An Update on Remote Sensing Metrics to Support USACE Planning & Operations

Lauren Dunkin and Molly Reif
US Army Engineer Research and Development Center
Joint Airborne Lidar Bathymetry Technical Center of Expertise

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US Army Corps of Engineers
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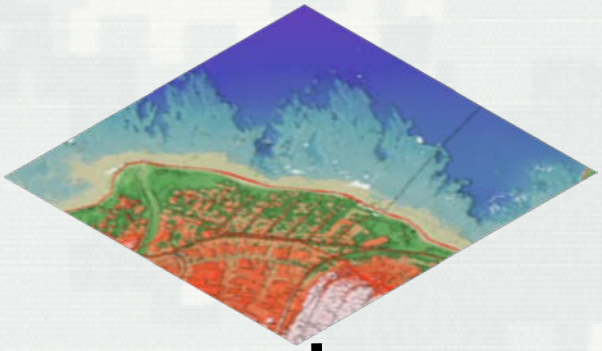
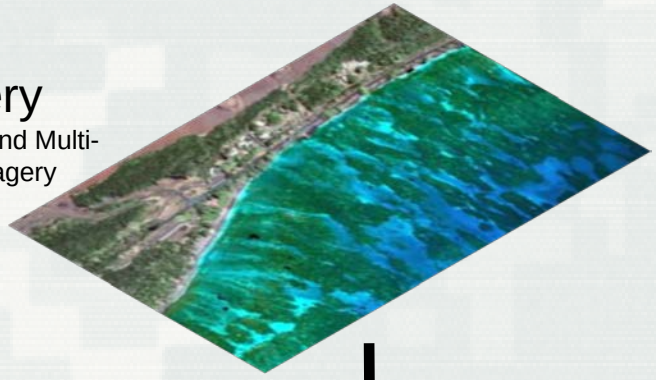
Metrics/Parameters

Elevation
Change
(elevation/volume)
Contour (change)
Shoal

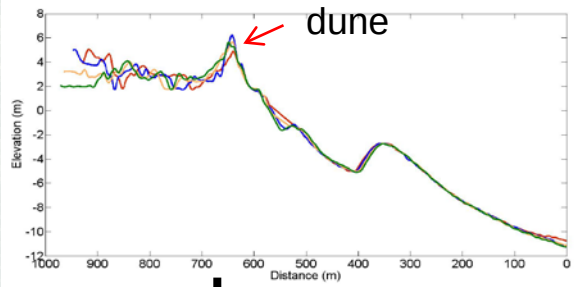


Imagery
Hyperspectral and Multi-Spectral Imagery

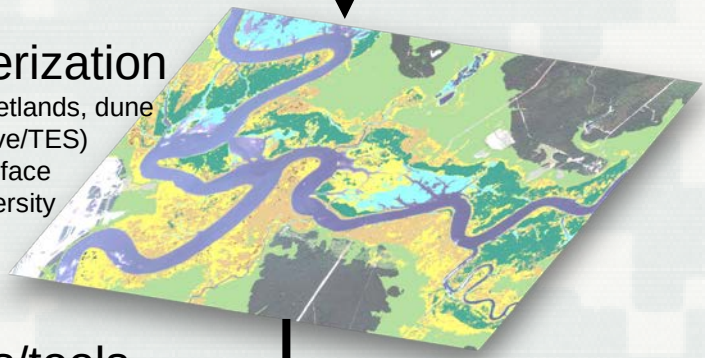


Dune
Elevation (crest/toe)
Continuity
Slope
Volume

Beach
Width
Slope



Land characterization
Critical habitat (SAV, wetlands, dune vegetation, invasive/TES)
Impervious surface
Landscape diversity



R&D/Value added products/tools

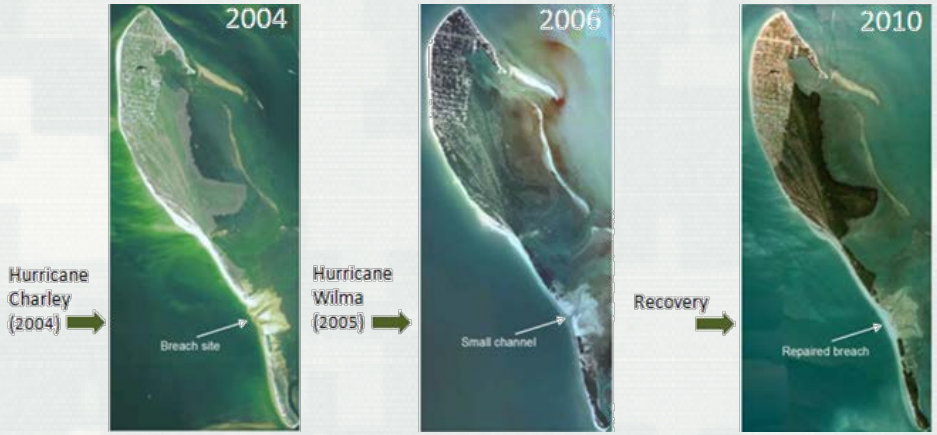
- Change Detection
  - Landscape change modeling
  - Volume/elevation/shoreline change
  - Structure assessment
- Sediment Budgets
- Monitoring Shore Protection
- Defining Coastal Regions

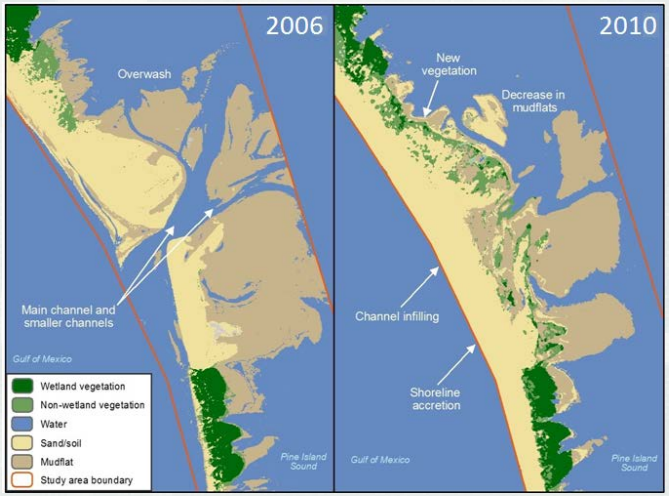
- Coastal Engineering Index
- Coastal Resilience
- Critical Species Detection and Modeling
  - Sea turtle nesting habitat
  - Oysters*
  - Salmonid

* ECO-PCX model certification

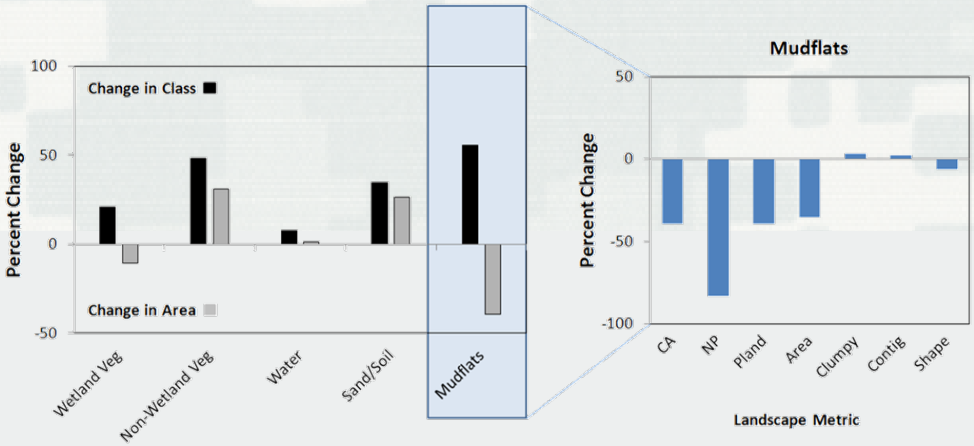
Ecological Modeling for Landscape Change Analysis

1) Identify changes to critical habitat using multi-temporal imagery and lidar data





2) Derive landscape metrics associated with landscape patterns



3) Integrate with ecological simulation to develop a better understanding of factors influencing change and a tool to assess project level impacts/benefits

Change in Landscape Pattern

Change in Ecosystem Function

Metric	Process	Benefit
Clumpiness	Biodiversity	↑↓
Cohesion	Connectivity	↓↑

Ecological Process-Pattern Database

Relational database

Landscape Pattern

Pattern Type	Pattern Metric	Metric Category
Habitat Fragmentation	Clumpiness Index	Categorical Map Pattern, Surface Pattern
Landscape Configuration	Patch Area	Categorical Map Pattern, Linear Network Pattern

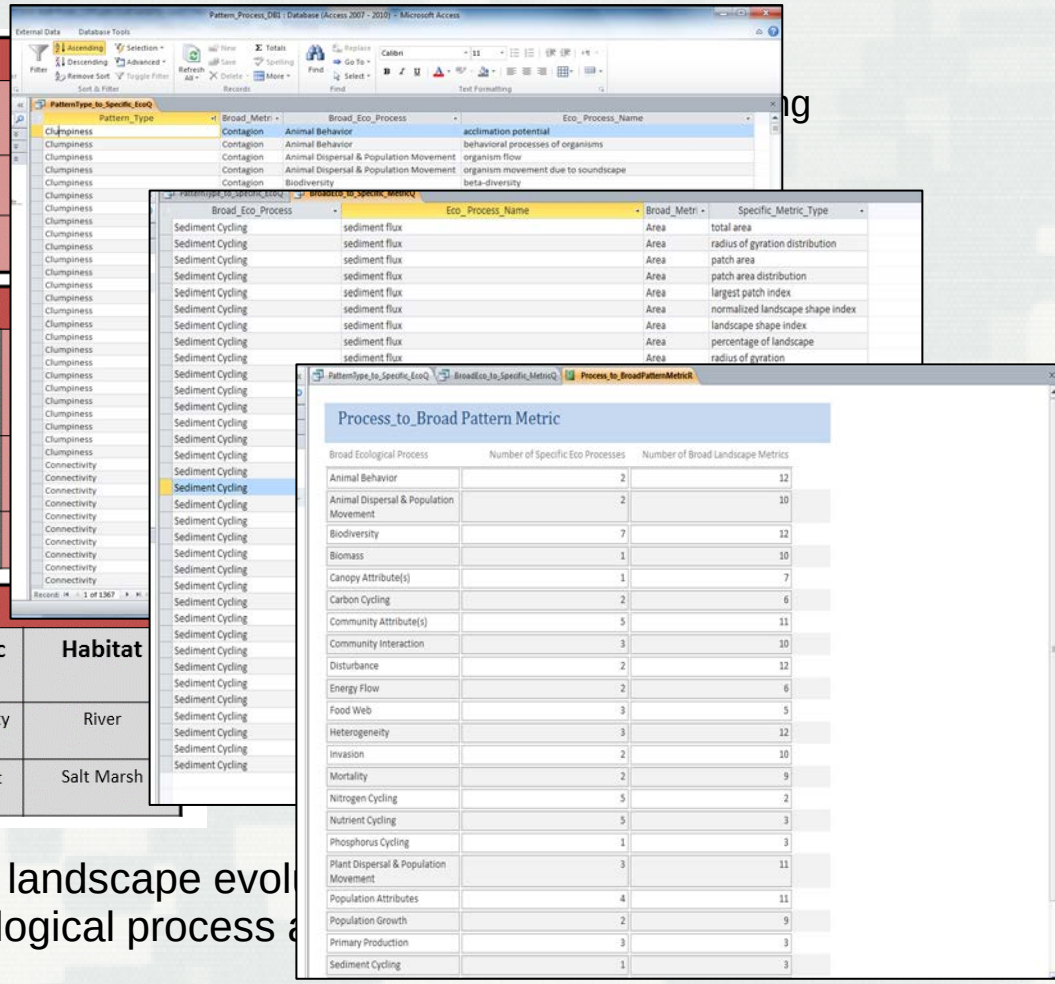
Ecological Process

Broad Process	Process Name	Ecosystem Goods & Services Category (UNEP)	Process Category	Spatial Scale
Biodiversity	Species Richness	Supporting/Provisioning	Community Dynamics	Local - Global
Sediment Cycling	Sediment Flux	Supporting/ Regulating	Other	Local - Global

Study

Study ID	Process Name	Temporal Scale	Spatial Scale	Study Metric	Habitat
3	Species Richness	1 week	30 Km^2	Shannon's Diversity Index	River
8	Sediment Flux	Daily tidal cycles	14,500 Km^2	$VS=\int^{thigh}_{tlow} CsQdt$	Salt Marsh

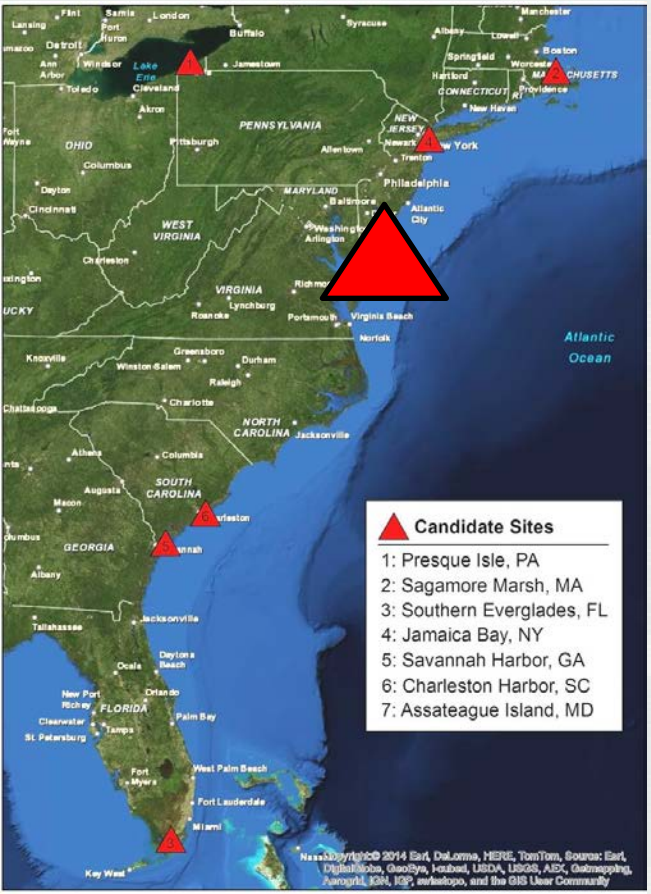
Queries and Forms



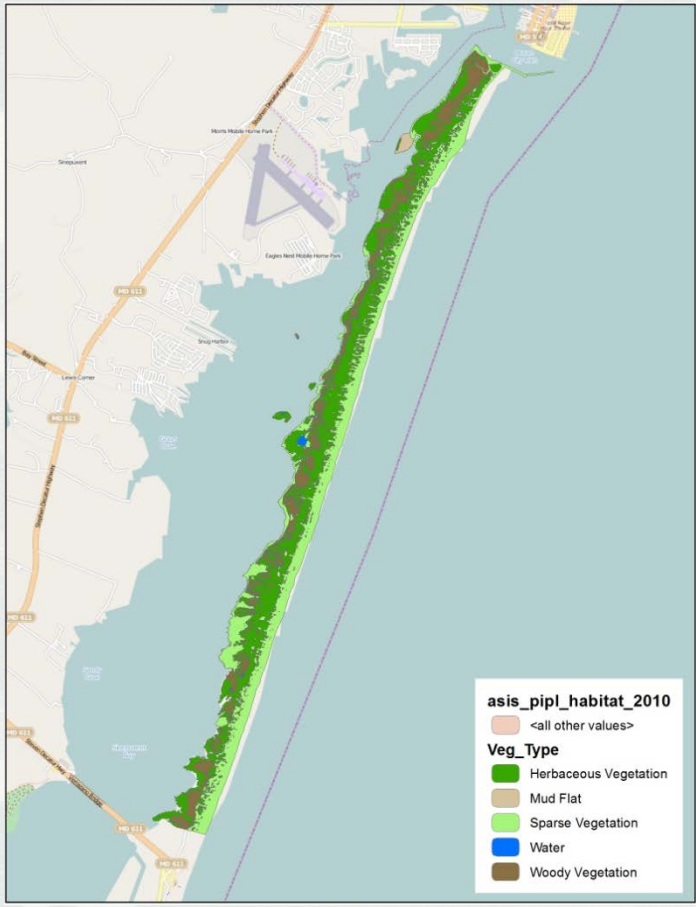
Broad Ecological Process	Number of Specific Eco Processes	Number of Broad Landscape Metrics
Animal Behavior	2	12
Animal Dispersal & Population Movement	2	10
Biodiversity	7	12
Biomass	1	10
Canopy Attribute(s)	1	7
Carbon Cycling	2	6
Community Attribute(s)	5	11
Community Interaction	3	10
Disturbance	2	12
Energy Flow	2	6
Food Web	3	5
Heterogeneity	3	12
Invasion	2	10
Mortality	2	9
Nitrogen Cycling	5	2
Nutrient Cycling	5	3
Phosphorus Cycling	1	3
Plant Dispersal & Population Movement	3	11
Population Attributes	4	11
Population Growth	2	9
Primary Production	3	3
Sediment Cycling	1	3

