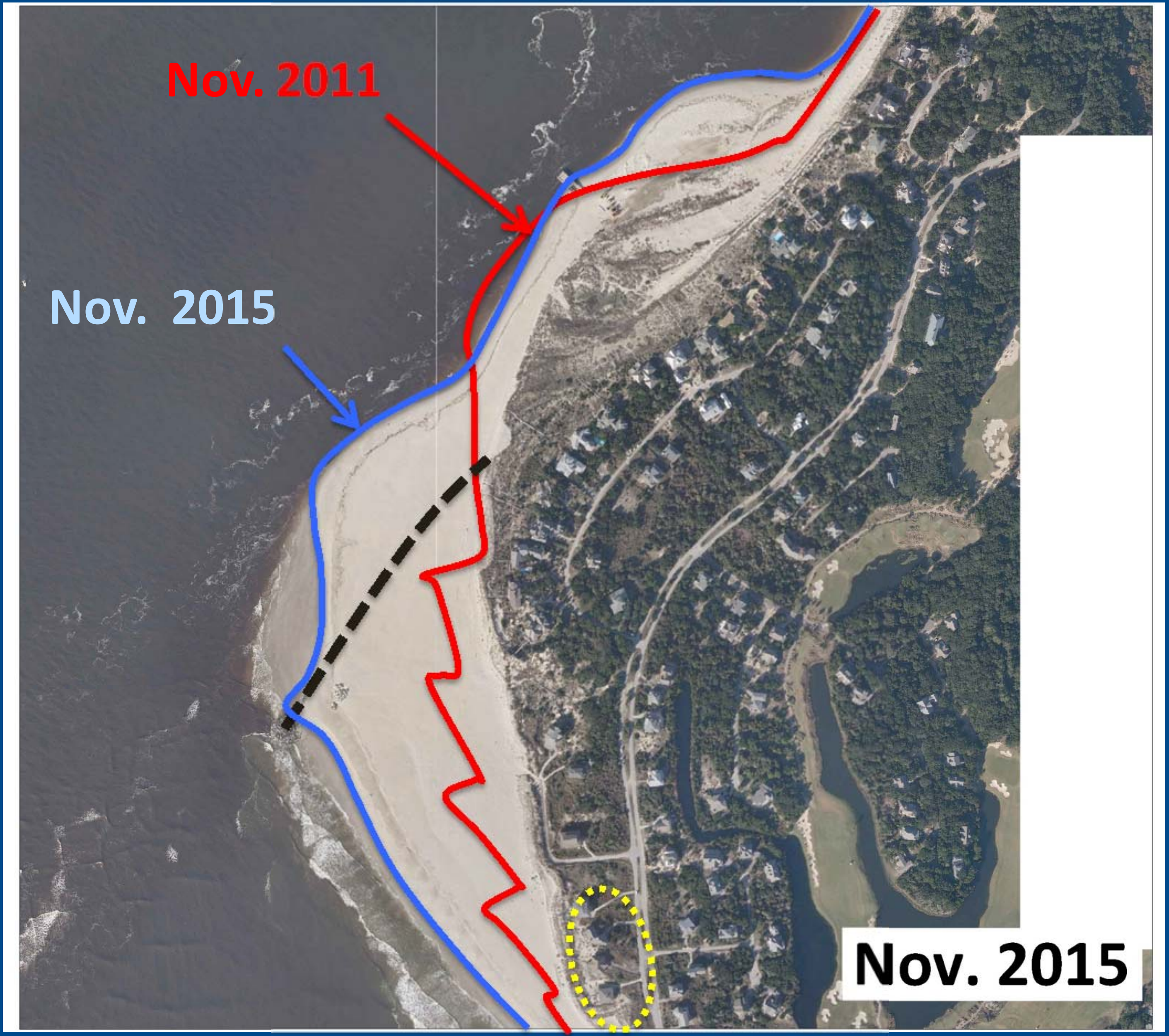
M-3	43,559.05	2,300,122.18

