



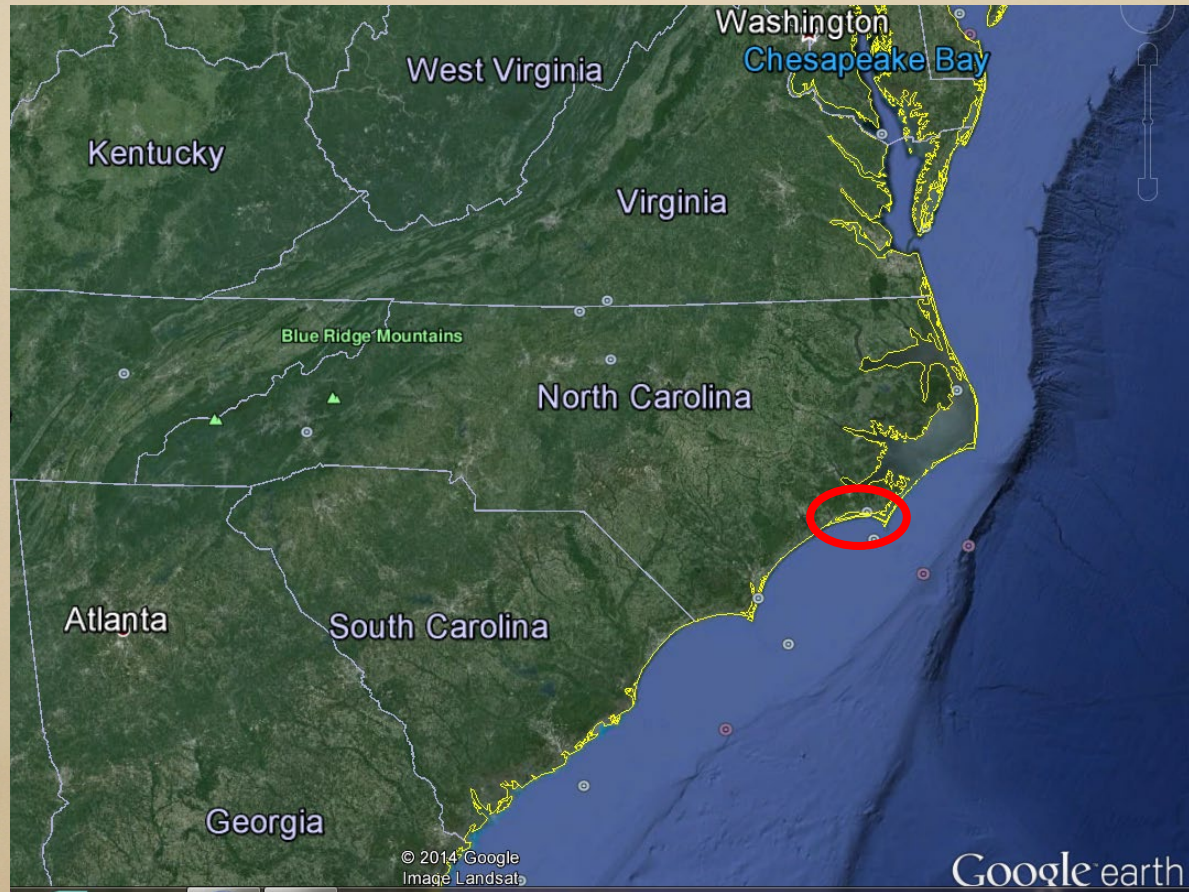
# *Bogue Banks*

Master Beach Nourishment Plan  
Carteret County, North Carolina



moffatt & nichol

# Project Study Area



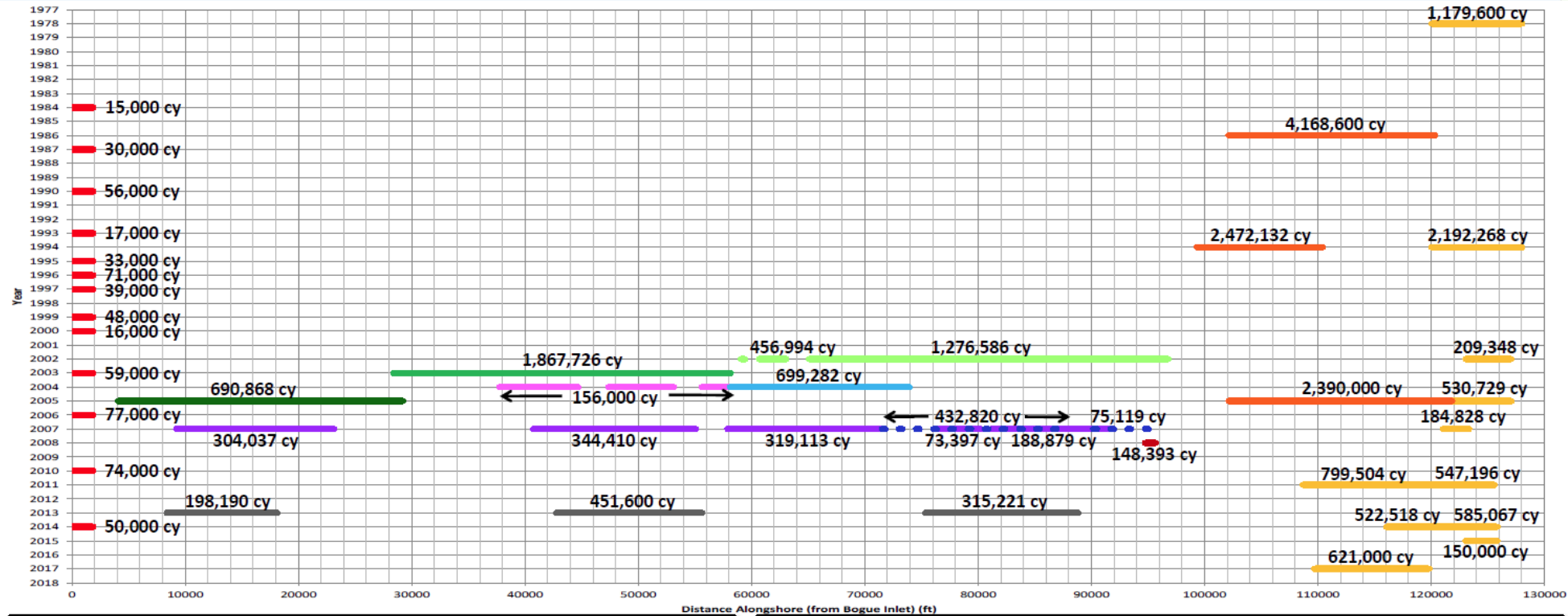
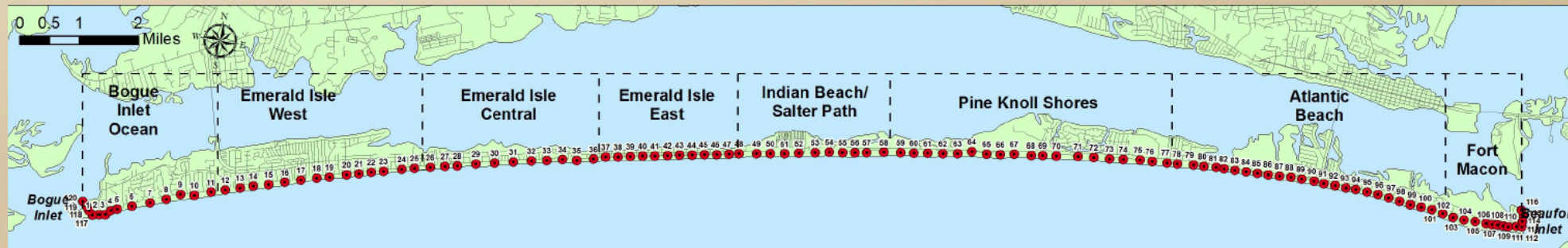
# 1990 Hurricanes Were the Catalyst



VS.



# Historical Nourishment Projects



## Bogue Banks Beach Nourishment Projects 1978-2017

<ul style="list-style-type: none"> <li><span style="color: red;">■</span> Bogue Inlet AIWW Crossing Disposal</li> <li><span style="color: red;">■</span> AIWW Tangent B Disposal</li> <li><span style="color: orange;">■</span> MCH Inner Harbor Maintenance Dredge Disposal</li> <li><span style="color: orange;">■</span> Brandt Island Pump-Out</li> <li><span style="color: lightgreen;">■</span> Bogue Banks Restoration - Phase I</li> <li><span style="color: green;">■</span> Bogue Banks Restoration - Phase II</li> </ul>	<ul style="list-style-type: none"> <li><span style="color: green;">■</span> Bogue Banks Restoration - Phase III</li> <li><span style="color: blue;">■</span> Section 933 - Phase I</li> <li><span style="color: blue;">■</span> Section 933 - Phase II</li> <li><span style="color: magenta;">■</span> FEMA Post-Isabel Restoration</li> <li><span style="color: purple;">■</span> FEMA Post-Ophelia Restoration</li> <li><span style="color: grey;">■</span> Post-Irene Restoration</li> </ul>
---	---