- Database serves as a foundation for the landscape evol
  providing key relationships between ecological process a
  parameterize spatially-explicit model
- Describing: 1) relevant landscape patterns and metrics, 2) ecological processes, 3) specific studies, and 4) linkage of patterns, processes, and studies

Site Selection

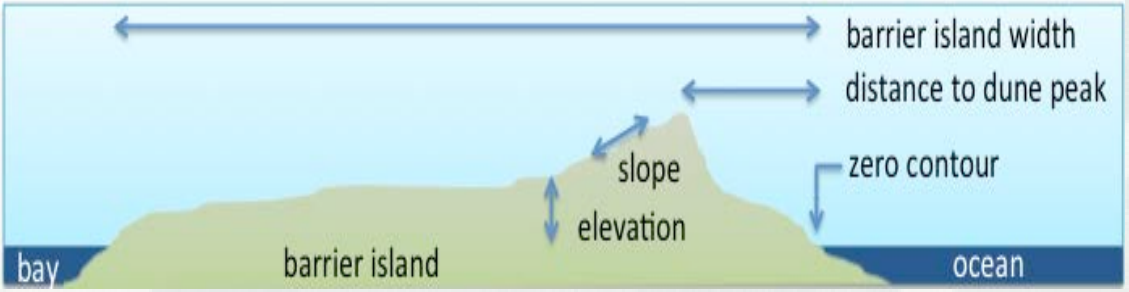


- Sites selected as a result of feedback from the Coastal Working Group and Environmental Chiefs
- Sites evaluated based on selection criteria:
  - *Coastal and dynamic*
  - *O&M activity*
  - *Ecosystem restoration activity*
  - *Long project history with visible landscape changes*
  - *Represents typical coastal project*



- Site selected: Assateague Island, MD due to data richness and historical evaluation
- Includes time series of lidar data and habitat classification by the National Park Service

Metrics Development



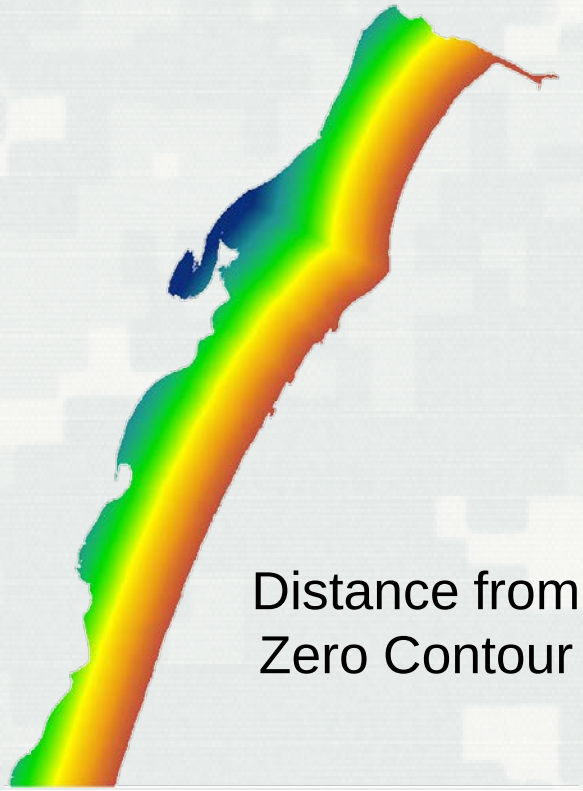
Distance to ocean	O	I I I Lucas and Carter, 2013 (would need further adjustment); Geider et al 2014; Tissier et al 2013	I		I
Distance to sound	O	I I Geider et al 2014	I		
distance to dune crest	O	I I Geider et al 2014			
distance to dune toe	O	I I Grafals-Soto 2012; Geider et al 2014			
beach width	O				
zero contour to dune to	O				
dune field volume	O	I I Preistas and Fagherazzi 2010, implied			
beach slope	O	I I		I	
barrier island width	O	I I I Claudino-Sales et al 2008; background: Houser and Hamilton, 2009; Smith et al 2008		O	
elevation	O	I I I Lucas and Carter, 2013; Geider, 2014; Judd et al, 2008; Miller et al, 2010; Sellars and Jolls, 2007 *(Amaranthus)*; Priestas and Fagherazzi, 2010	I		I
slope	O	Tisser et al 2013, slope angle			
aspect	O				
foredune continuity (?)	O	I I I Preistas and Fagherazzi 2010; Miller et al 2010			

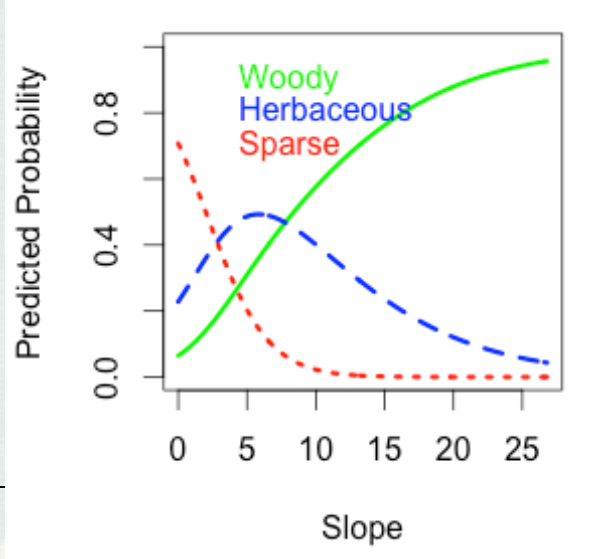
- Metrics identified from literature reviews and developed from a time series of lidar data (2000 - 2012) collected by the U.S. Geological Survey, NASA and The USACE National Coastal Mapping Program

- Focused on 6 metrics:
  - **Elevation**
  - **Slope**
  - **Barrier island width**
  - **Distance from zero contour**
  - **Distance to dune peak**
  - **Elevation change**

Metrics Analysis

- Predicted probability of vegetation type for each metric determined using logistic regression
- Influence of interactions between metrics investigated
- Relationships incorporated into spatial model





Probabilities

$$\ln\left(\frac{p(herbaceous2000)}{p(woody2000)}\right) = -6.90 + 1.45\left(dist\ zero\ contour^{\frac{1}{3}}\right) + 8.46\left(slope^{\frac{1}{3}}\right) - 1.52\left(slope^{\frac{1}{3}} * dist\ zero\ contour^{\frac{1}{3}}\right)$$

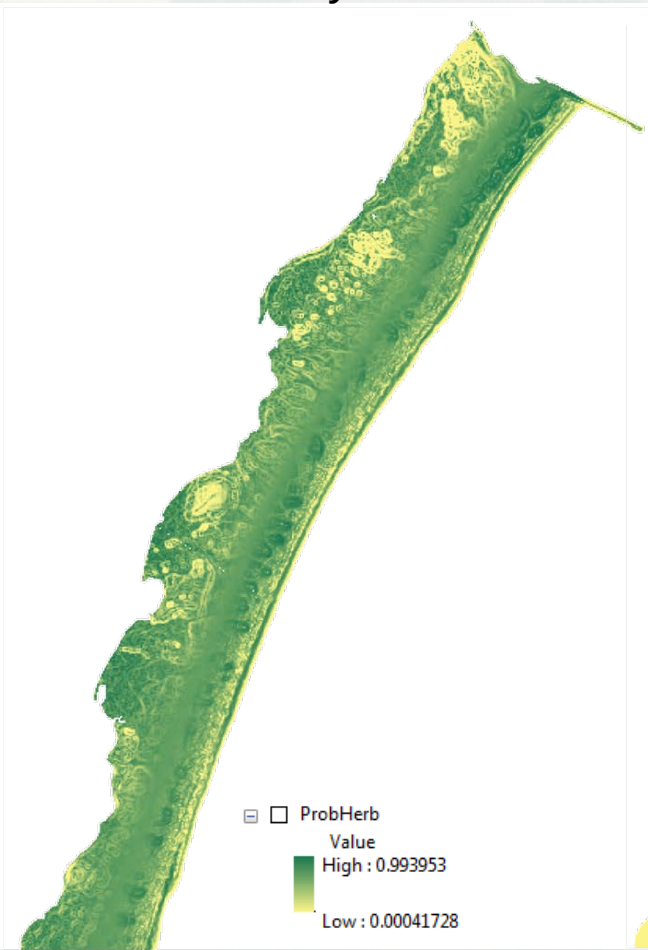
$$Probability(herbaceous) = \frac{e^{(L_{herbaceous})}}{1 + e^{L_{herbaceous}} + e^{L_{sparse}}}$$

$$\ln\left(\frac{p(sparse2000)}{p(woody2000)}\right) = 1.59 - 0.71\left(dist\ zero\ contour^{\frac{1}{3}}\right) + 6.67\left(slope^{\frac{1}{3}}\right) - 1.82\left(slope^{\frac{1}{3}} * dist\ zero\ contour^{\frac{1}{3}}\right)$$

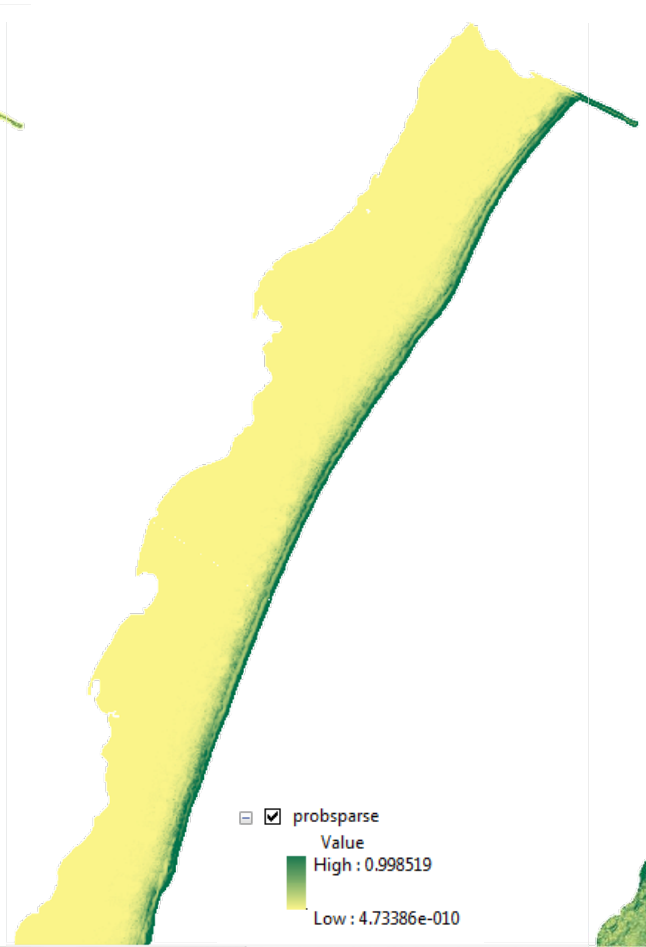
$$Probability(sparse) = \frac{e^{(L_{sparse})}}{1 + e^{L_{herbaceous}} + e^{L_{sparse}}}$$