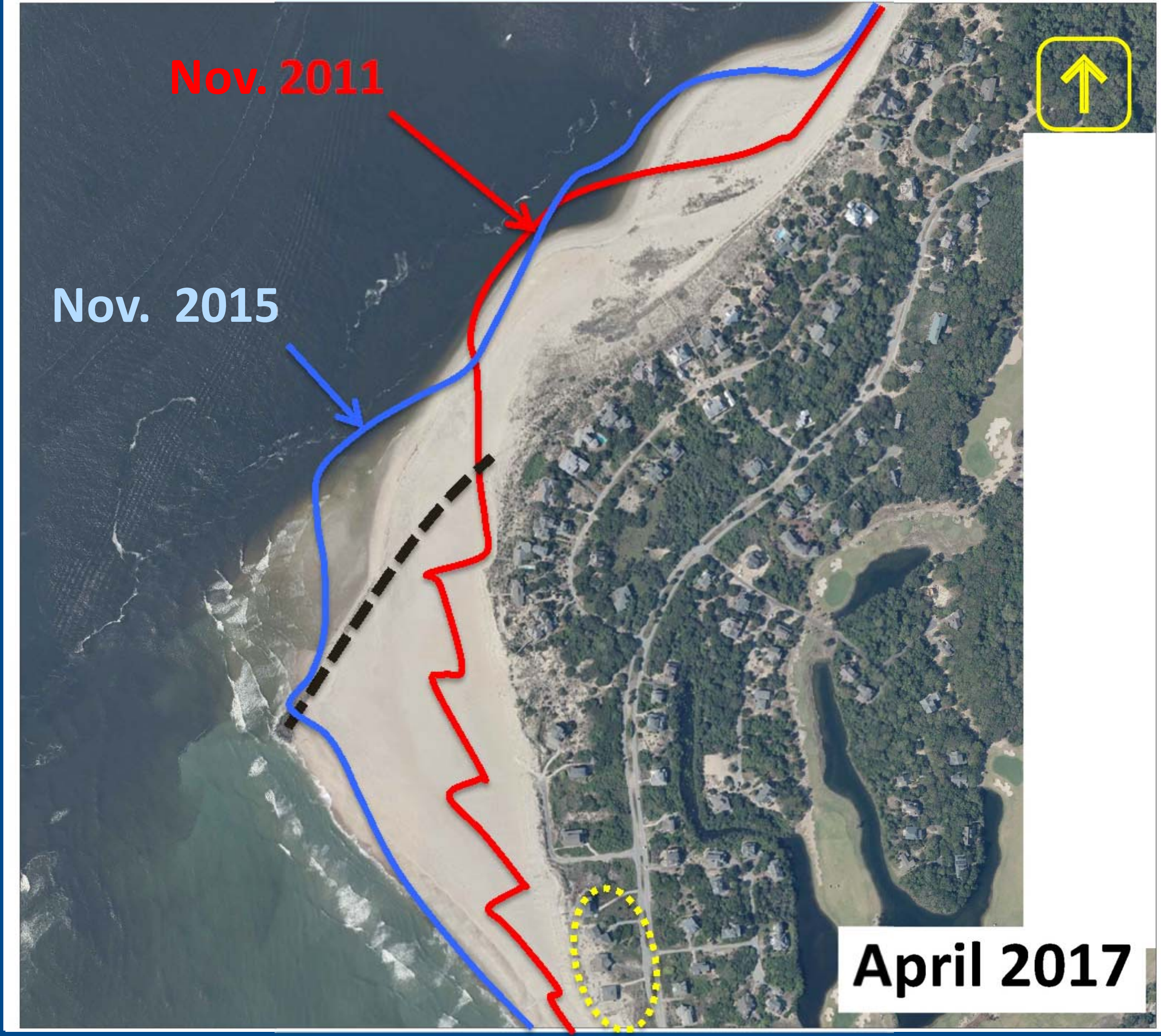
PRE-CONSTRUCTION BEACH (AUG. 2015)