# Historical Nourishment Projects

## Cumulative Costs and Volume

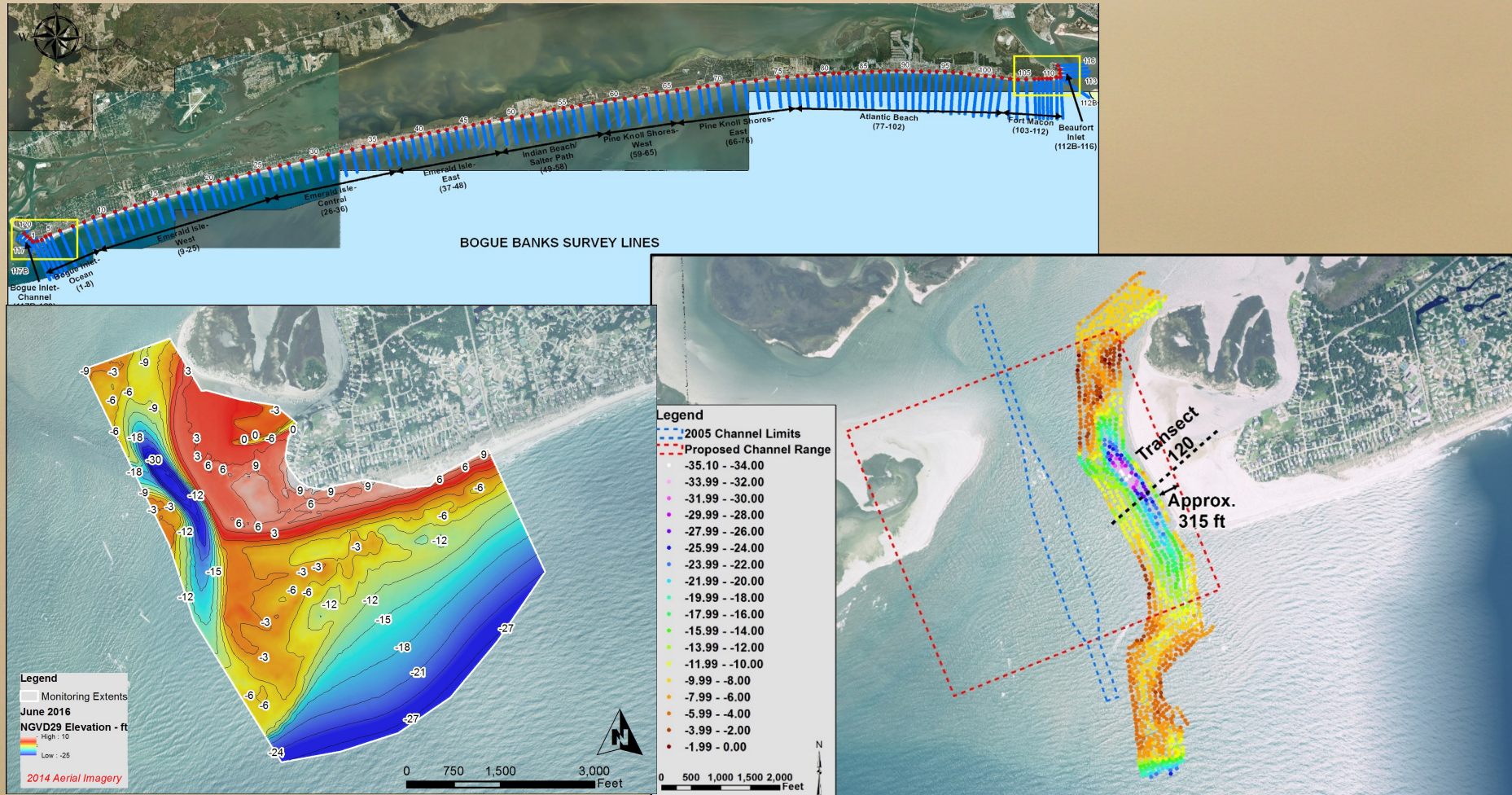


Project	Local (\$)	State (\$)	Federal (\$)	Total (\$)	cubic yards
Phase I ('01-'02)	\$11,700,000	\$900,000	\$0	\$12,600,000	1,733,580
Phase II ('03)	\$11,800,000	\$0	\$0	\$11,800,000	1,867,726
Phase III ('05)	\$7,100,000	\$3,800,000	\$0	\$10,900,000	690,868
933 Phase I ('04)	\$400,000	\$1,200,000	\$3,800,000	\$5,400,000	699,282
Pump-Out ('04-'05)	\$0	\$1,000,000	\$9,600,000	\$10,600,000	2,920,729
933 Phase II ('07)	\$678,000	\$2,000,000	\$7,600,000	\$10,278,000	507,939
Harbor ('10-'11)	\$0	\$0	\$12,762,429	\$12,762,429	1,346,700
Harbor ('14)	\$0	\$0	\$9,415,774	\$9,415,774	1,107,585
Harbor ('15)	\$0	\$0	\$0	\$0	150,000
Harbor ('17)	\$0	\$0	\$9,435,825	\$9,435,825	621,000
Isabel ('04)	\$0	\$0	\$1,956,175	\$1,956,175	156,000
Ophelia ('07)	\$0	\$0	\$13,773,768	\$13,773,768	1,229,836
Irene ('13)	\$7,875,810	\$0	\$7,076,155	\$14,951,965	965,011
<b>TOTALS</b>	<b>\$39,553,810</b>	<b>\$8,900,000</b>	<b>\$75,420,126</b>	<b>\$123,873,936</b>	<b>13,996,256</b>
%	32%	7%	61%	100%	