$$Probability(woody) = \frac{1}{1 + e^{L_{herbaceous}} + e^{L_{sparse}}}$$

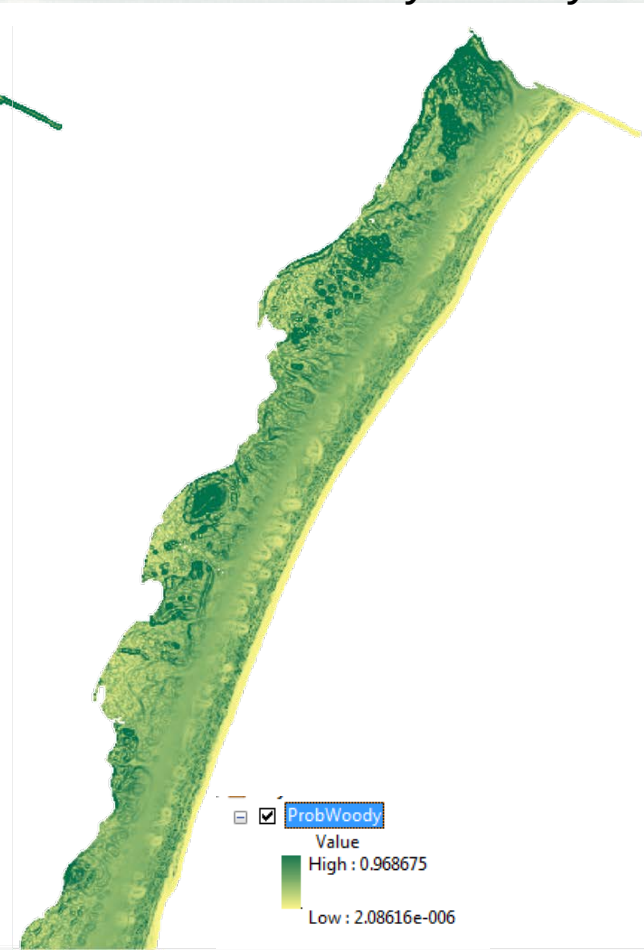
Probability Herbaceous



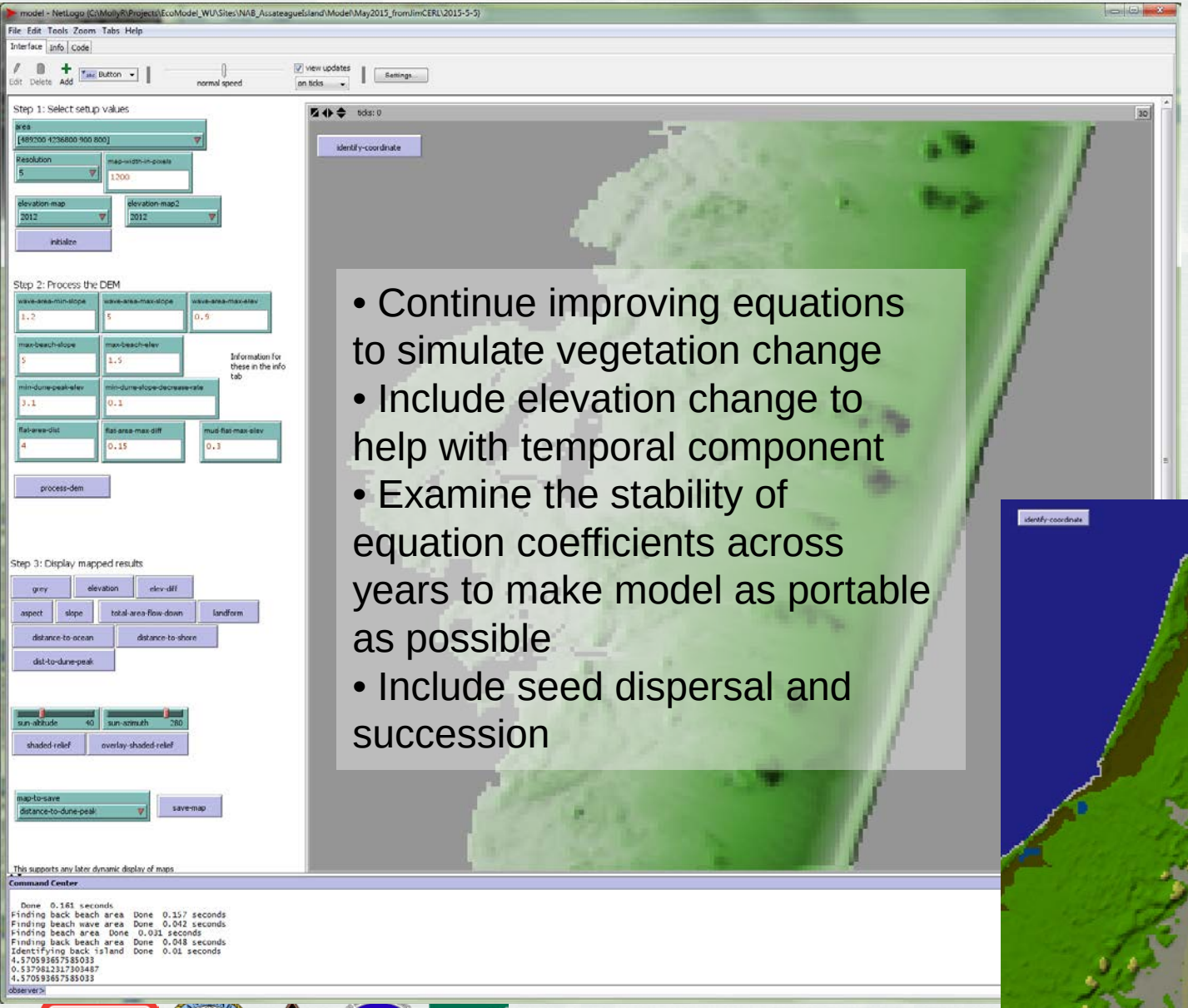
Probability Sparse



Probability Woody

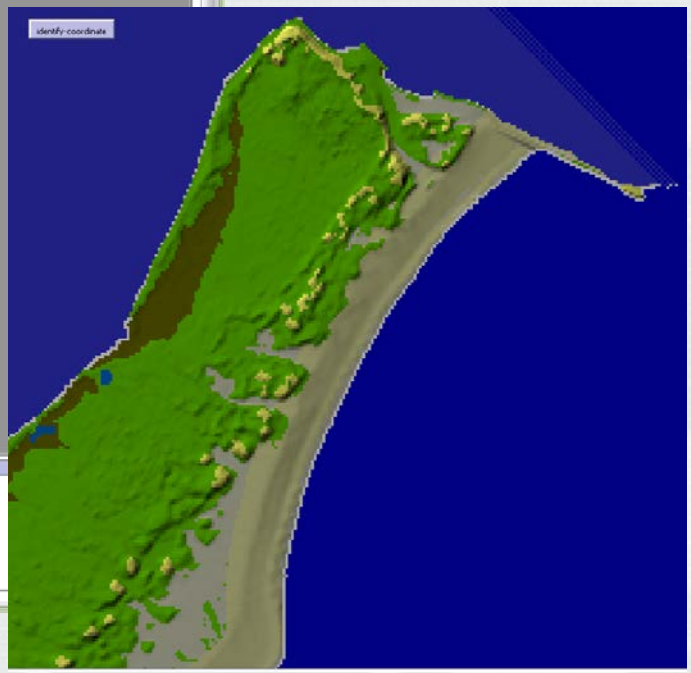


Model Development



- Continue improving equations to simulate vegetation change
- Include elevation change to help with temporal component
- Examine the stability of equation coefficients across years to make model as portable as possible
- Include seed dispersal and succession

Using the results from the statistical analysis, develop a Monte Carlo based probabilistic approach that simulates changes in the distribution of the vegetative communities



Project Value

- **Operations**: evaluate potential impacts of operational activities to get more environmental benefit (Engineering with Nature, etc)
- **Planning**: evaluate alternative scenarios as they relate to vegetation changes and describe benefits/impacts outside of habitat unit creation (i.e. how do changes tie back to ecological processes?)
- **R&D**: evaluate landscapes for better understanding of ecological impacts

Water Quality Monitoring: Harmful Algal Bloom Detection

- Support the Great Lakes & Ohio River Division's water quality monitoring program
  - ✓ Assess hyperspectral and other imagery to identify water quality indicators of Harmful Algal Blooms (i.e. toxic algae)
  - ✓ Limited resources for monitoring hundreds of USACE lakes/reservoirs
  - ✓ RS tools to help prioritize field-based monitoring and provide early warning system
- Approach:

1. Coordinated CASI hyperspectral flights and field sampling:
   - Taylorsville Lake, KY: June 18 2014
   - Harsha (East Fork) Lake OH: June 27 2014
2. Work with the UC and NOAA to develop/refine algorithms to estimate HAB indicators such as chlorophyll (Bloom Index, Cyanobacterial Bloom Index, Maximum Chlorophyll Index, etc)

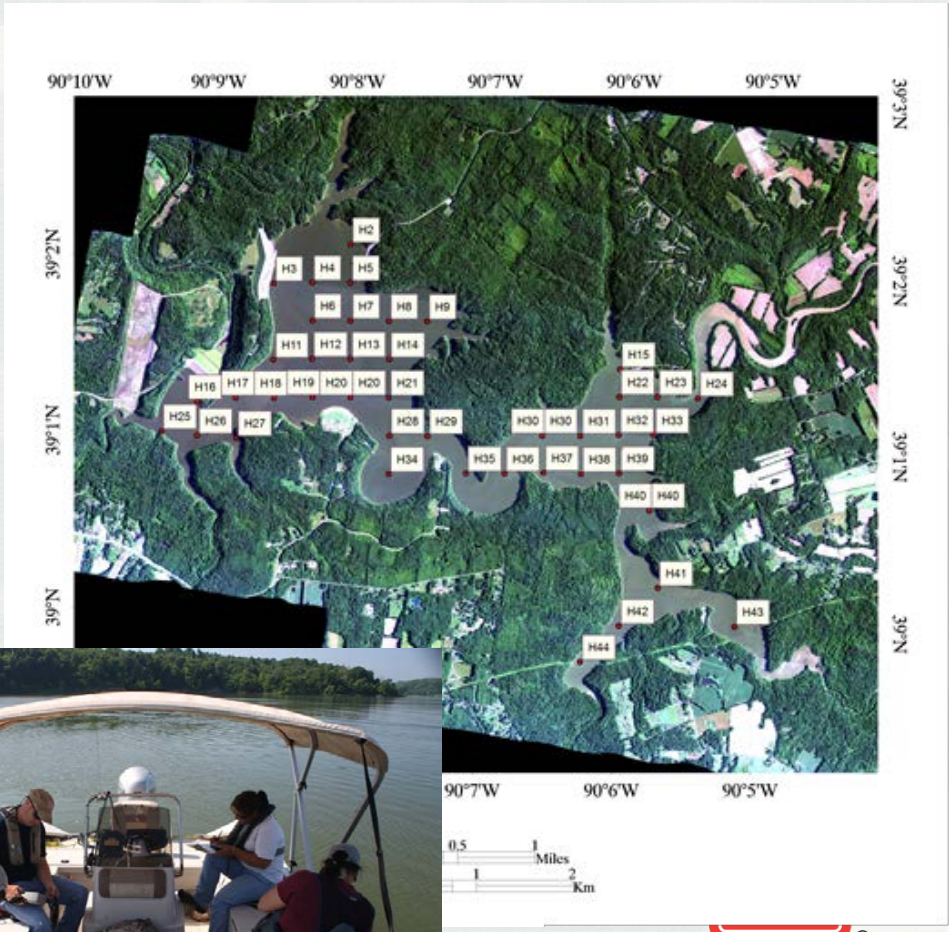
Methods

- Many partners for coordinated airborne and field surveys:

  Great Lakes & Ohio River Division, the Louisville District, the Huntington District, The University of Cincinnati, USEPA, the Kentucky Division of Water, the ERDC Environmental Laboratory, and JALBTCX

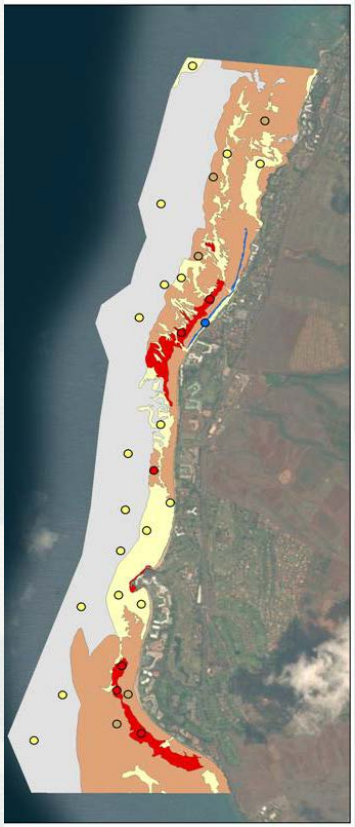
- **Field Samples:**

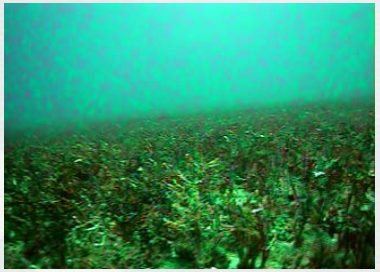
1. Water samples for lab analysis by USEPA
2. ASD spectra to evaluate atmospheric correction of CASI imagery
3. In situ sensor measurements of Chl-a indicator, Phycocyanin indicator, Turbidity, Specific Conductance, pH, water temperature, and dissolved oxygen
4. Secchi Depth measurements
5. GPS location

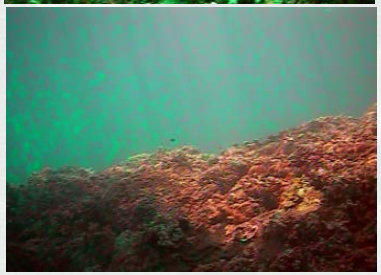


Benthic Classification

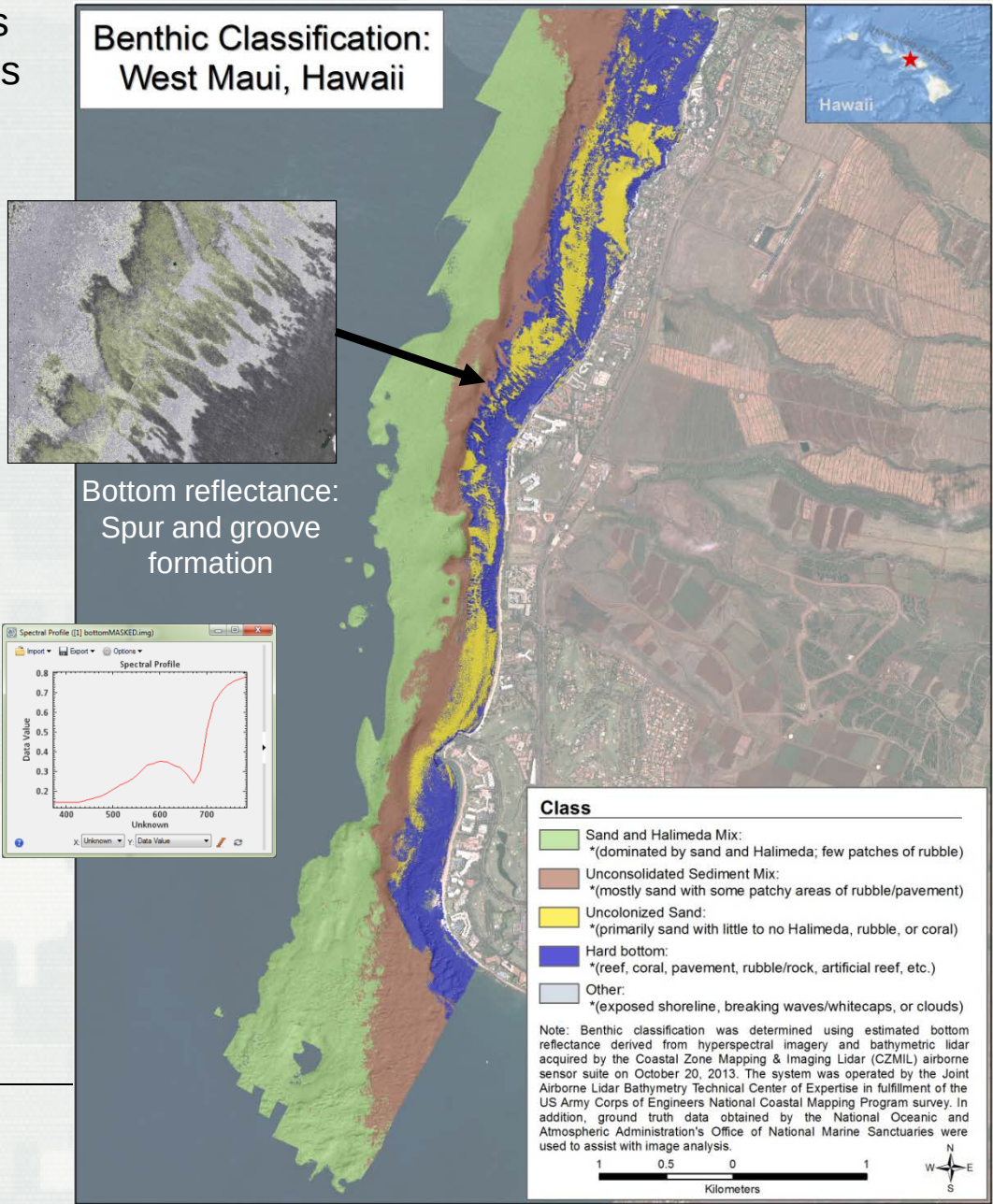
- Develop enhanced seafloor data products to assist with identification of hard bottoms (e.g. corals) and sand fields in support of RSM and dredge material management