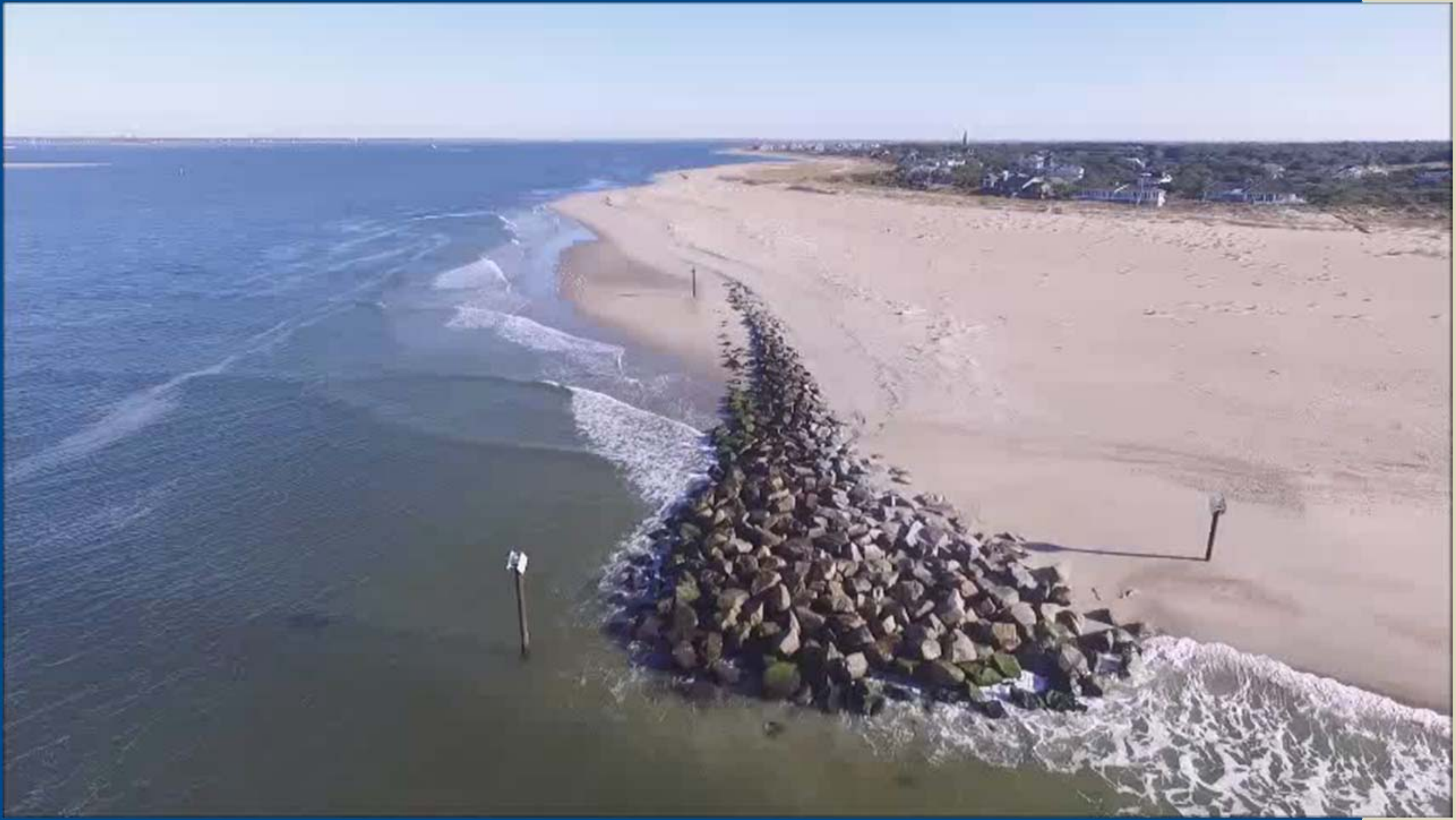


POST-CONSTRUCTION (Nov. 2015)


Nov. 2011
Sept. 2011


Nov. 2011
Nov. 2015
Nov. 2015


Nov. 2011
Nov. 2015
↑
April 2017



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Summary

- Use of the Delft3D model was critical to navigating both the regulatory framework and NGO concerns.
- Thus far, the terminal groin at Bald Head is meeting expectations.

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