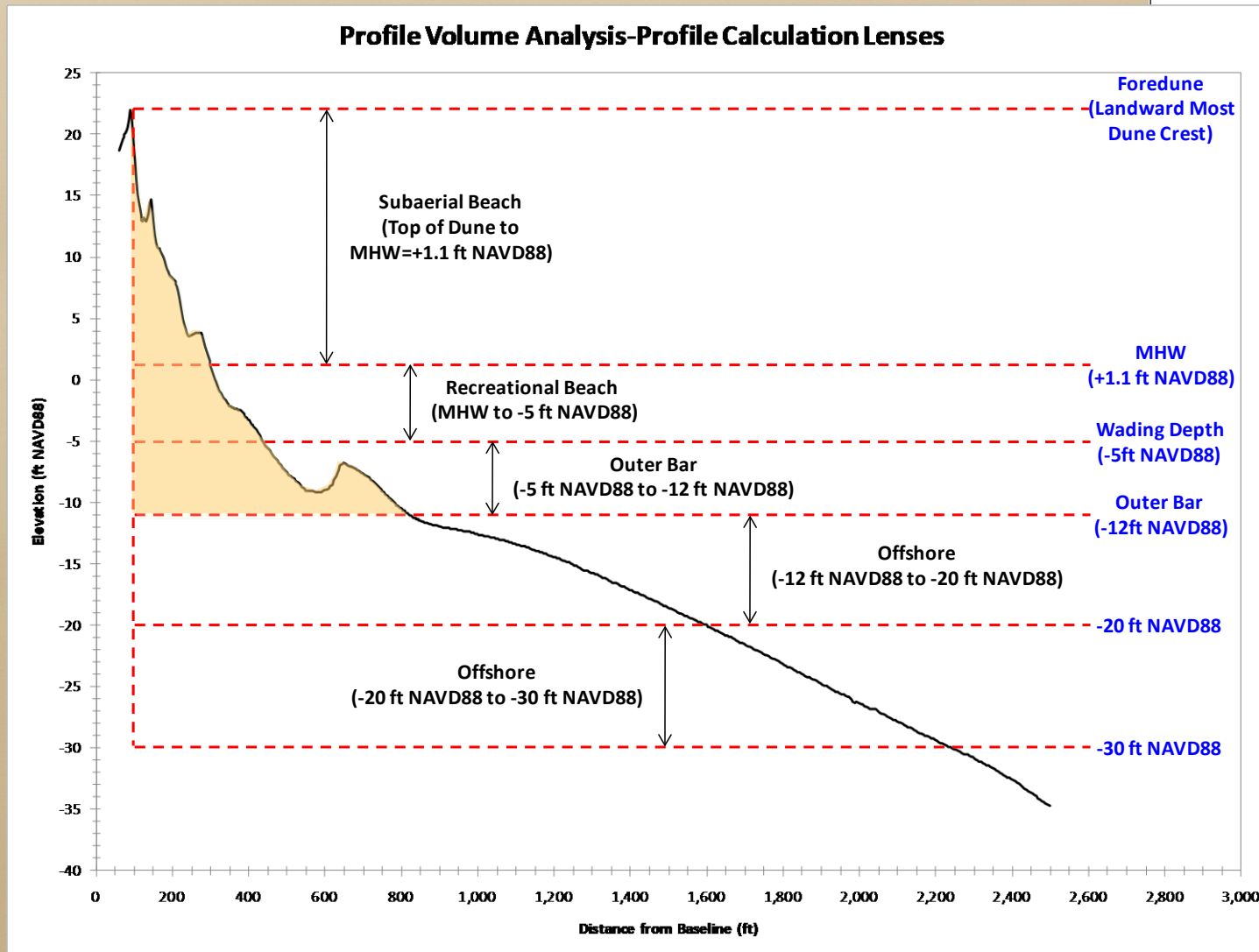
# Commitment to Monitoring

## RICH DATASET – Surveys Dating Back to 1999 – Annual Since 2004 – Added Shackeford and Bear Island

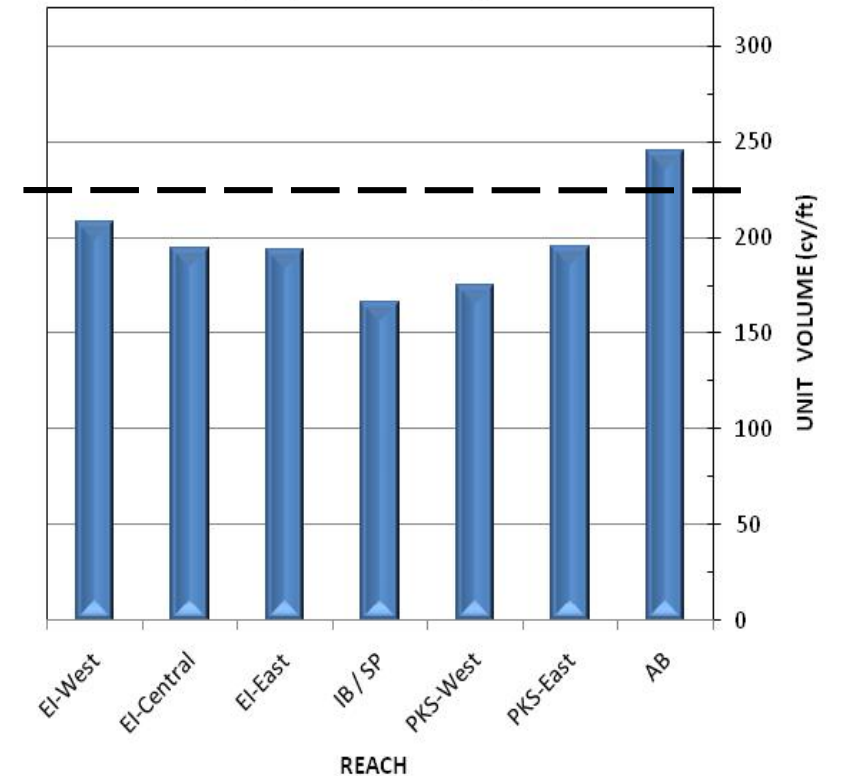


# Key Terms

## Profile (Volume) Change



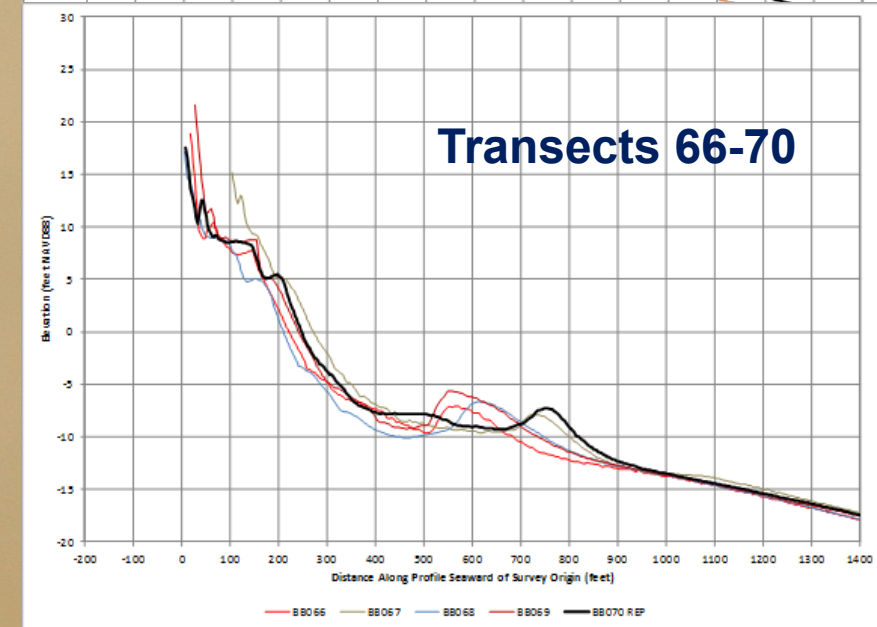
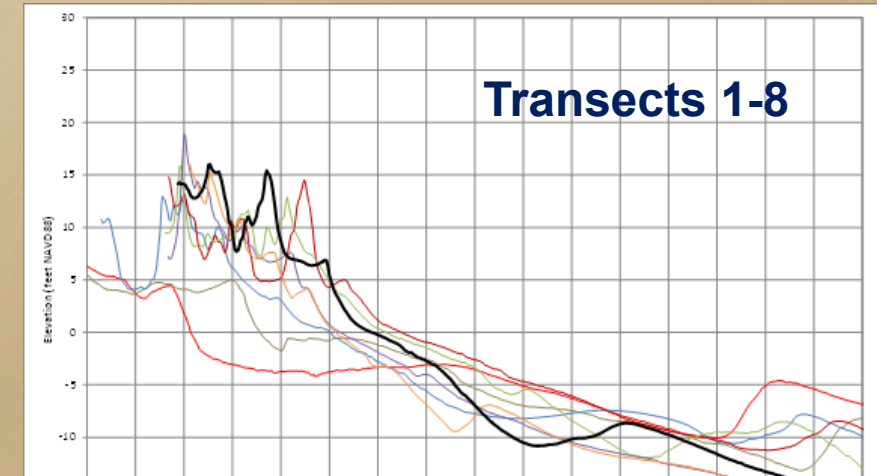
**Average Profile Volume by Bogue Banks Reach**  
(September 1999)



# Study Reaches

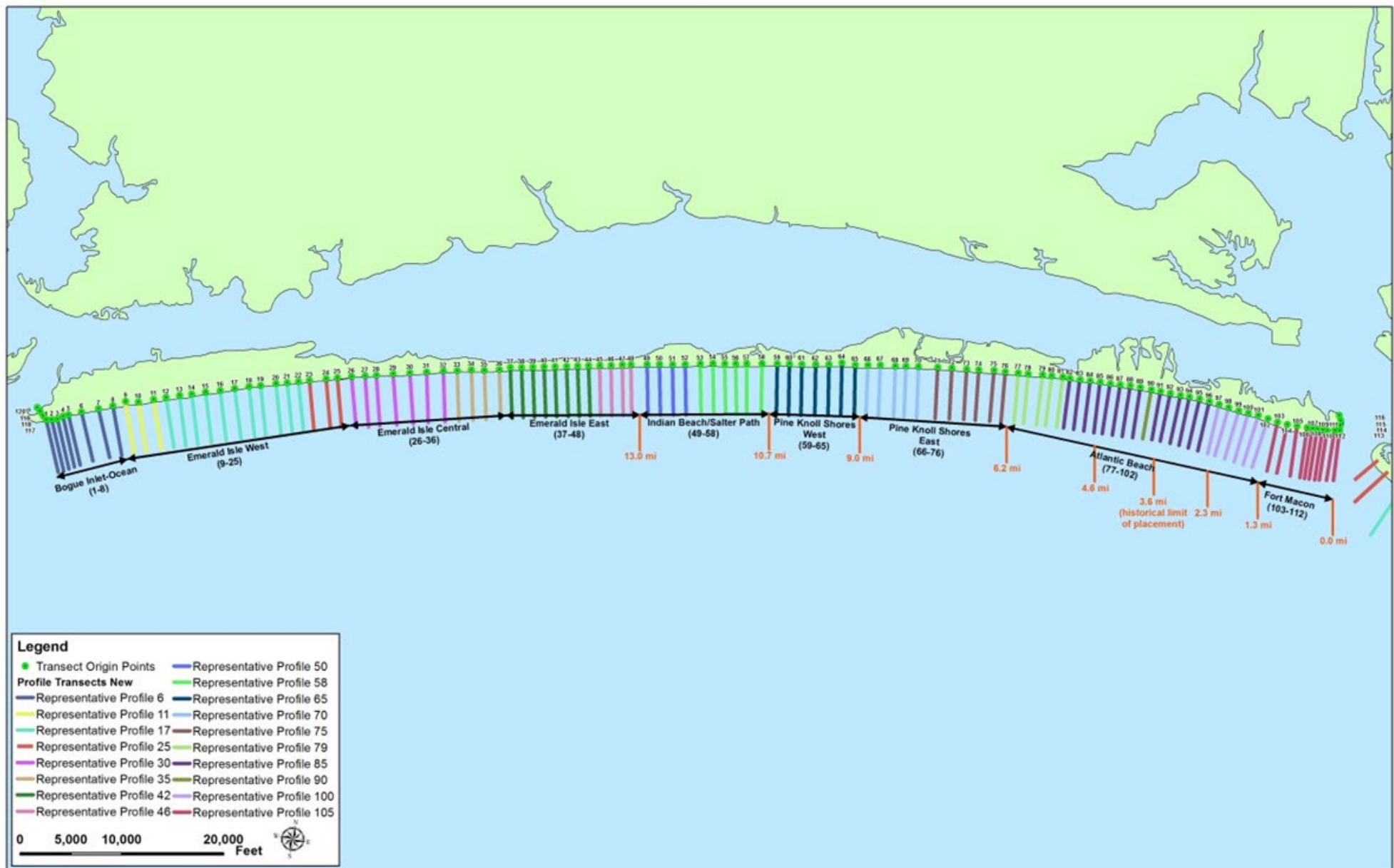
- Similar Profiles Grouped Together Based on Dune/Berms Shape, and Height to Determine Reaches

Reach	Bogue Banks Transects	Length (feet NAVD88)	Representative Transect
Bogue Inlet – Ocean (1-8)	1 through 8	7,432	6
Emerald Isle – West (9-25)	9 through 11	4,056	11
	12 through 22	14,283	17
Emerald Isle – Central (26-36)	23 through 25	4,005	25
	26 through 32	10,428	30
Emerald Isle – East (37-48)	33 through 36	5,374	35
	37 through 44	8,814	42
Indian Beach – Salter Path (49-58)	45 through 48	4,406	46
	49 through 52	5,275	50
Pine Knoll Shores – West (59-65)	53 through 58	7,575	58
	59 through 65	9,063	65
Pine Knoll Shores – East (66-76)	66 through 70	6,564	70
	71 through 76	8,251	75
	77 through 81	5,388	79
	82 through 89 & 91 through 96	13,771	85
Atlantic Beach (77-102)	90	1,006	90
	97 through 102	6,011	100
Fort Macon State Park (103-112)	103 through 112	6,691	105