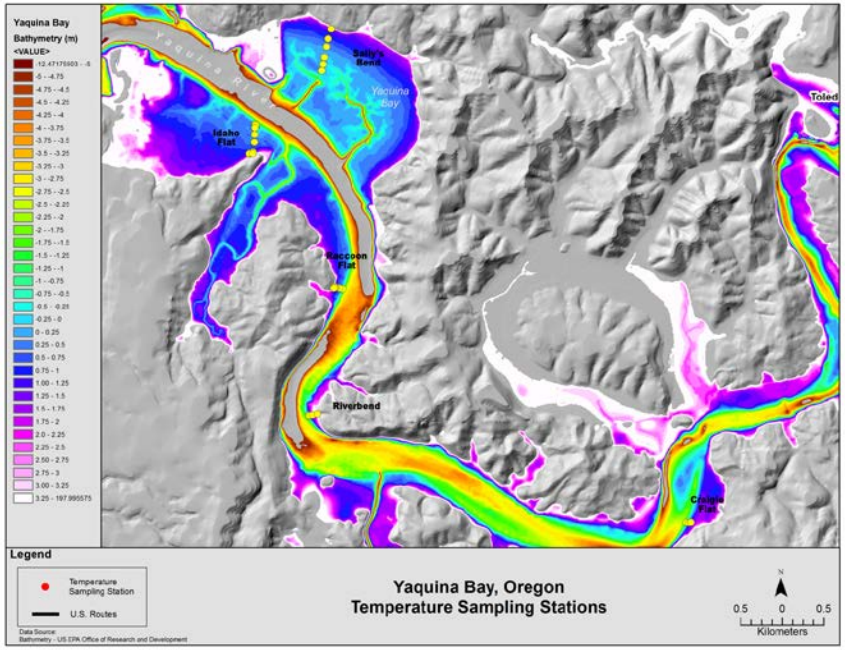




NOAA field sites and drop camera photos

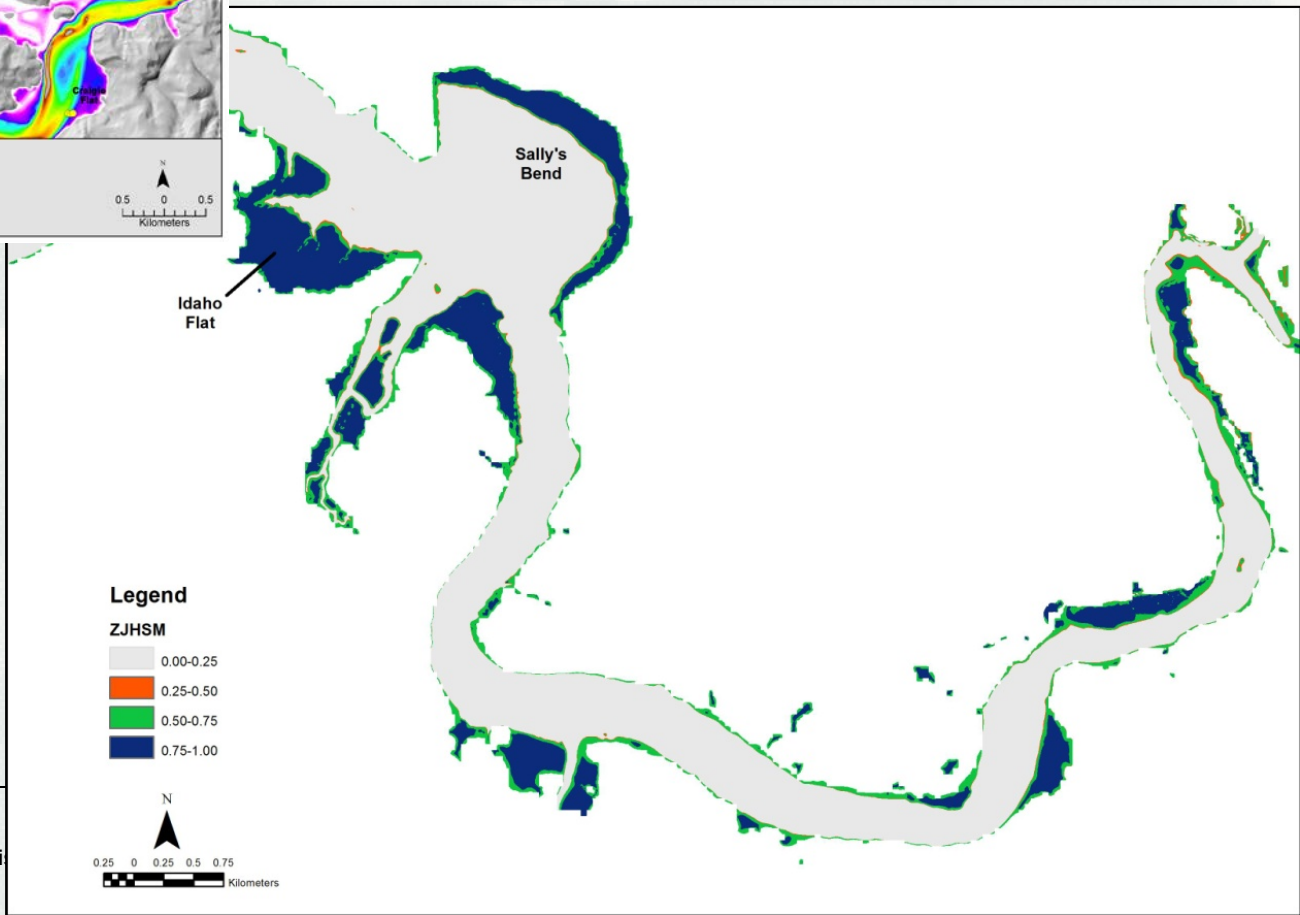


SAV Mapping & Modeling



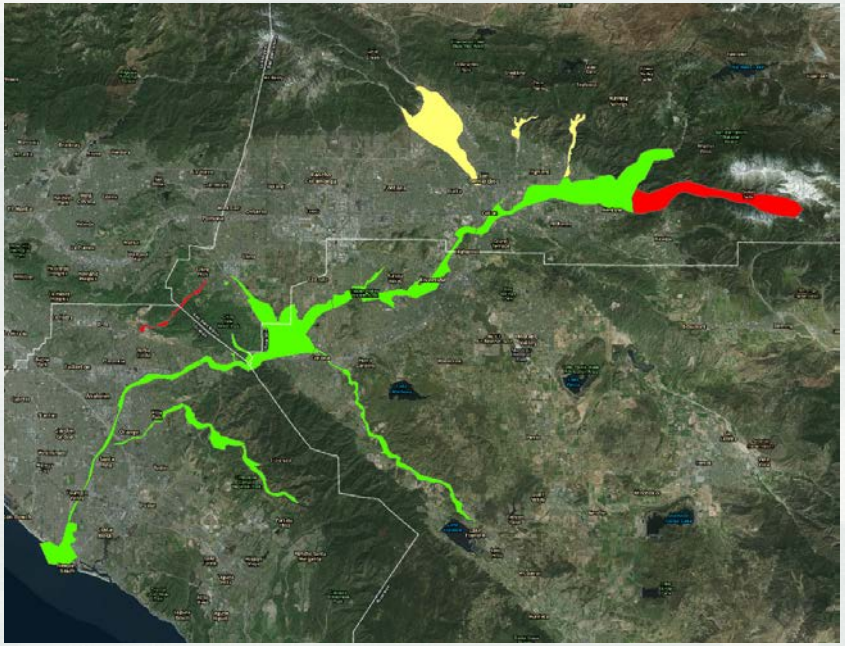
- Spatially-explicit, flexible 3-parameter habitat suitability model can be used to identify and predict areas at higher risk for non-native dwarf eelgrass (*Z. japonica*) species colonization

- Model uses environmental parameters (depth, nearshore slope, and salinity) to quantitatively describe habitat suitability



Mapping Invasive Giant Reed

- Support the LA District's Santa Ana River Main Stem Project, a flood risk reduction project, through species-level mapping using high resolution imagery and lidar
  - ✓ Detailed and updated maps of Giant Reed (*Arundo donax*) will allow for more efficient and effective ways to identify new mitigation areas as well and monitor progress of existing mitigation areas
  - ✓ Fusing high spatial and spectral resolution imagery and lidar will allow for more accurate identification especially in cases where the high chlorophyll content of Giant Reed can result in spectral confusion with other species



Santa Ana River, CA: survey priorities

Photo courtesy of the Center for Invasive Species Research

Demonstration of a Sea Turtle Nesting Habitat Model Using Remotely Sensed Data

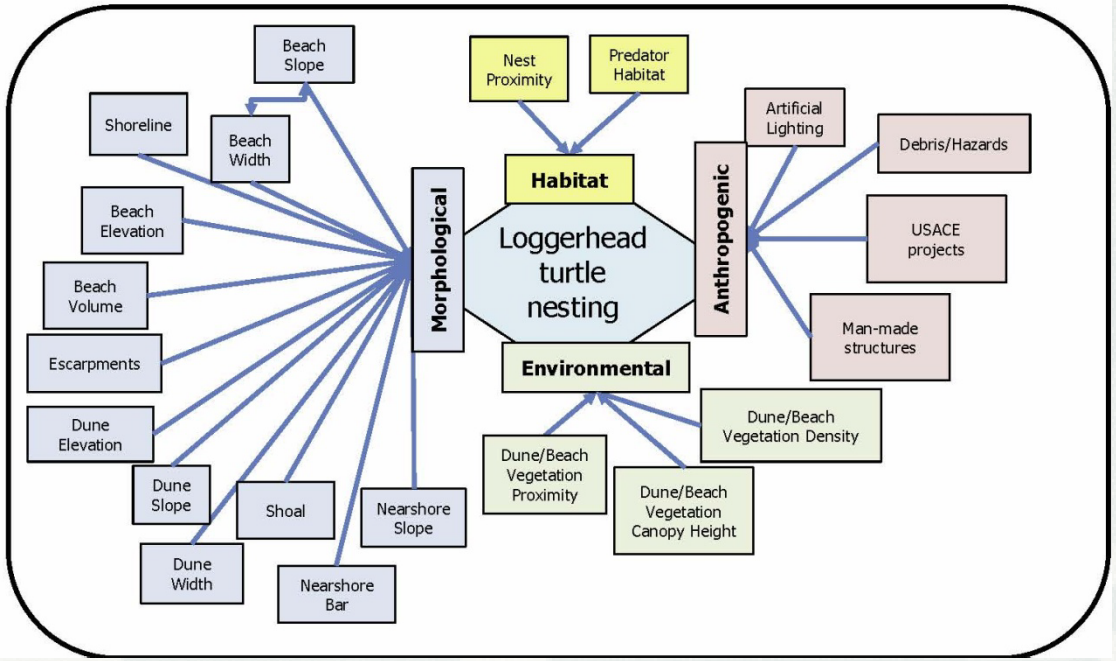
- 700 miles of coastline designated as critical nesting habitat (CH) for loggerhead sea turtle (*Caretta caretta*) conservation

- The nesting habitat suitability model will:
  - provide an information tool to better evaluate management strategies
  - provide decision-support for USACE operations/planning activities

http://www.fws.gov/northflorida/SeaTurtles/2014_Loggerhead_CH/Terrestrial_critical_habitat_loggerhead.html

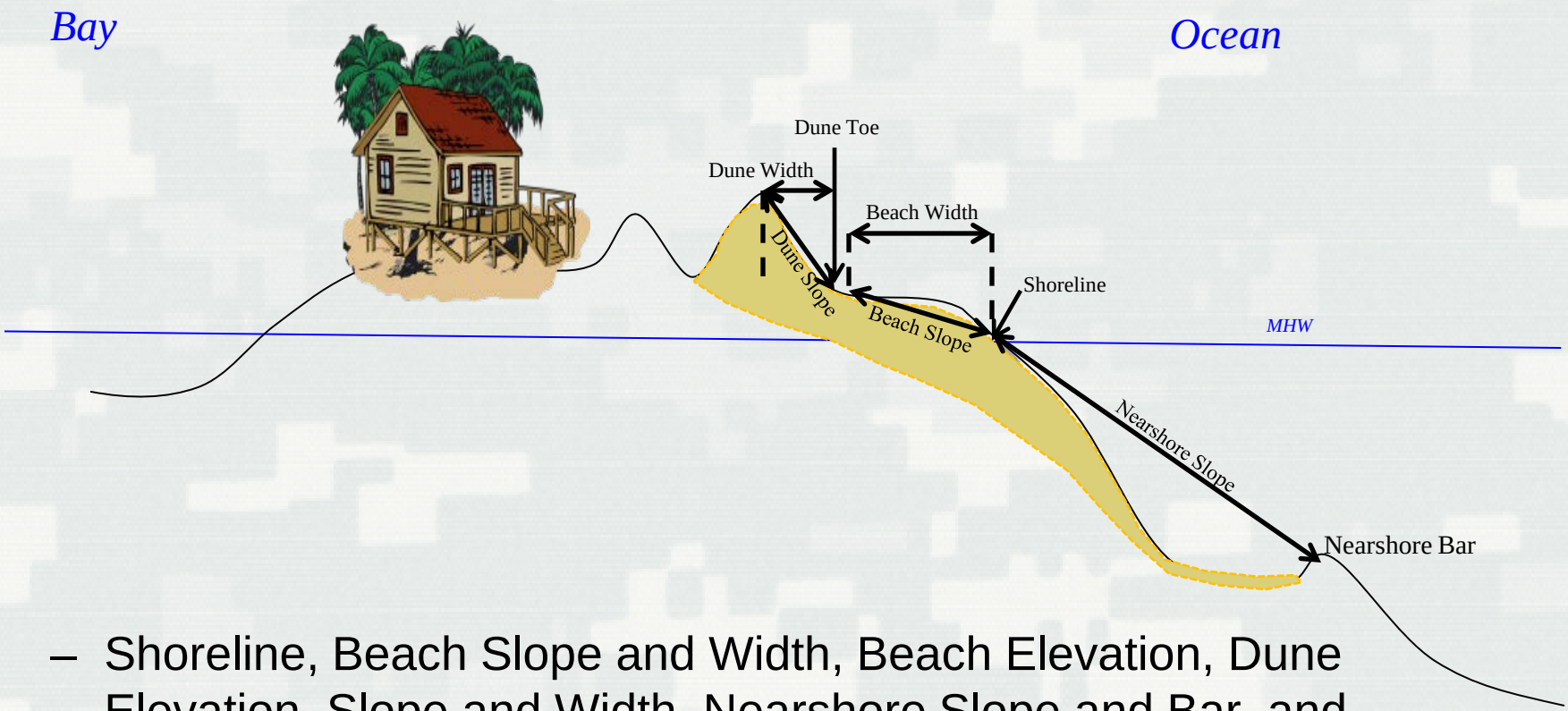
GOAL: **Demonstrate relative suitability of selected sites within the CH zone for C. caretta by developing a spatially-explicit ecological model**

Spatial Parameter Identification



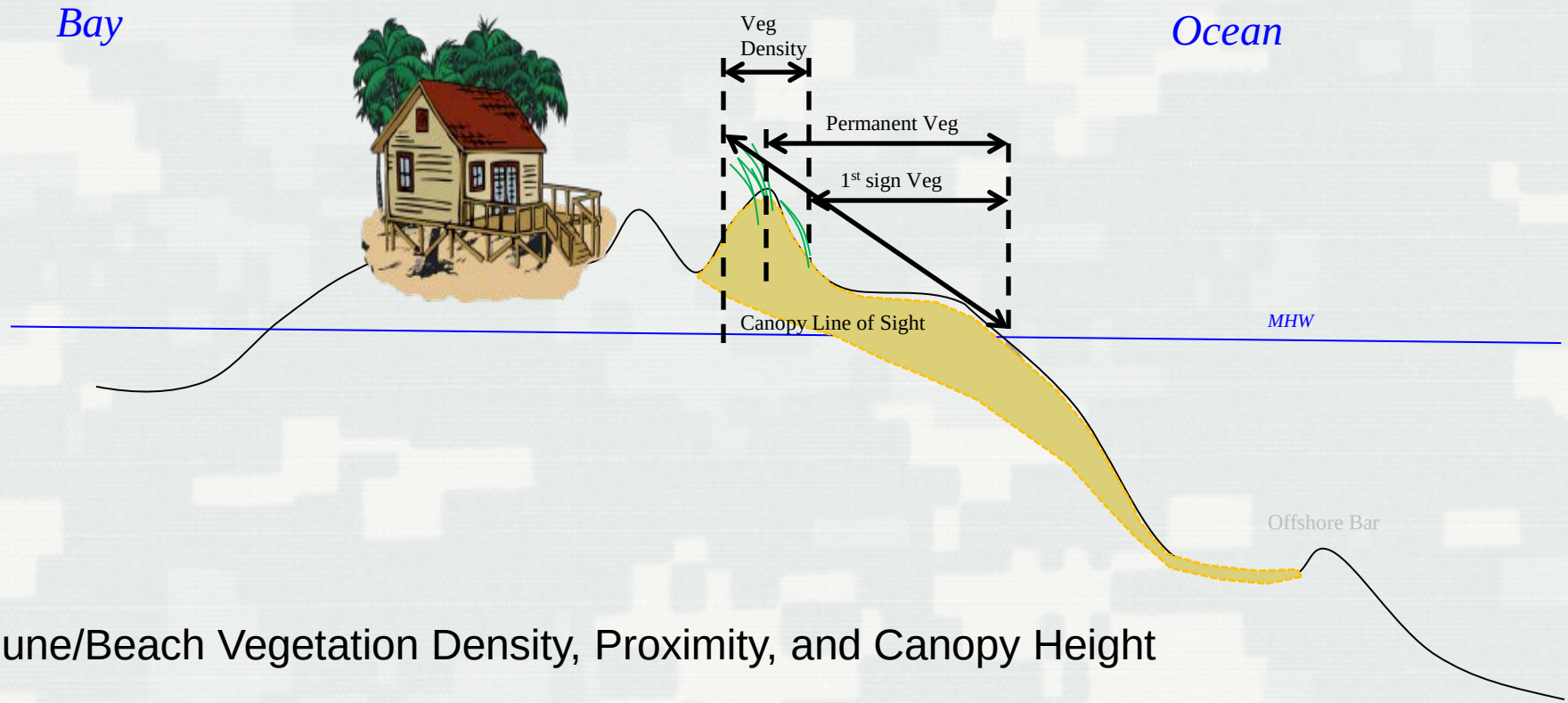
- Mappable/spatial parameters identified through literature review
  - Morphological
  - Environmental
  - Anthropogenic
  - Habitat
- Parameter list refined based on feedback from subject matter experts
  - important for nesting habitat
  - correlates with the resolution of the spatial datasets

Morphological Parameters



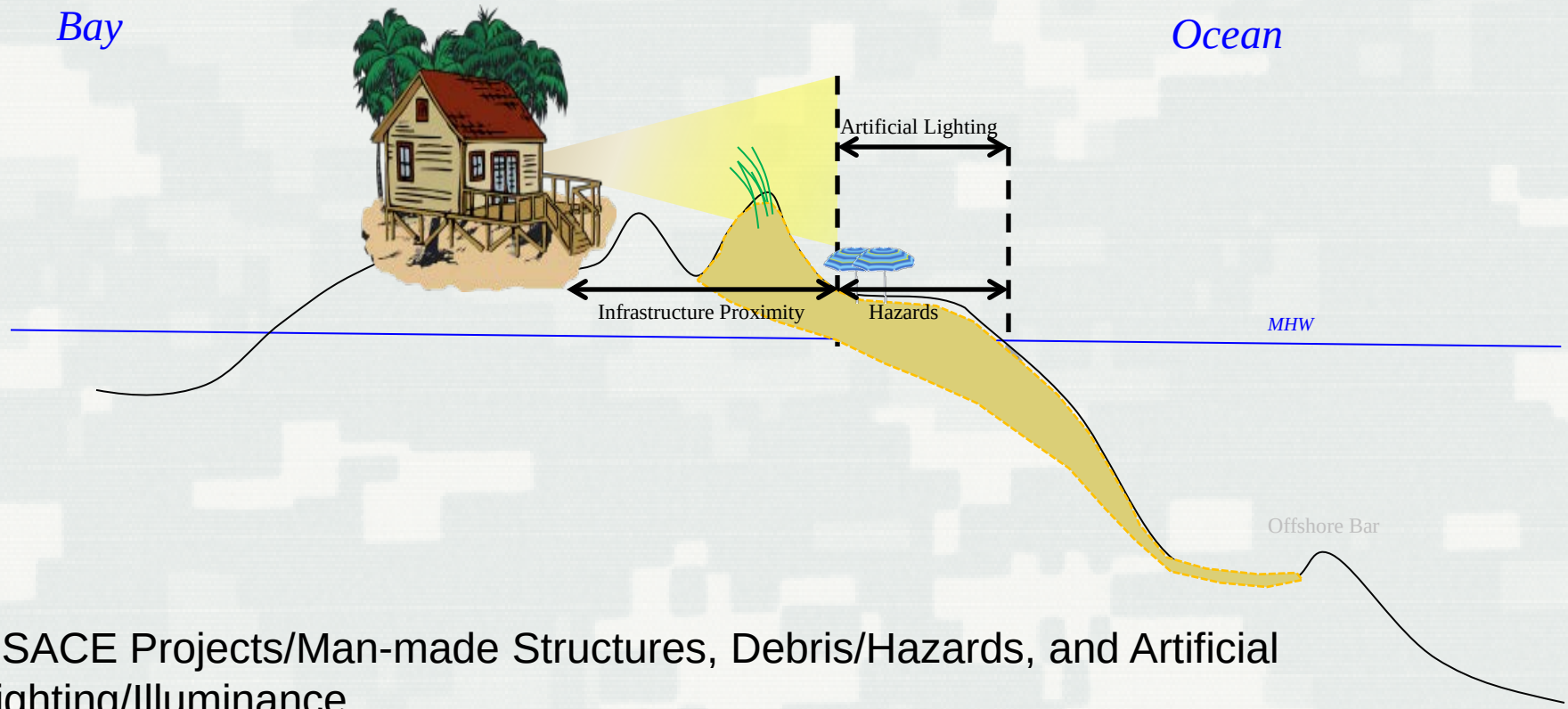
– Shoreline, Beach Slope and Width, Beach Elevation, Dune Elevation, Slope and Width, Nearshore Slope and Bar, and Shoal

Environmental Parameters



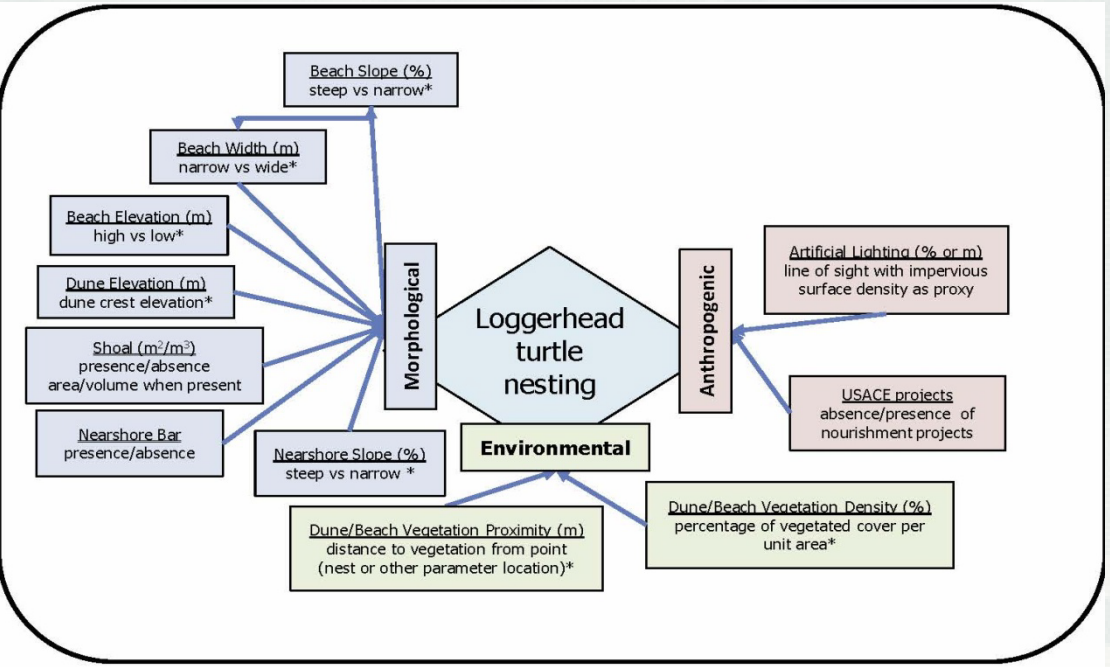
Dune/Beach Vegetation Density, Proximity, and Canopy Height

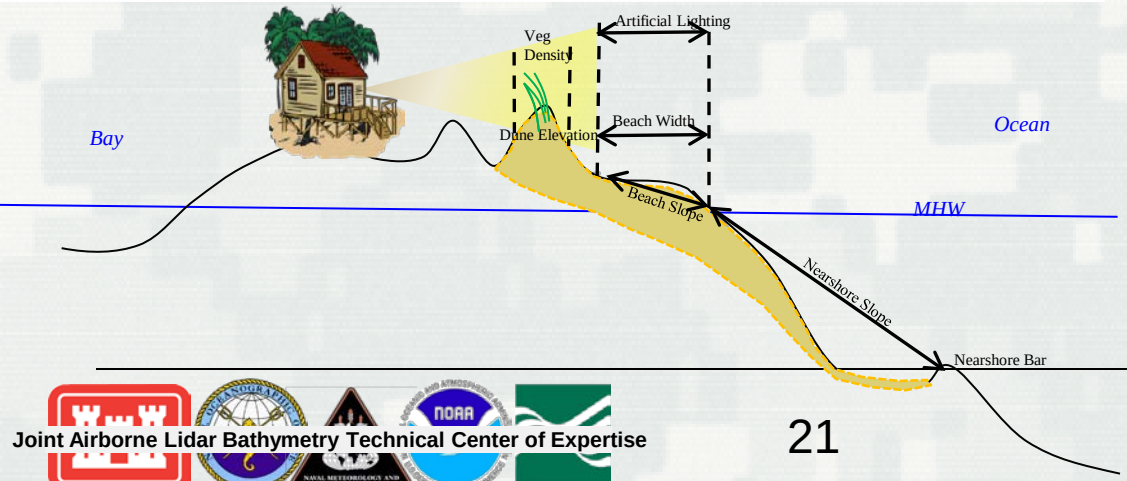
Anthropogenic Parameters



USACE Projects/Man-made Structures, Debris/Hazards, and Artificial Lighting/Illuminance