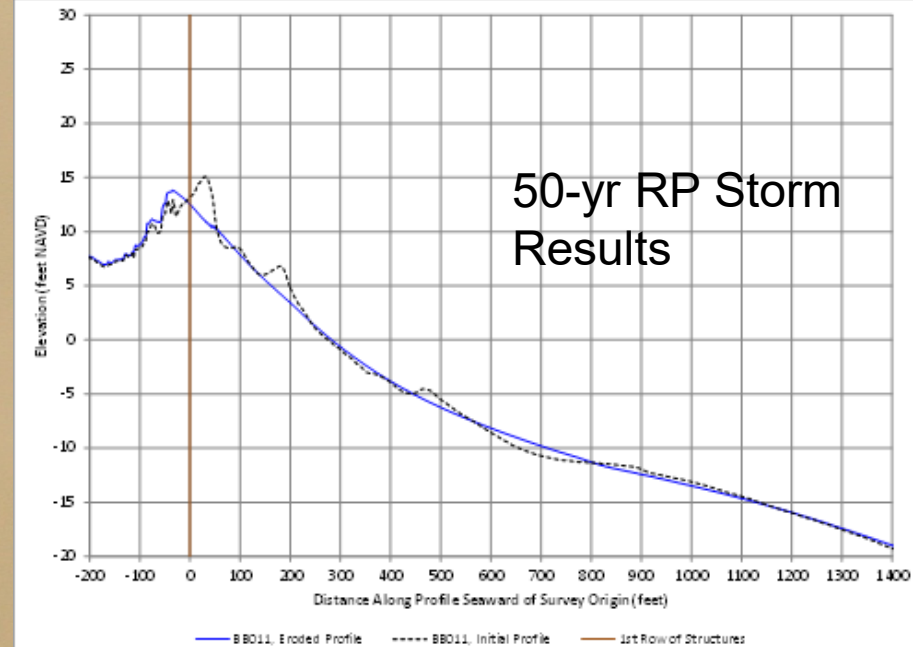
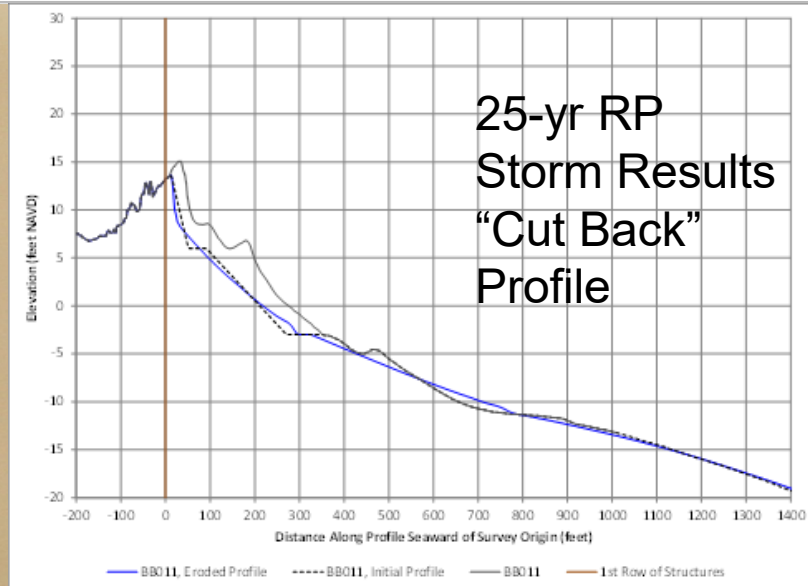
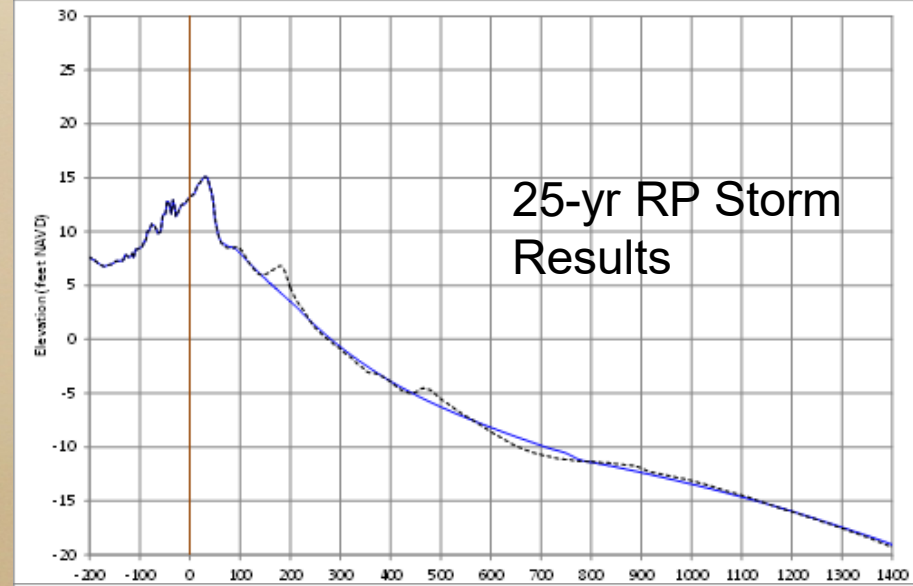
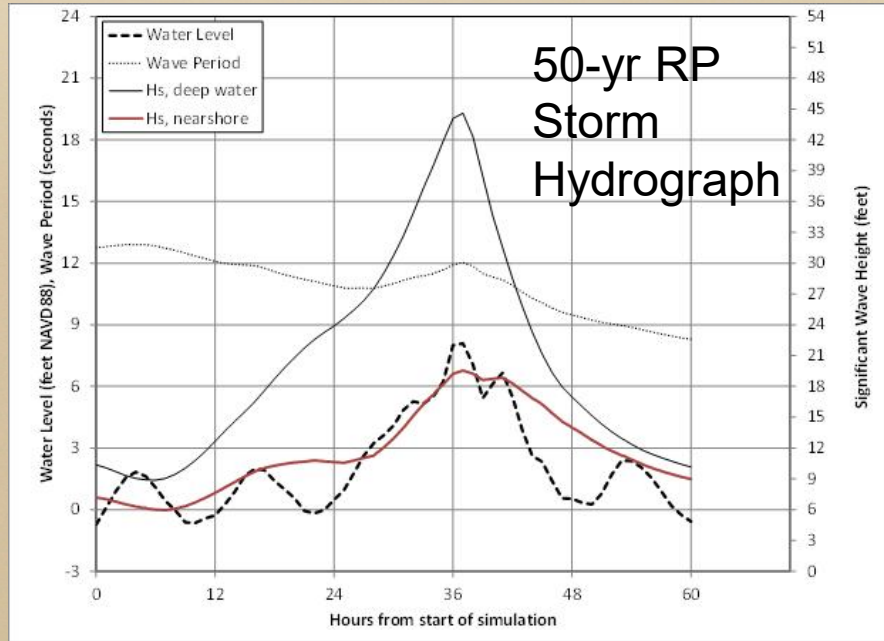
# Study Reaches



# Level of Protection Determination

- Synthetic Storms Developed for 10, 25, 50 and 100 yr RP
- Hurricane Fran Estimated to Be Between 20 - 25 yr Event
- SBEACH Runs Made at Representative Profiles (2011)
- Level of Protection Determination – 1<sup>st</sup> Row of Structures

# Level of Protection Determination



# Level of Protection Determination

- Good for 25-yr RP Currently – 2011 Profile
- Would Take Some Dune/Berm Building in EI-West/Central/East, and AB to Get to 50-yr Level of Protection

Reach	Bogue Banks Transect	Initial Volume (cy/ft)	25-year RP Level of Protection	50-year RP Level of Protection	100-year RP Level of Protection
Bogue Inlet – Ocean	6	254	No Impact	No Impact	Minor Overtopping
Emerald Isle – West	11	282	No Impact	No Impact	Threatened
	17	319	No Impact	No Impact	Undermined
	25	323	No Impact	Minor Overtopping	Threatened
Emerald Isle – Central	30	266	No Impact	No Impact	No Impact
	35	277	No Impact	No Impact	Undermined
Emerald Isle – East	42	268	No Impact	No Impact	Major Overtopping
	46	299	No Impact	No Impact	Undermined
Indian Beach – Salter Path	50	290	No Impact	No Impact	No Impact
	58	267	No Impact	No Impact	No Impact
Pine Knoll Shores – West	65	235	No Impact	Minor Overtopping	Undermined
Pine Knoll Shores – East	70	271	No Impact	Minor Overtopping	Major Overtopping
	75	276	No Impact	Minor Overtopping	Major Overtopping
Atlantic Beach	79	269	No Impact	Minor Overtopping	Undermined
	85	375	No Impact	No Impact	Major Overtopping
	90	408	No Impact	Threatened	Threatened
	100	495	No Impact	No Impact	No Impact
Fort Macon State Park	105	365	n/a	n/a	n/a

# Level of Protection Determination

- Develop Preliminary Management Reaches

Reach	Reach Length (ft)	50-yr, -12 ft Trigger (cy)	25-yr, -12 ft Trigger (cy)	Adjusted 25-yr, -12 ft Trigger (cy)	Preliminary -12 ft Trigger (cy)	-12 ft 2011 Volume (cy)
Bogue Inlet (1-8)	7,432	238	103	238	235	389
Emerald Isle West - A (9-11)	4,056	282	230	230		277
Emerald Isle West - B (12-22)	14,283	319	272	272	266	295
Emerald Isle West - C (23-25)	4,005	323	242	242		303
Emerald Isle Central - A (26-32)	10,428	237	213	213	211	292
Emerald Isle Central - B (33-36)	5,374	277	207	207		262
Emerald Isle East - A (37-44)	8,814	268	214	214	221	242
Emerald Isle East - B (45-48)	4,406	299	235	235		264
Indian Beach/Salter Path - West (49-52)	5,275	243	216	216	224	263
Indian Beach/Salter Path - East (53-58)	7,575	241	229	229		298
Pine Knoll Shores - West (59-65)	9,063	235	196	196	211	253
Pine Knoll Shores - East - A (66-70)	6,564	271	218	218		240
Pine Knoll Shores East - B (71-76)	8,251	287	222	222		262
Atlantic Beach - West (77-81)	5,388	269	225	225	254	281
Atlantic Beach - Central (82-89, 91-96)	13,771	375	248	248		291
Atlantic Beach - Circle (90)	1,006	408	364	364		330
Atlantic Beach - East (97-102)	6,011	318	276	276		384
<b>TOTAL</b>	<b>121,702</b>					
<b>AVERAGE</b>		<b>288</b>	<b>230</b>	<b>238</b>	<b>233</b> Weighted	<b>290</b>