Spatial Parameter Identification

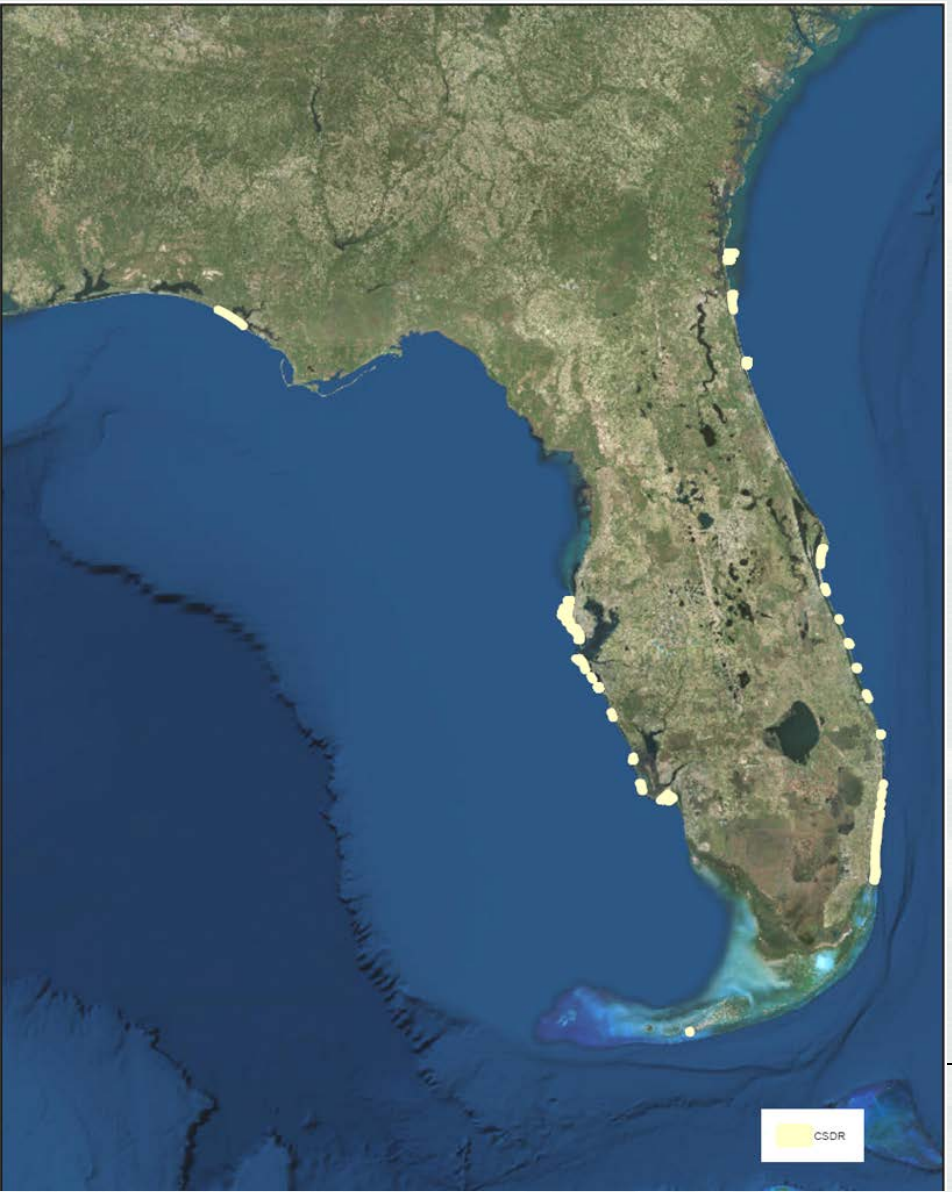




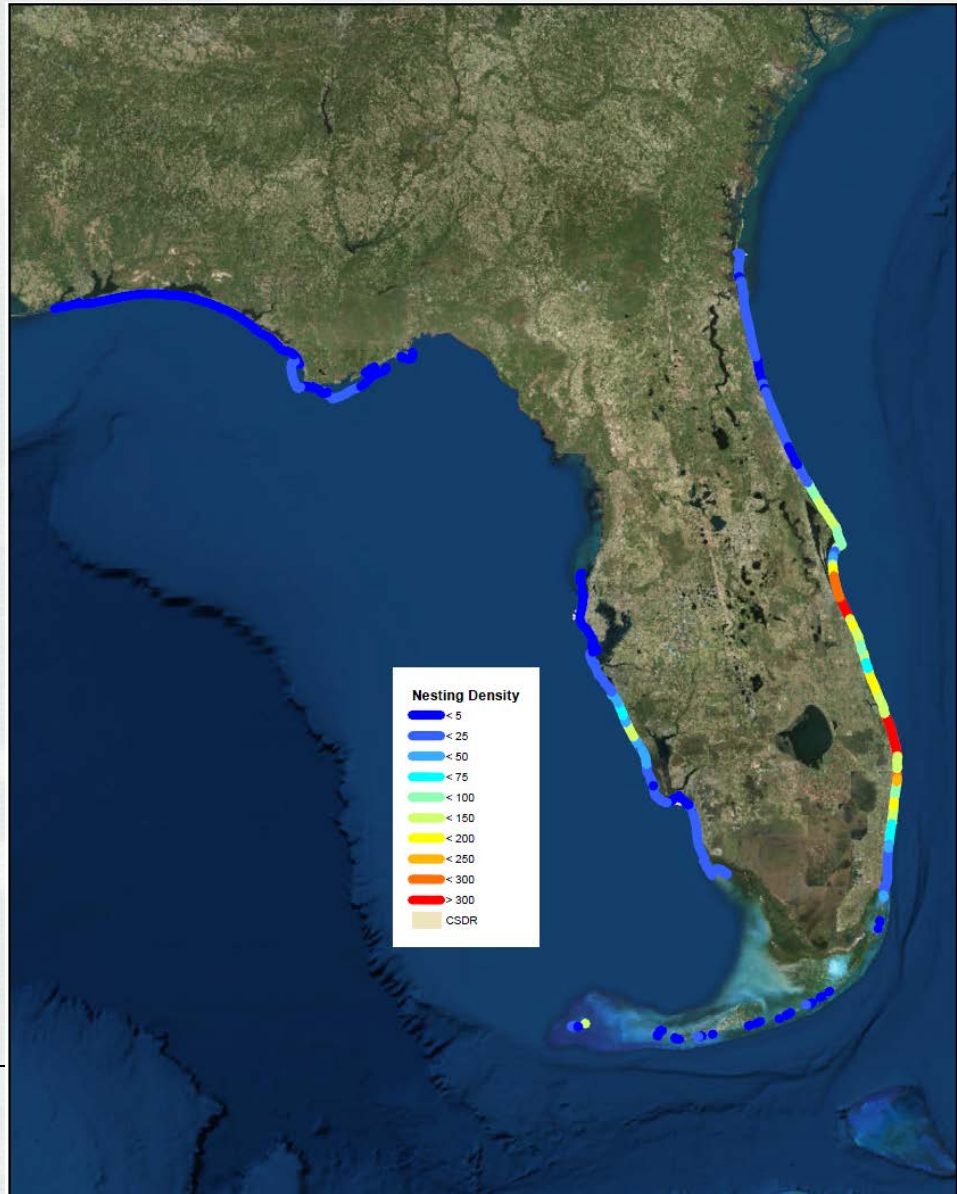
- Value ranges are relative functions based on regional data values
- Regional data values more advantageous to the proposed decision support tool than specific numerical value ranges that are site specific
- The process/methods for the model will be transferable to other sites

Case Study: Southeast FL

Coastal Storm Damage Risk Reduction Projects

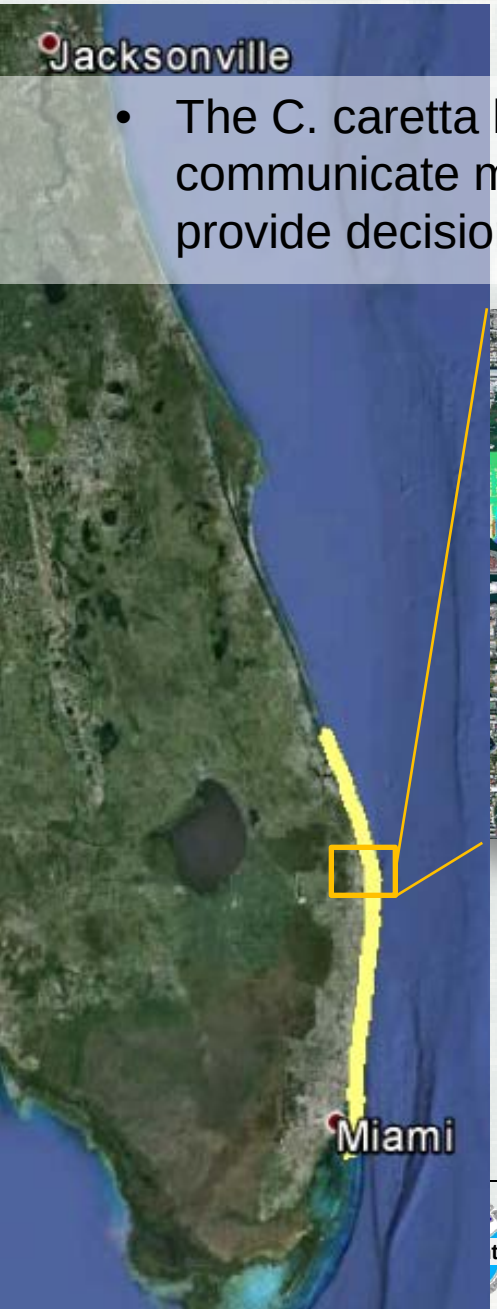


Turtle Nesting Density



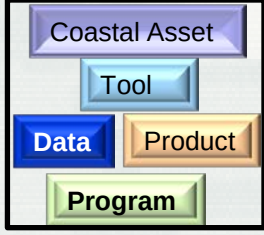
Project Value

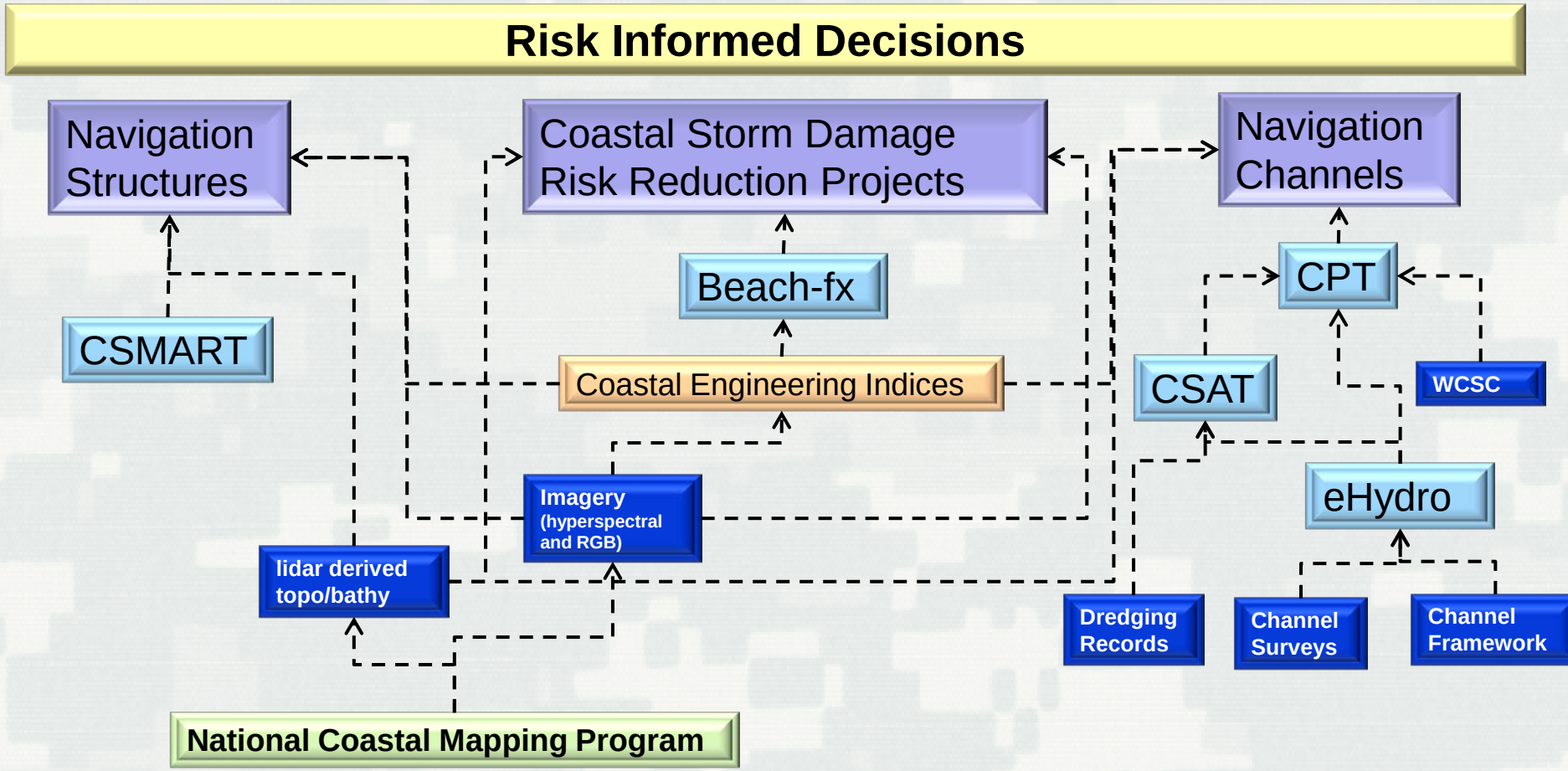
- The C. caretta habitat suitability model will provide an information tool to better communicate management priorities, evaluate management strategies, and provide decision-support for USACE operations/planning activities.



- Map of relative suitability based on spatially derived parameters
  - Regional value ranges (transferable to other sites)

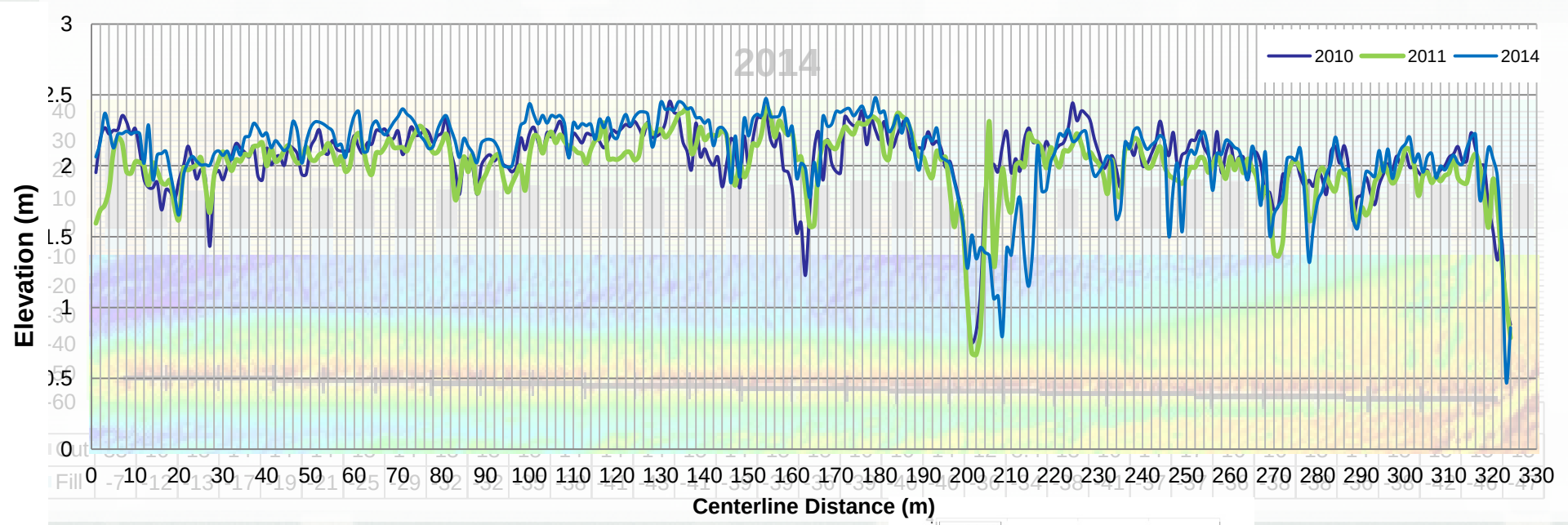
Coastal Systems Asset Management

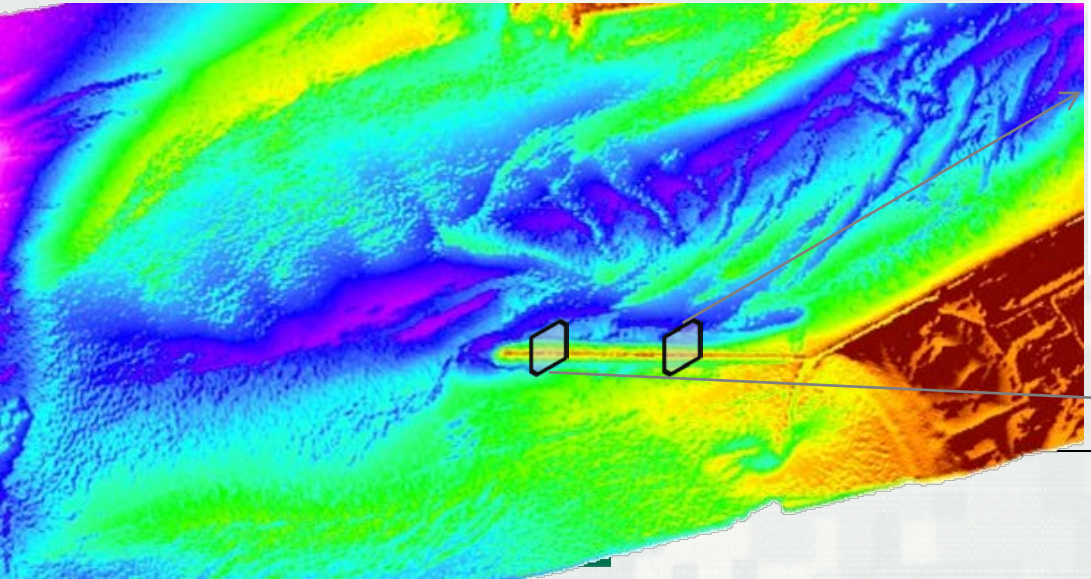


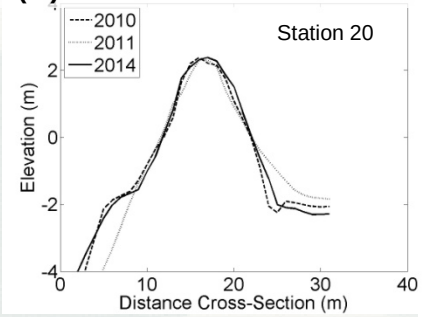


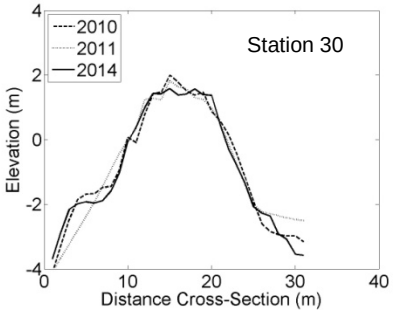
- Spatial and economic datasets provide input for tools and are used to generate value added products to support coastal systems asset management.

Navigation Structures





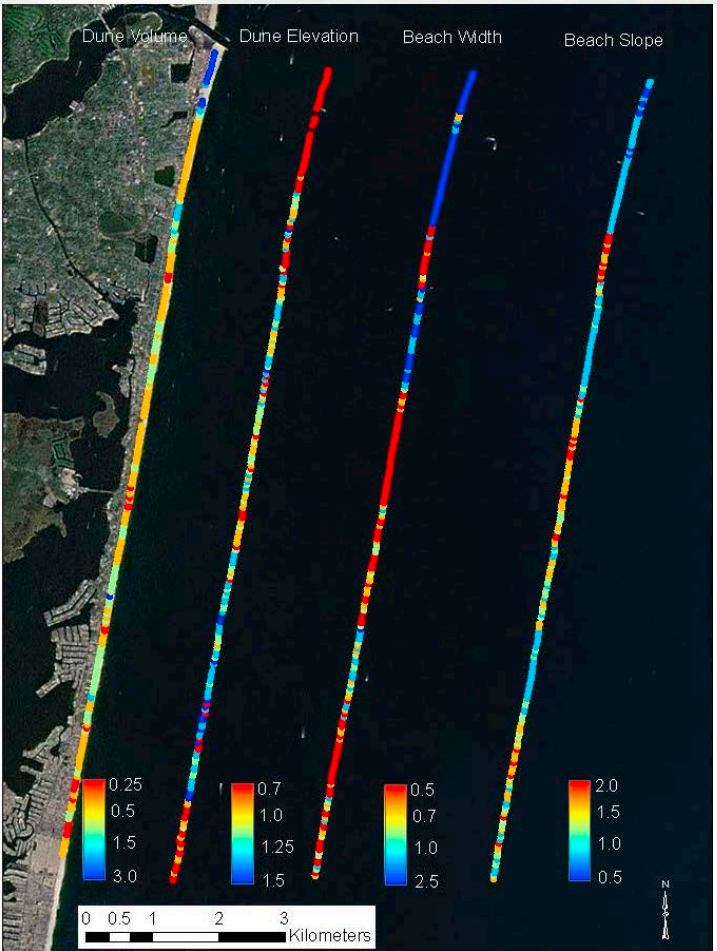


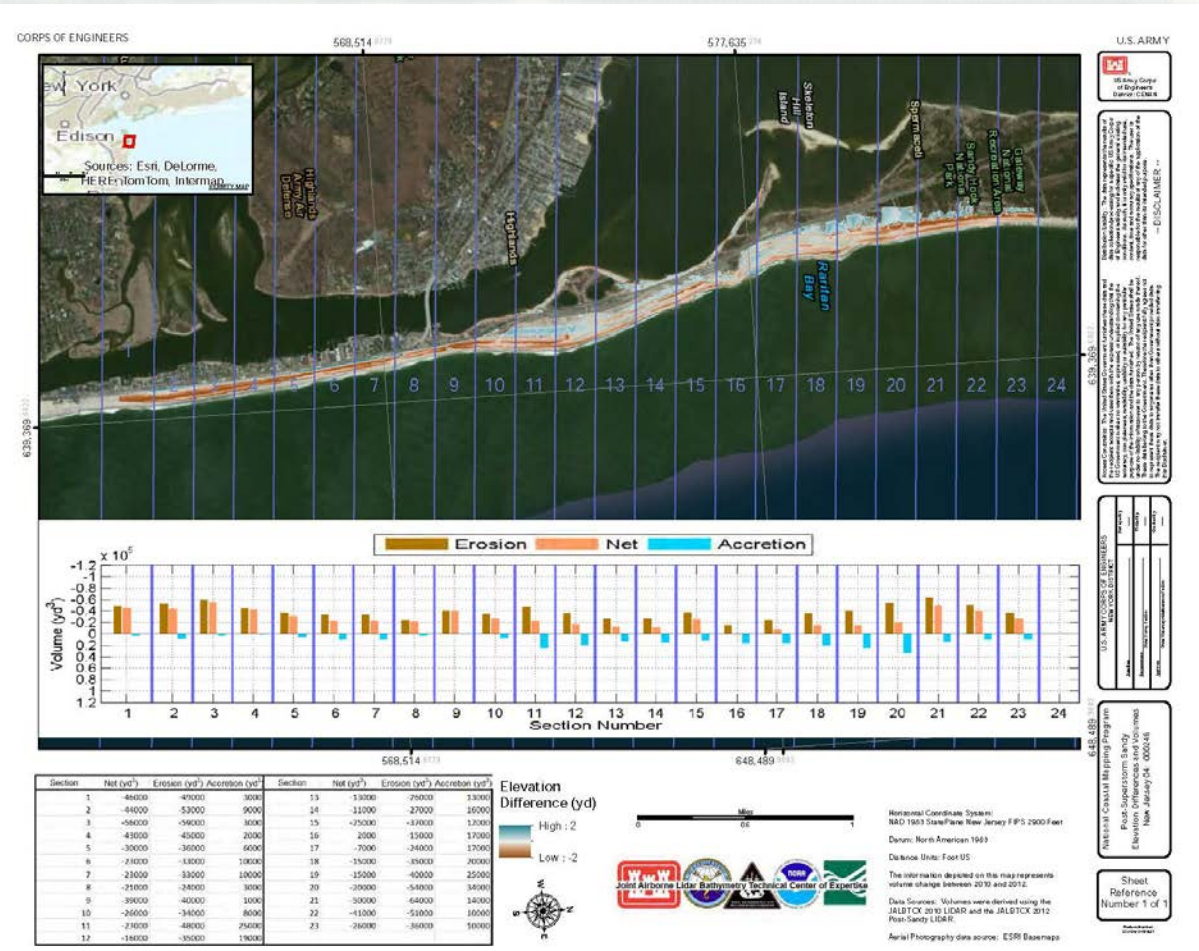


Coastal Storm Damage Risk Reduction

JALBTCX.tbx
ArcGIS Toolbox

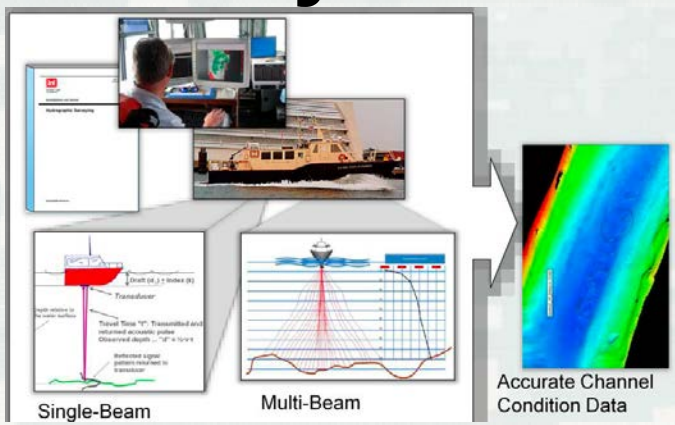
- Profile parameters provide input into Beach-fx (B/C ratio)
- Volume/elevation/shoreline change





eHydro: Enterprise Hydrosurvey Processing

- Accessing channel condition
- Geo-process hydrosurveys using automated GIS scripts
- Reports/Products generated
  - Channel Condition Report (CCR)
  - Channel Condition Index (CCI)
  - Channel Availability Reports
  - Condition plots
- Coastal districts using eHydro
  - National Channel Framework
  - Uploading surveys



REPORT OF CHANNEL CONDITIONS — Page 1 of 4
400 FEET WIDE OR GREATER — Date 3/3/2015

To: Navigation Interests

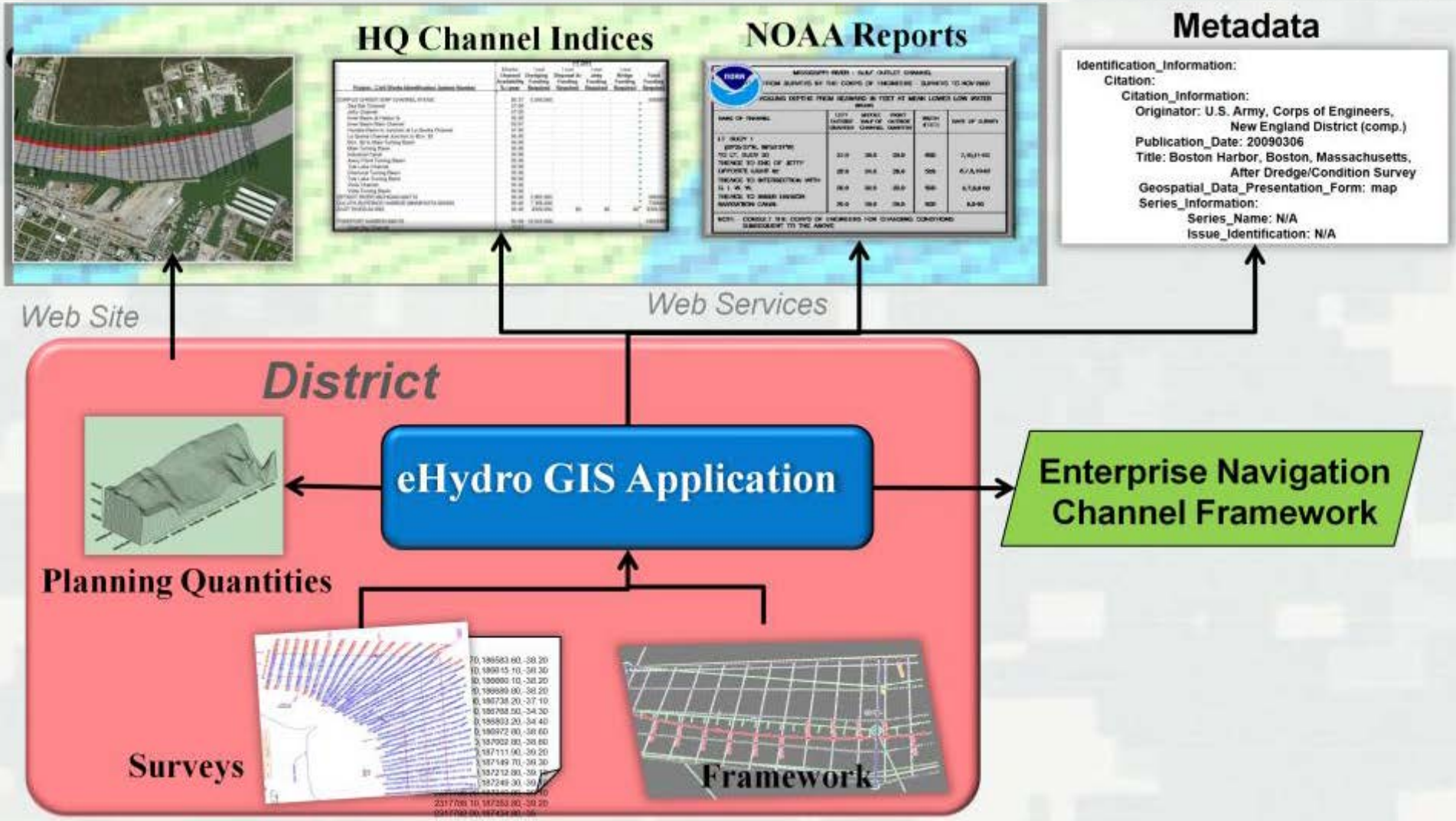
From: US Army Engineer District, Portland
333 SW First Avenue
Portland, OR 97204-3495

RIVER/HARBOR NAME AND STATE
COLUMBIA RIVER
OREGON & WASHINGTON

MINIMUM DEPTHS IN EACH 1/4 WIDTH OF CHANNEL ENTERING FROM SEAWARD

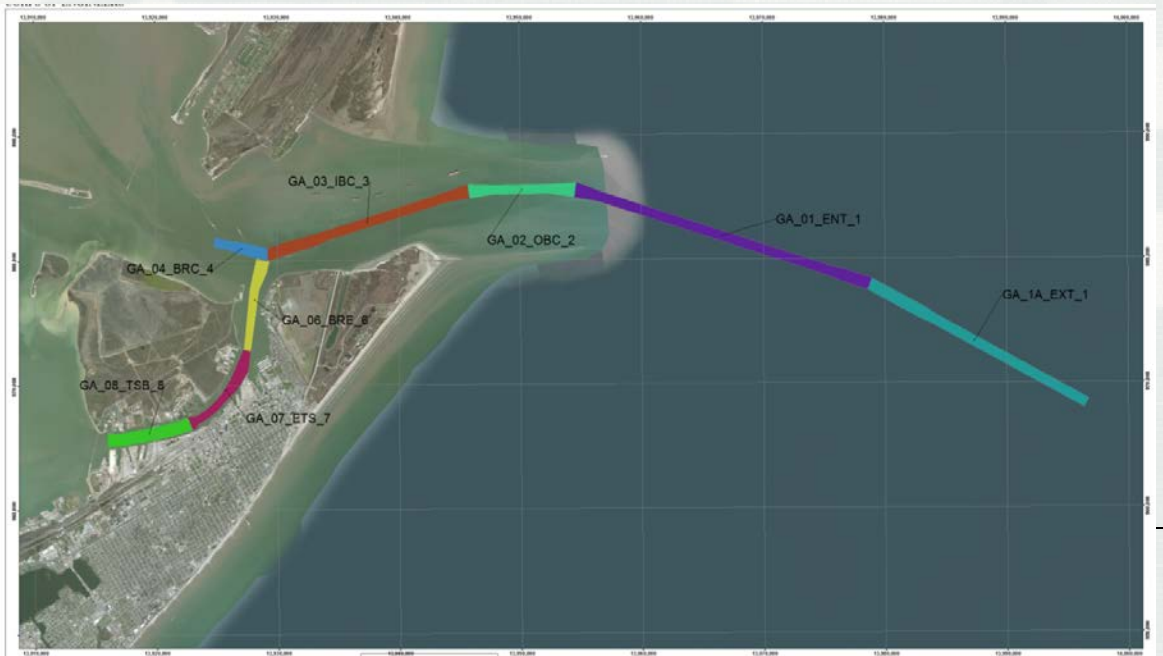
NAME OF CHANNEL	DATE OF SURVEY	AUTHORIZED PROJECT WIDTH (feet)	AUTHORIZED PROJECT LENGTH (miles)	AUTHORIZED PROJECT DEPTH (feet)	LEFT OUTSIDE QUARTER (feet)	LEFT INSIDE QUARTER (feet)	RIGHT INSIDE QUARTER (feet)	RIGHT OUTSIDE QUARTER (feet)
MOUTH OF COLUMBIA RIVER Entrance Range	11-07-2014	2000	3.30	55	51	51	52	
MOUTH OF COLUMBIA RIVER Entrance Range	11-07-2014	640	3.30	48				41
MOUTH OF COLUMBIA RIVER Sand Island Range	11-07-2014	2000	2.20	55	50	52	53	
MOUTH OF COLUMBIA RIVER Sand Island Range	11-07-2014	640	2.20	48				42
LOWER DESDEMONA SHOAL Lower Desdemona Shoal	02-18-2015	600	3.40	43	46	47	49	50
UPPER DESDEMONA SHOAL Upper Desdemona Shoal	01-22-2015	600	3.60	43	42	44	43	41