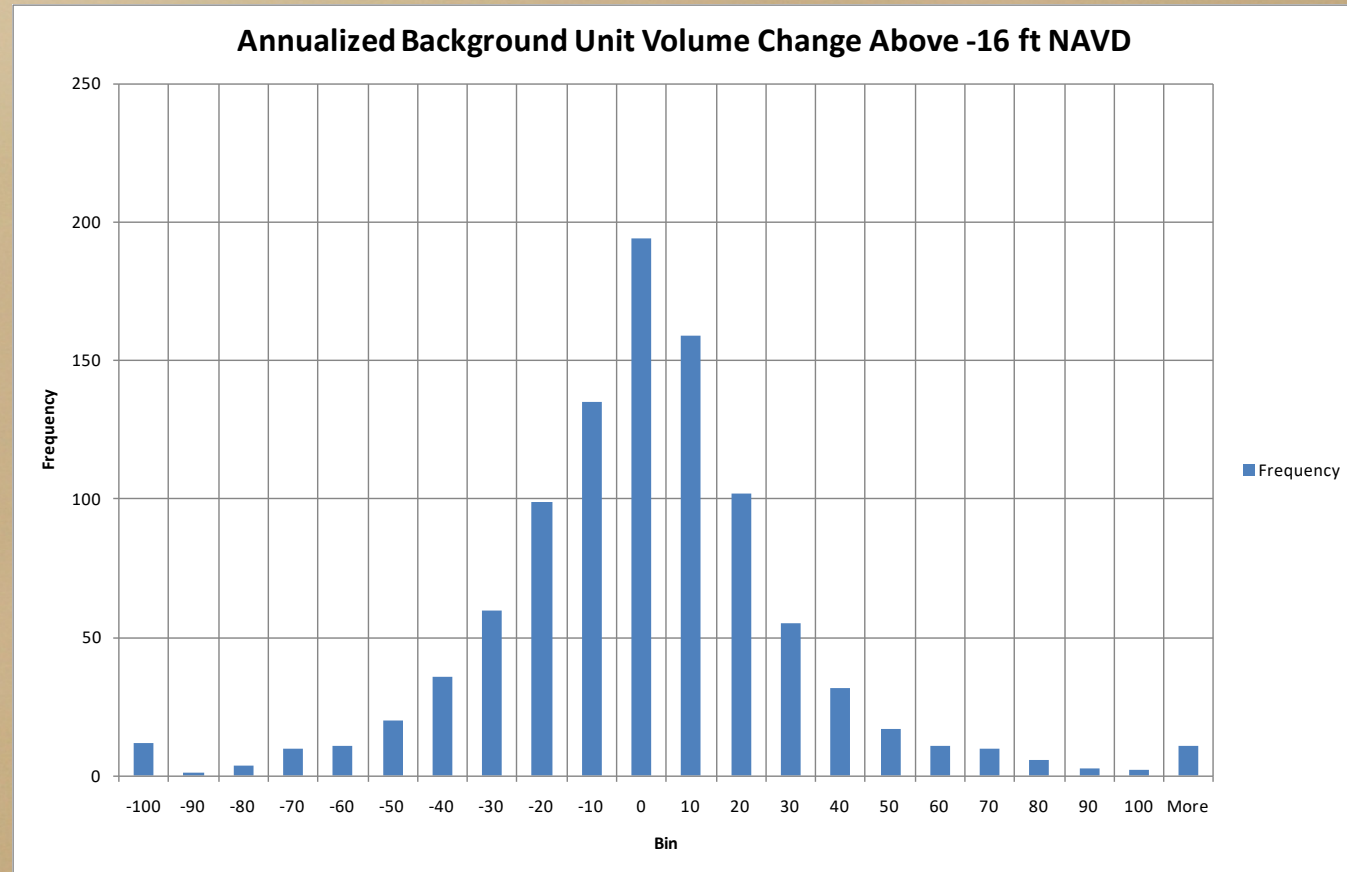
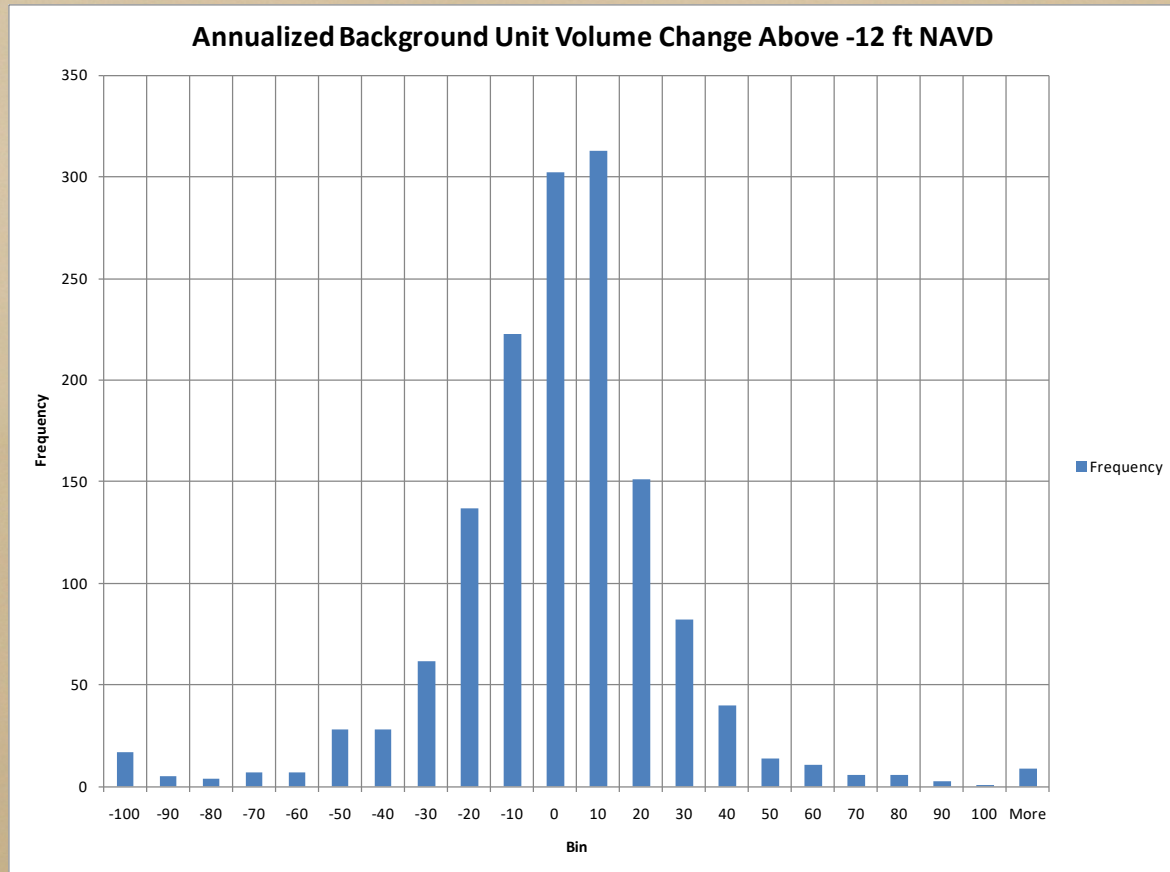
# Estimation of Maintenance Project Volumes

## Profile (Volume) Change

- *Complete volume change calculations for all available profiles between top of dune and following elevations:*
  - +1.1 ft NAVD (MHW - visible beach), -5.0 ft NAVD (wading beach)
  - -12 ft NAVD (offshore bar), -16 ft NAVD (near closure depth)
  - -20 ft NAVD (near closure depth), -30 ft NAVD (~ survey limits)
- *All profiles loaded into USACE Beach Morphology Analysis Package (BMAP) software for volume calculations*
  - Resulting volumes loaded into Excel to compute change rates
  - Nourishment volumes subtracted out to determine background change rates – factor determined for +1.1' (35%) and -5.0' (65%)
  - Annualized to develop annual need

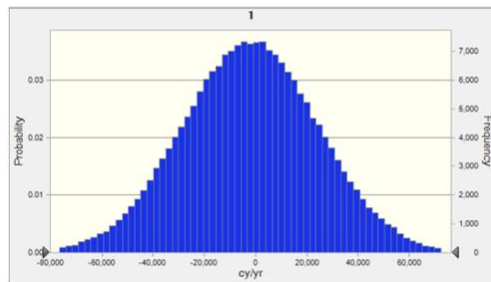
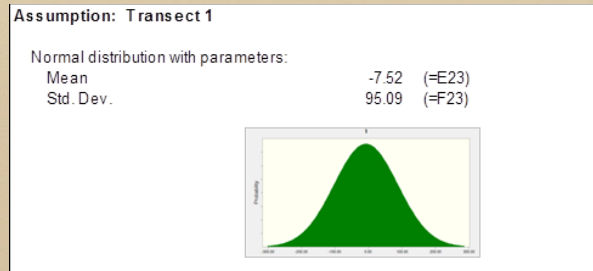
# Crystal Ball Analyses

- Ran Crystal Ball Models with Reach Breakdowns for All Studied Elevations (+1.1', -5', -12', -16', -20', -30') For All Data (1999-2012)
- Normal Distribution was Valid Assumption Based on Data



# Crystal Ball Analyses

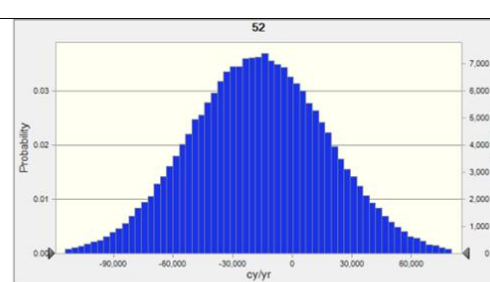
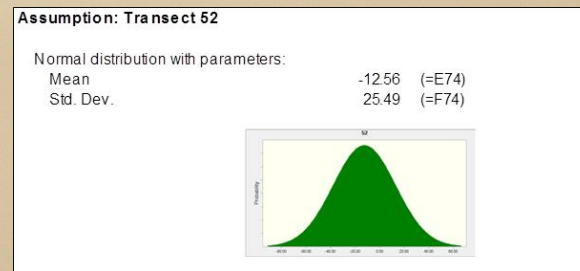
- Crystal Ball – Monte Carlo Simulation Run for 200,000 Trials



Statistics:	Forecast values
Trials	200,000
Base Case	-2.103
Mean	-2.075
Median	-2.051
Mode	---
Standard Deviation	26.595
Variance	707,276.897
Skewness	-0.0021
Kurtosis	2.99
Coeff. of Variability	-12.81
Minimum	-113,841
Maximum	106,340
Range Width	220,181
Mean Std. Error	59

**Forecast: 1 (cont'd)**

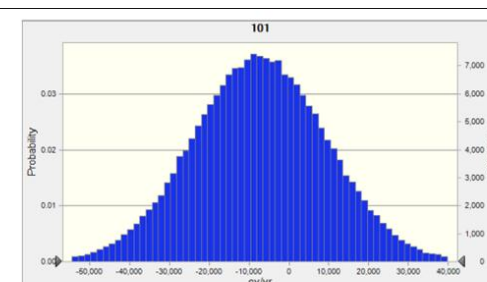
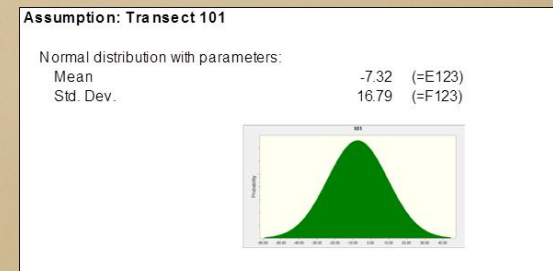
Percentiles:	Forecast values
100%	-113,841
90%	-36,239
80%	-24,470
70%	-16,025
60%	-8,782
50%	-2,051
40%	4,675
30%	11,862
20%	20,324
10%	32,013
0%	106,340



Statistics:	Forecast values
Trials	200,000
Base Case	-17,124
Mean	-17,079
Median	-17,104
Mode	---
Standard Deviation	34,785
Variance	1,209,977.139
Skewness	0.0108
Kurtosis	2.98
Coeff. of Variability	-2.04
Minimum	-212,899
Maximum	135,374
Range Width	348,273
Mean Std. Error	78

**Forecast: 52 (cont'd)**

Percentiles:	Forecast values
100%	-212,899
90%	-61,626
80%	-46,477
70%	-35,407
60%	-26,003
50%	-17,105
40%	-8,299
30%	1,200
20%	12,188
10%	27,523
0%	135,374



Statistics:	Forecast values
Trials	200,000
Base Case	-7,333
Mean	-7,339
Median	-7,353
Mode	---
Standard Deviation	16,820
Variance	282,901,208
Skewness	-0.0040
Kurtosis	3.01
Coeff. of Variability	-2.29
Minimum	-86,408
Maximum	63,769
Range Width	150,177
Mean Std. Error	38

**Forecast: 101 (cont'd)**

Percentiles:	Forecast values
100%	-86,408
90%	-28,797
80%	-21,480
70%	-16,130
60%	-11,618
50%	-7,353
40%	-3,101
30%	1,471
20%	6,810
10%	14,202
0%	63,769



# Crystal Ball Analyses

- Final Estimates Use 50% Exceedance (All Loss) – for Accretional Reaches Select 1<sup>st</sup> Loss % (55-70%)

	Reach Length (ft)	USACE Annual Renourishment (cy)	USACE Annual Renourishment Density (cy/ft)		-12 ft Annual Loss 50% (All Loss)(cy)	-12 ft Annual Loss Density 50% (All Loss) (cy/ft)
Bogue Inlet (1-8)	7,432	-19,228	-2.6		-39,468	-5.3
Emerald Isle West - West (9-11)	4,056	-24,225	-6.0		-5,384	-1.3
Emerald Isle West - Central (12-22)	14,283	-16,233	-1.1		-4,768	-0.3
Emerald Isle West - East (23-25)	4,005	-295	-0.1		-1,566	-0.4
Emerald Isle Central - West (26-32)	10,428	-5,245	-0.5		-14,093	-1.4
Emerald Isle Central - East (33-36)	5,374	-2,133	-0.4		-10,890	-2.0
Emerald Isle East - West (37-44)	8,814	-22,025	-2.5		-40,472	-4.6
Emerald Isle East - East (45-48)	4,406	-8,410	-1.9		-23,272	-5.3
Indian Beach/Salter Path - West (49-52)	5,275	-18,144	-3.4		-54,380	-10.3
Indian Beach/Salter Path - East (53-58)	7,575	-23,753	-3.1		-8,187	-1.1
Pine Knoll Shores - West (59-65)	9,063	-31,057	-3.4		-13,726	-1.5
Pine Knoll Shores - East - West (66-70)	6,564	-19,056	-2.9		-24,709	-3.8
Pine Knoll Shores East - East (71-76)	8,251	-31,562	-3.8		-46,360	-5.6
Atlantic Beach - West (77-81)	5,388	-26,533	-4.9		-5,881	-1.1
Atlantic Beach - Central (82-89, 91-96)	13,771	-52,361	-3.8		-96,718	-7.0
Atlantic Beach - Circle (90)	1,006	-4,280	-4.3		-12,948	-12.9
Atlantic Beach - East (97-102)	6,011	-51,707	-8.6		-49,398	-8.2
<b>TOTAL ANNUAL VOLUME CHANGE</b>	<b>121,702</b>	<b>-356,247</b>	<b>-2.9</b>		<b>-452,220</b>	<b>-3.7</b>
<b>50-yr Nourishment Need</b>	<b>121,702</b>	<b>-17,812,350</b>			<b>-22,611,000</b>	

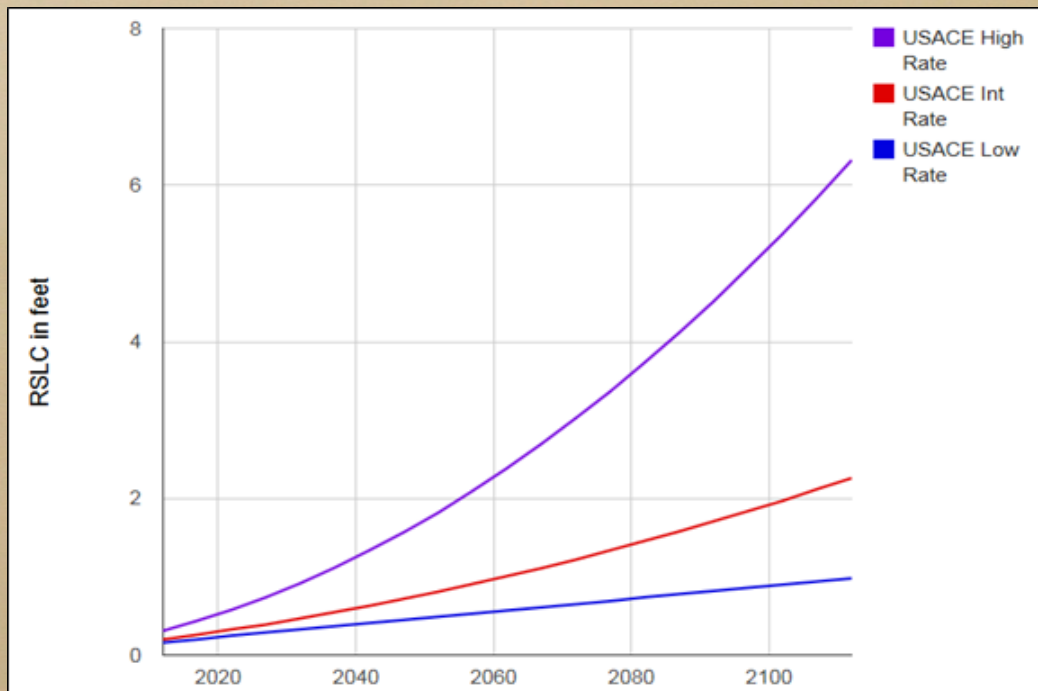
# Crystal Ball Analyses

- Storm Losses Apparent in Higher % Exceedance Results So the 50% Results Were Felt to Be Indicative of Background Erosion
- Separate Crystal Ball Analysis Run for Three Storm Years (Isabel, Ophelia and Irene)
- Storm Losses ~ 1.4 – 1.7 Mcy per Event – Happens ~3 yrs

Probability	Storm Loss above -12 ft NAVD (cy)	Storm Loss above -16 ft NAVD (cy)
85%	-1,644,909	-1,847,667
84%	-1,636,034	-1,839,681
80%	-1,602,871	-1,809,816
75%	-1,567,196	-1,776,197
70%	-1,534,995	-1,747,197
65%	-1,506,039	-1,719,307
60%	-1,477,667	-1,693,397
55%	-1,450,894	-1,668,206
50%	-1,424,153	-1,644,355

# Crystal Ball Analyses

- Total 50 yr need = 22.6 Mcy (Background) + 22.4 to 27.2 Mcy (Storm) = 45.0 – 49.8 Mcy
- Roughly 50/50 Split – Background vs. Storm
- Total 50 yr need with Potential Sea Level Change = 46.8 – 51.6 Mcy



Project Time-Frame	Relative Sea-Level Change Scenario		
	Low (feet)	Intermediate (feet)	High (feet)
Year 2022 (10 years)	0.25	0.33	0.58
Year 2037 (25 years)	0.37	0.55	1.12
Year 2062 (50 years)	0.57	1.01	2.39
Year 2087 (75 years)	0.78	1.58	4.12
Year 2112 (100 years)	0.98	2.26	6.32

Low SLC: +0.57 feet	Intermediate SLC: +1.01 feet	High SLC: +2.39 feet
1,030,000 cubic yards	1,825,000 cubic yards	4,300,000 cubic yards

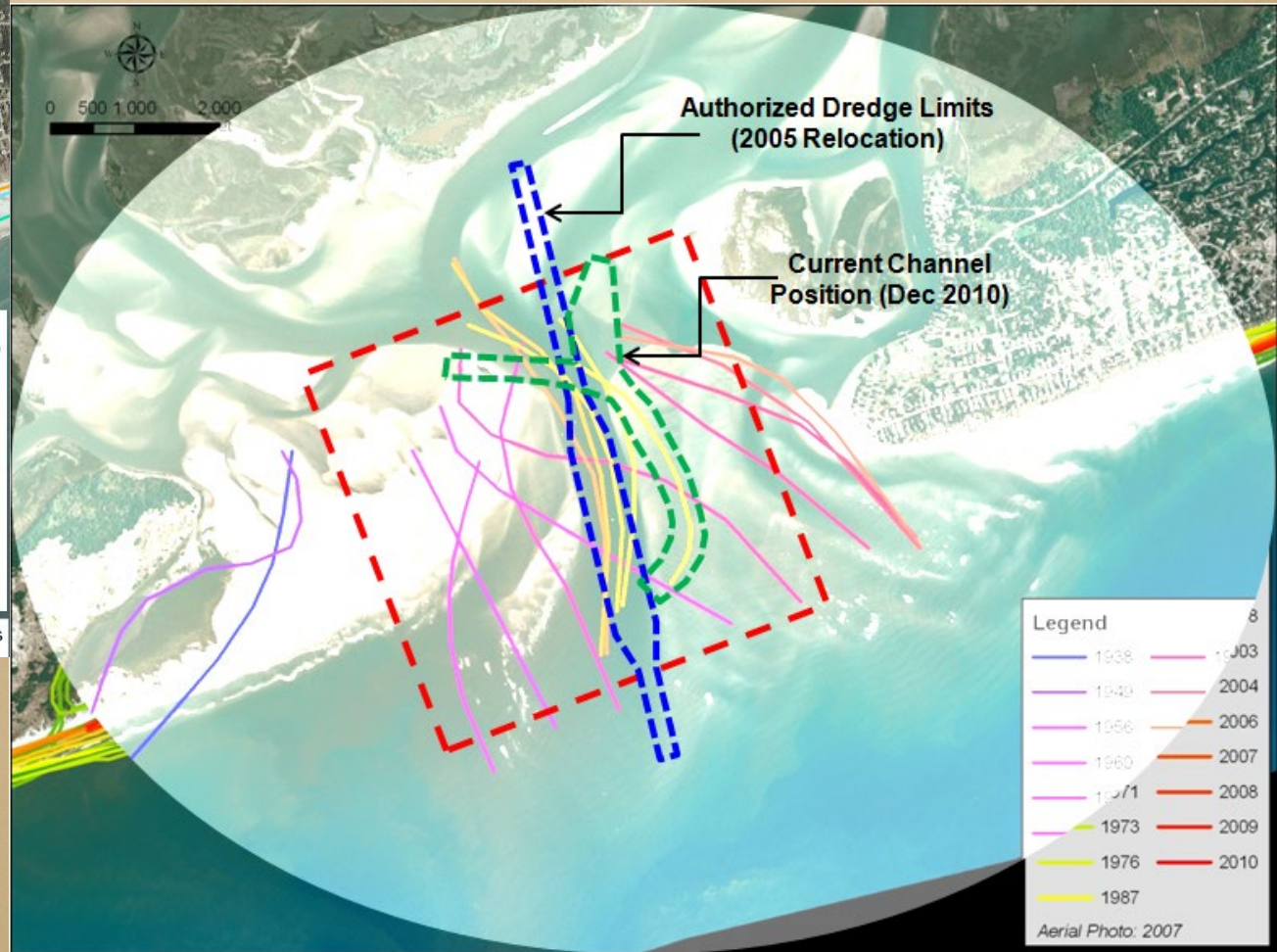
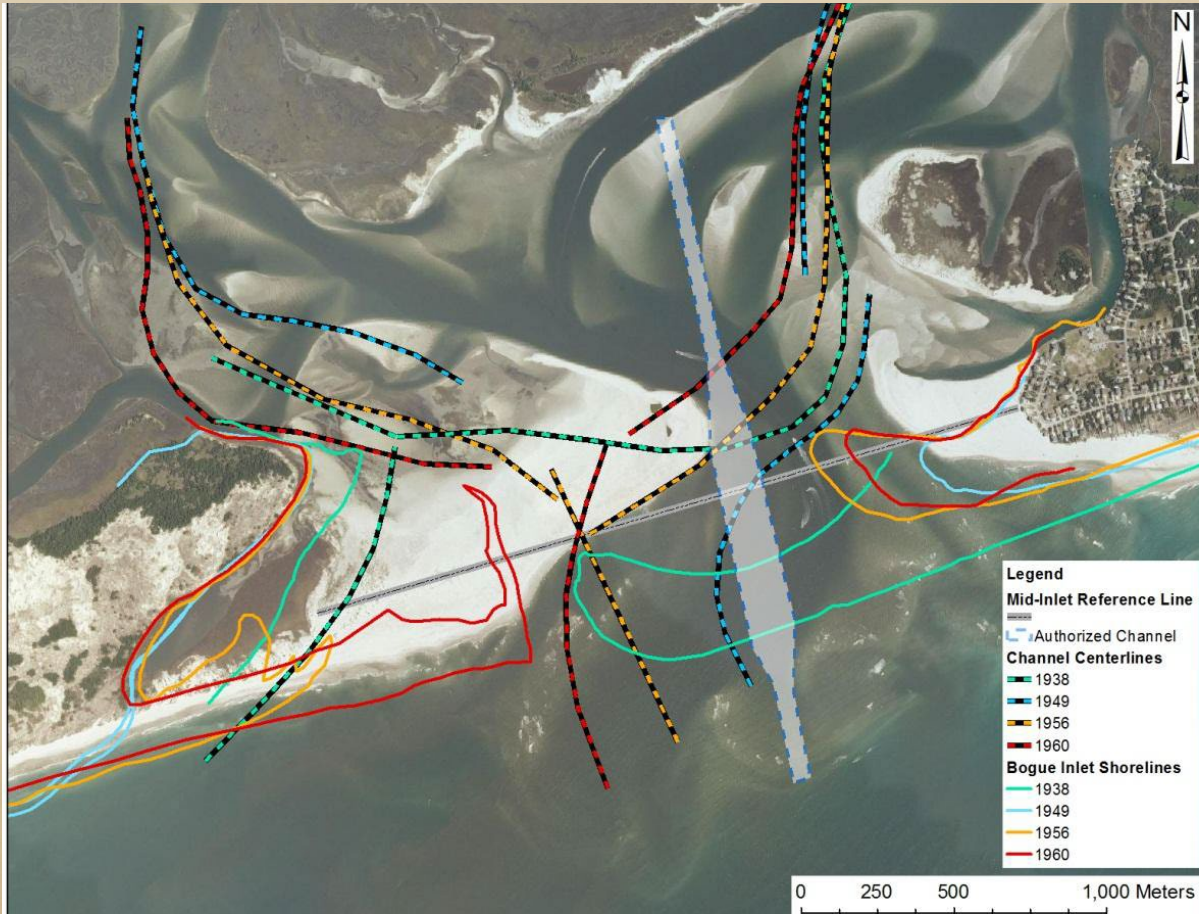
# Applicant's Preferred Alternative

- Alternative #1 - No Action (Status Quo)
- Alternative #2 - No Action (Relocation/Abandonment)
- Alternative #3 – USACE SAW 50-yr Project
- Alternative #4 – Beach Renourishment Only
  - Upland Sources Only
  - AIWW Sources Only
  - Offshore Sources Only
  - Offshore/AIWW/Upland Sources
- Alternative #5 – Beach Renourishment and Inlet Management
  - Non-Structural Inlet Management
  - Structural Inlet Management
  - Hybrid Approach

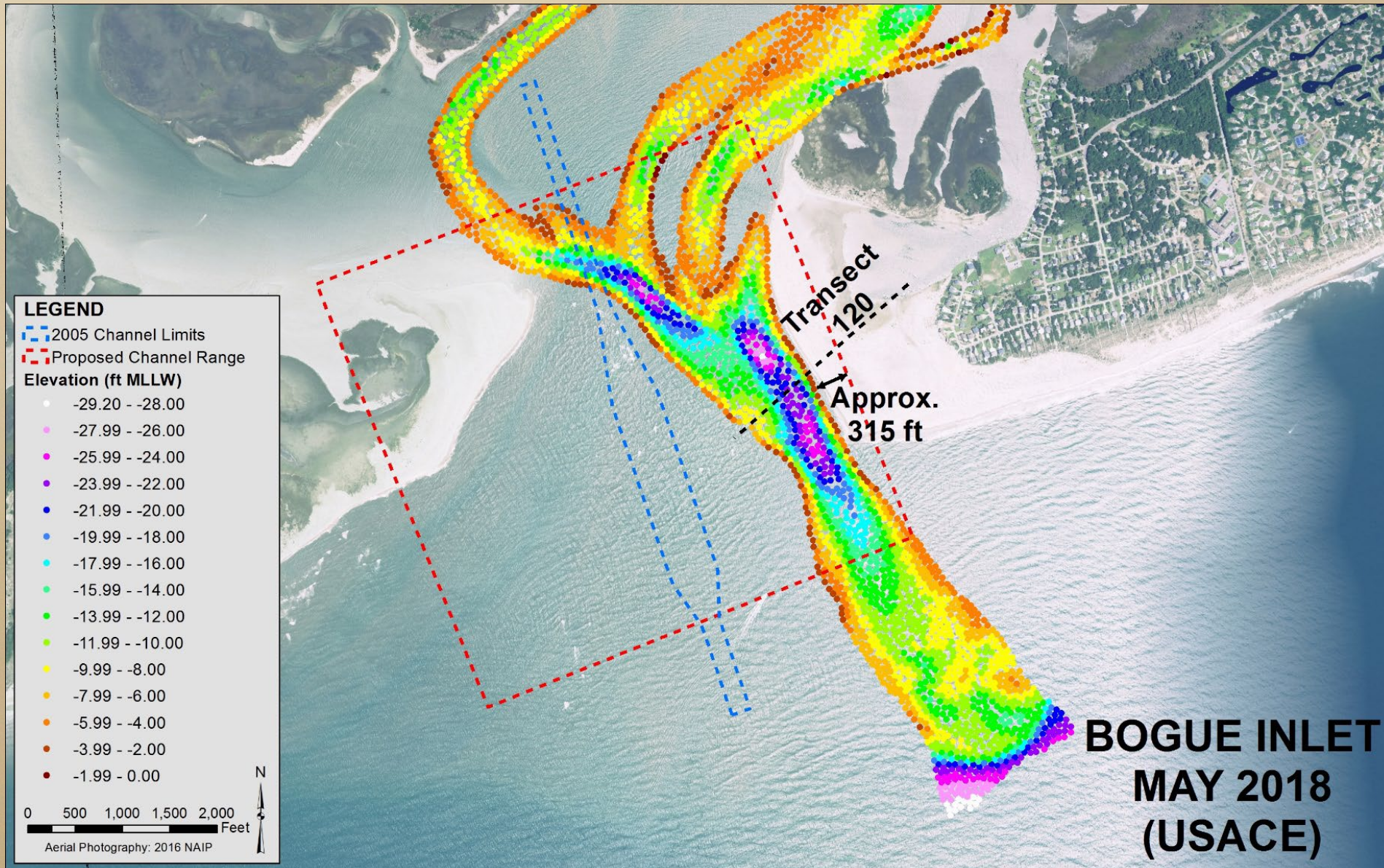
# Bogue Inlet Management



# Bogue Inlet Management



# Bogue Inlet Management



# Applicant's Preferred Alternative

## Beach Nourishment with Non-Structural Inlet Management Meets The Project Need

- **Total 50 yr need = 22.6 Mcy (Background) + 22.4 to 27.2 Mcy (Storm) = 45.0 – 49.8 Mcy**
- **Total 50 yr need with Potential Sea Level Change = 46.8 – 51.6 Mcy**

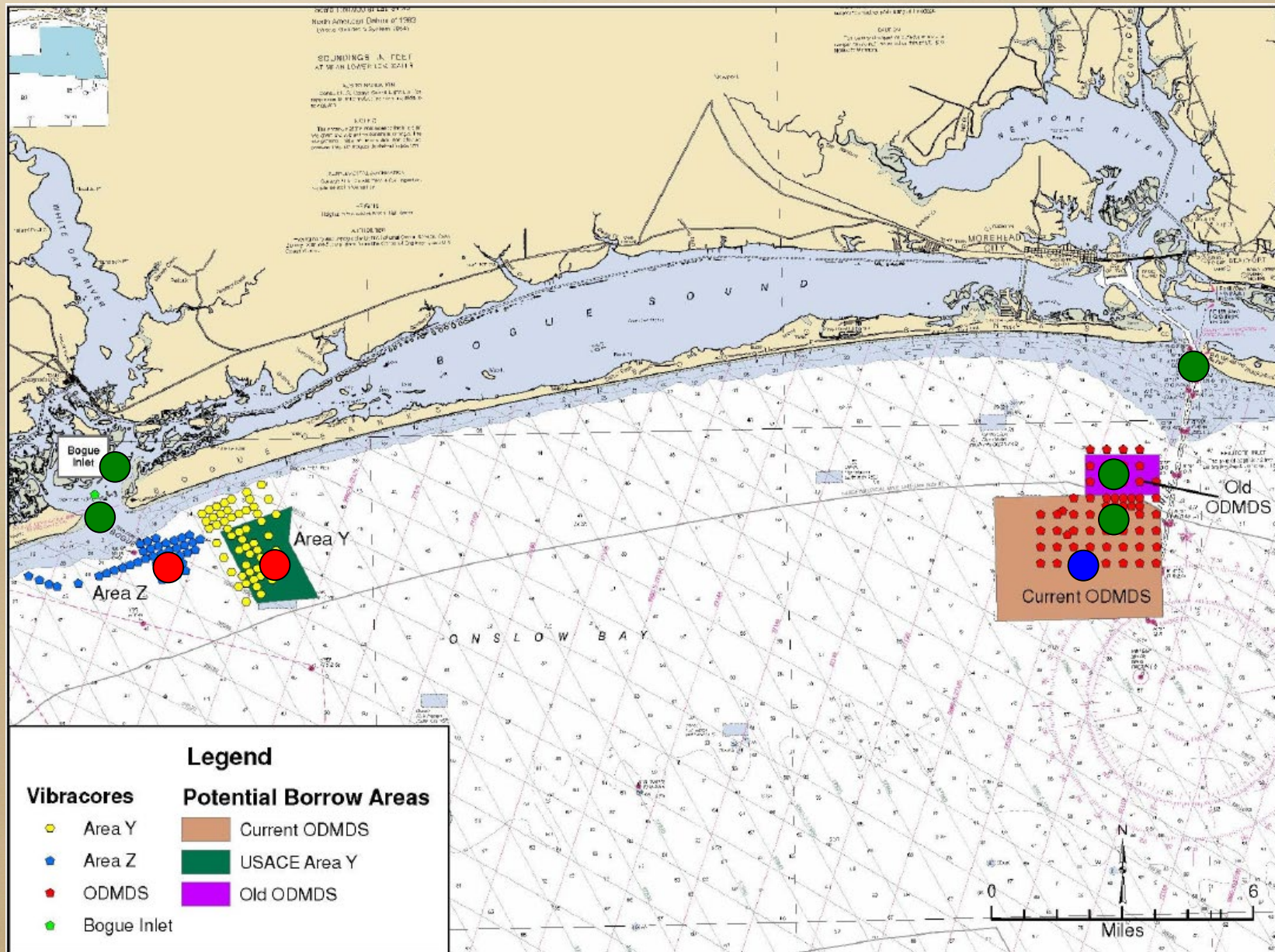
Area	Total Volume (cy)
Sand Mines	1,380,700
AIWW Disposal Areas	1,288,800
Offshore Sources	22,453,557
<b>TOTAL</b>	<b>25,123,057</b>

Source	50-Yr Total Volume (cy)
<b>Renewable</b>	25,130,000
<b>Non-Renewable</b>	25,123,057
<b>TOTAL</b>	<b>50,253,057</b>

Area	Section	Volume	Dredging Frequency	50 yr Total
<b>MHC Outer Harbor</b>	Cutoff+Range A to STA 110	400,000 cy (assumed)	1 years	20,000,000
<b>Bogue Inlet</b>	Inlet Relocation	850,000 cy	10 years	4,250,000
	AIWW Crossing	44,000 cy	2.5 years	880,000
<b>Totals:</b>				<b>25,130,000</b>



# Potential Borrow Areas: Summary



# Applicant's Preferred Alternative

- Reaches Require Nourishment at 3, 6, and 9 yr Cycles – Feeder Beach/Accretional Areas – Cycles Based on Expected Project Nourishment Density – (25 – 50 cy/ft) & Loss Rates



# Applicant's Preferred Alternative

- Reaches Require Nourishment at 3, 6, and 9 yr Cycles – Feeder Beach / Accretional Areas

<u>Year</u>	<u>Reach Nourishment Volume (cy)</u>	<u>Nourishment Project</u>
2019	686,067	3
2022	1,839,351	6
2025	967,920	9
2028	1,839,351	6
2031	686,067	3
2034	2,121,204	6,9
2037	686,067	3
2040	1,839,351	6
2043	967,920	9
2046	1,839,351	6
2049	686,067	3
2052	2,121,204	6,9
2055	686,067	3
2058	1,839,351	6
2061	967,920	9
2064	1,839,351	6
Total	21,612,609	

# Applicant's Preferred Alternative

**Again, It Is VERY IMPORTANT To Note That The Results Are Based Upon Average Erosion Rates Across The Island**

**Storm Effects And Other Factors Will Control the Specific Timing and Locations of the Individual Nourishment Actions Completed as Part of the MBNP**

**Permitting Led to Development of Sand “Bank Accounts” for Background and Storm Volume Losses – Event Notification Protocol Developed for Accelerated Approval Timelines**

**Received an Allowable Construction Window of November 16 Thru April 30 for All Projects**

# Discussion

Johnny Martin, PE

[jmartin@moffattnichol.com](mailto:jmartin@moffattnichol.com)



moffatt & nichol