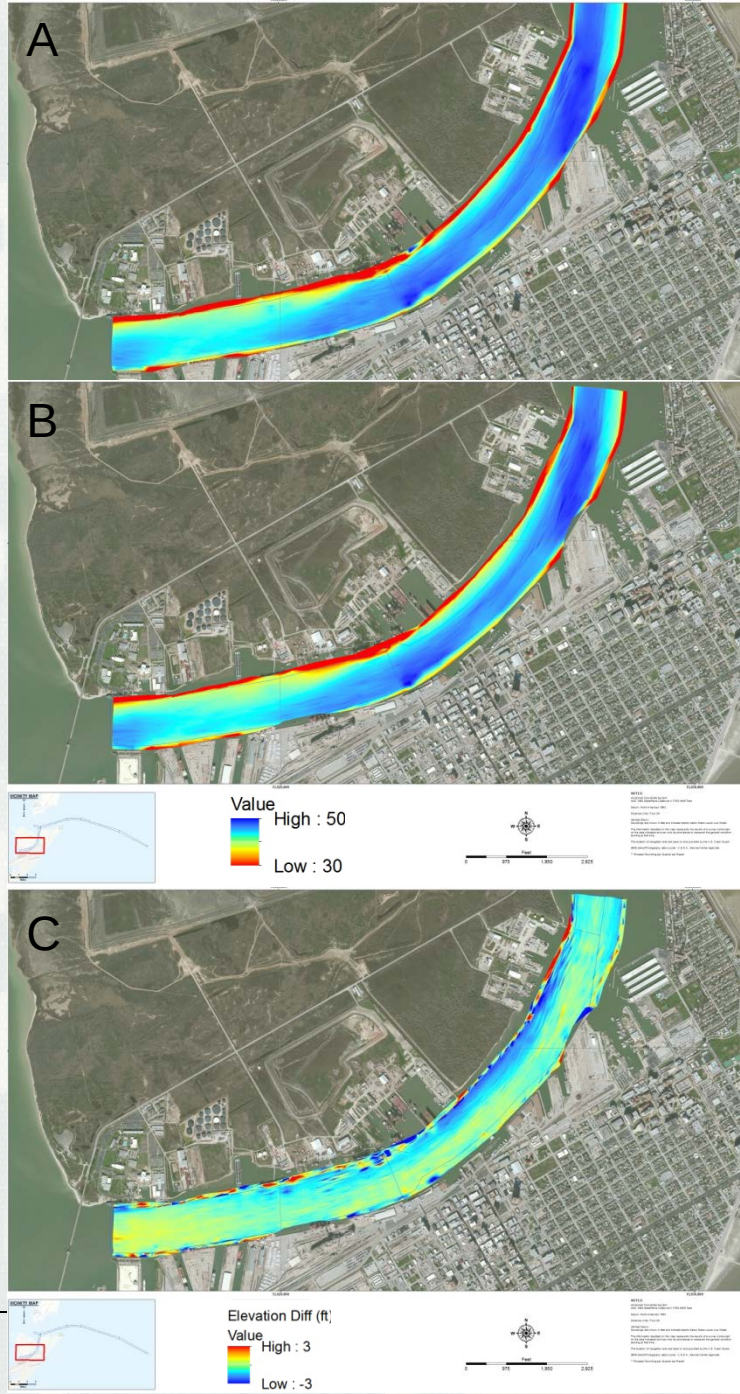
eHydro: Application and Reporting Process



Corps Shoaling Analysis Tool

- Use all available survey data from eHydro to find shoaling rates and dredging requirements per channel reach
- Volumes at different depth/time intervals and shoaling rates





Shoaling Rate

Joint Airb

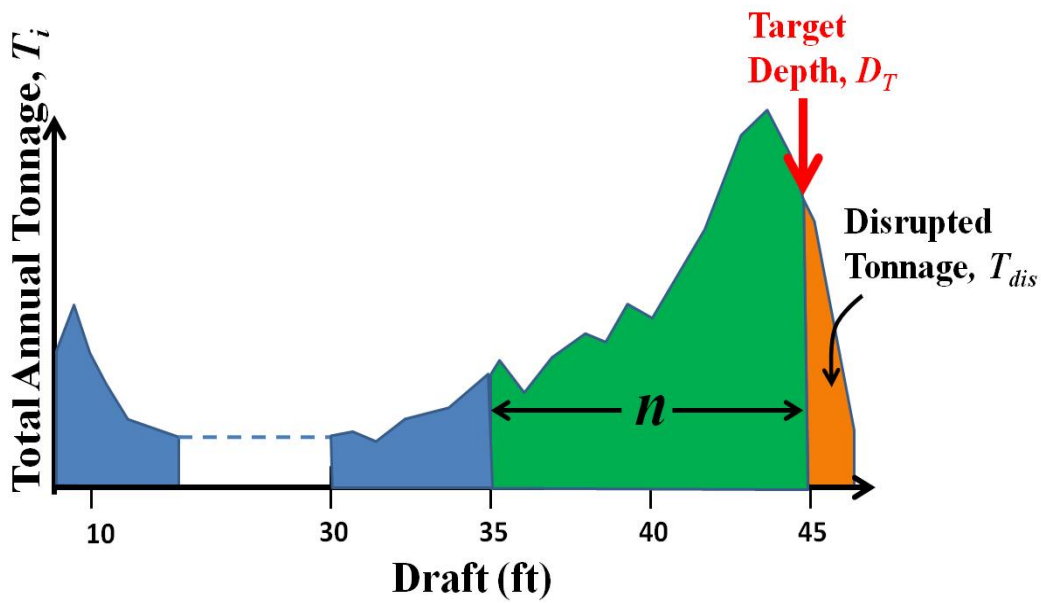
Volume Tables

Shoaling rate w/ last survey

Dredge Cut (ft)	Now (CY)	6 months (CY)	12 months (CY)	18 months (CY)	24 months (CY)	30 months (CY)	36 months (CY)
-45	195,320	271,020	373,070	492,200	624,890	771,020	931,220
-44	125,140	173,140	238,620	331,710	444,910	572,680	713,450
-43	76,249	109,860	153,260	210,570	293,080	399,730	522,310
-42	43,628	65,655	95,990	135,350	186,480	258,070	356,920
-41	24,409	37,093	56,313	83,402	119,100	165,270	227,370
-40	14,958	21,022	31,470	48,147	72,041	104,370	146,170
-39	10,060	13,343	18,250	26,832	41,017	61,922	91,020
-38	7,083	9,092	11,945	16,084	23,035	34,823	53,059
-37	5,194	6,480	8,241	10,728	14,312	19,888	29,576
-36	3,865	4,787	5,944	7,496	9,673	12,784	17,358
-35	2,806	3,555	4,412	5,465	6,843	8,751	11,457

Depth Utilization Data

Via Waterborne Commerce data, CPT can generate depth-utilization profiles showing the distribution of cargo across the range of maintained depths for any system of navigation channels.



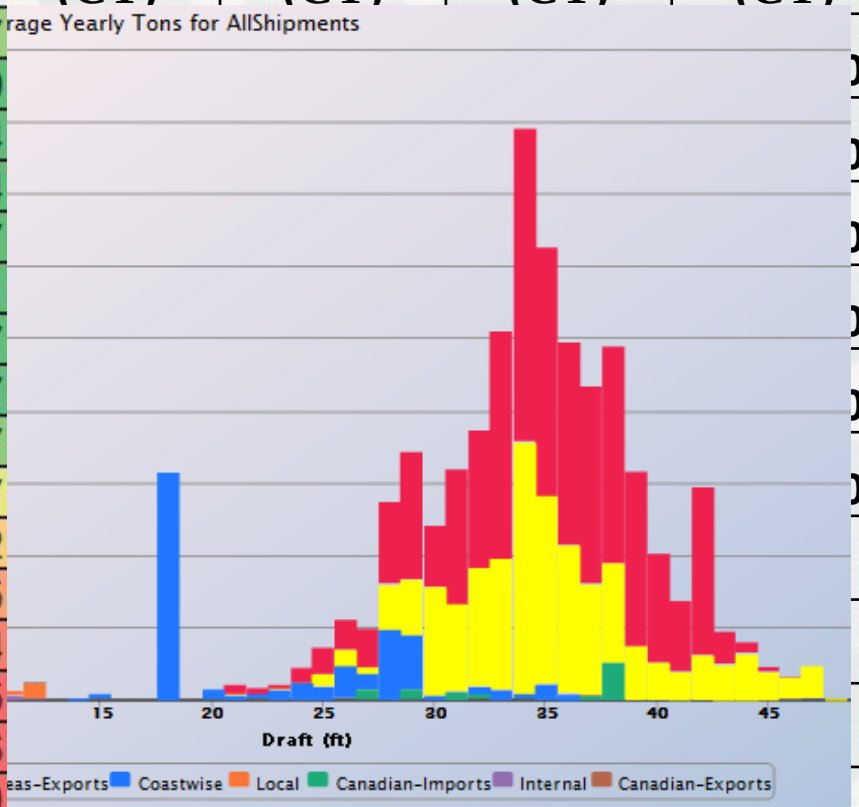
Proxy Benefit to Cost Ratio equation:

$$BCR_{D_T,k} = \frac{\left(1+\frac{k}{2}\right)\left[\left(\sum_{i=(D_T-n)}^{D_T} T_i\right)-T_{dis}\right]}{C_{MB}+C_{CY}V_{D_T,k}}$$

Depth-utilization profile showing various approaches to tallying supported waterborne cargo.

Dredging Work Package Formulation

Target Elev, ft (MLLW)	Years between Dredging Events: 1	1.5	2	2.5	3	3.5	4	18 months (CY)	24 months (CY)	30 months (CY)	36 months (CY)
45	16.16	21.71	25.15	27.35	29.03	30.70	33.17				
44	16.46	22.52	26.36	28.78	30.64	32.47	35.19				
43	16.71	23.30	27.58	30.27	32.32	34.34	37.34				
42	15.94	22.60	27.11	29.91	32.00	34.03	37.04				
41	15.75	22.73	27.65	30.68	32.92	35.04	38.17				
40	15.19	22.14	27.33	30.56	32.89	35.07	38.21				
39	14.48	21.32	26.71	30.12	32.52	34.73	37.87				
38	13.14	19.42	24.65	28.12	30.47	32.60	35.57				
37	11.96	17.76	22.82	26.35	28.68	30.74	33.57				
36	10.51	15.64	20.28	23.69	25.96	27.89	30.47				
35	8.92	13.30	17.39	20.57	22.71	24.44	26.72				
34	7.28	10.87	14.28	17.05	19.02	20.54	22.45				
33	5.93	8.86	11.69	14.11	15.89	17.23	18.84				
32	4.88	7.31	9.66	11.75	13.36	14.57	15.95				
31	4.13	6.19	8.20	10.04	11.53	12.65	13.86				
30	3.31	4.97	6.59	8.11	9.39	10.38	11.40				
29	2.47	3.70	4.92	6.08	7.10	7.91	8.71	7,496	9,673	12,784	17,358
28	1.92	2.88	3.83	4.75	5.58	6.27	6.92	5,465	6,843	8,751	11,457

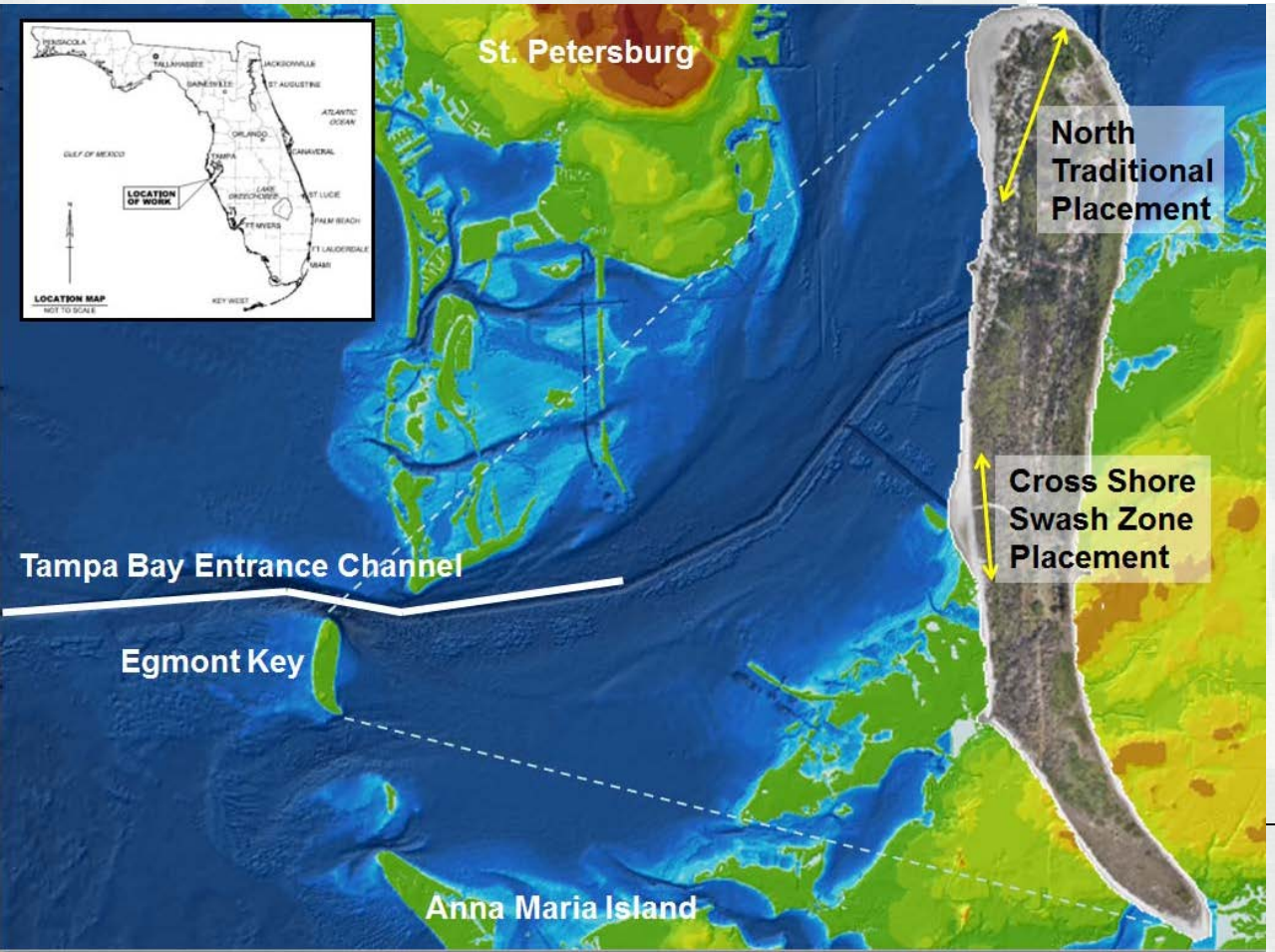


Beach Placement

Two beach placement methods:

1) Traditional Placement
2) Cross Shore Swash Zone Placement
   - Material discharged from dredge directly into swash zone

Traditional (North) Placement Area:		
	Cubic Yards (cy)	% of Total
Dredged in Channel	500,037	100.0%
Pumped to Beach	319,712	63.9%
Surveyed on Beach	222,068	44.4%
Cross Shore Swash Zone Placement Area:		
	Cubic Yards (cy)	% of Total
Dredged in Channel	180,512	100.0%
Pumped to Beach	107,225	59.4%
Surveyed on Beach	68,479	37.9%



Monitoring both placement sites – JALBTCX (bathy/topo), USF (beach profiles)

BUILDING STRONG®

Metrics/Parameters

Elevation
Change
(elevation/volume)
Contour (change)
Shoal

Imagery
Hyperspectral and Multi-
Spectral Imagery

Dune
Elevation (crest/toe)
Continuity
Slope
Volume

Beach
Width
Slope

Land characterization
Impervious surface
Landscape diversity

Questions?

Lauren.M.Dunkin@usace.army.mil
Molly.K.Reif@usace.army.mil

R&D/Value added products/tools

- Change Detection
  - Landscape change modeling
  - Volume/elevation/shoreline change
  - Structure assessment
- Sediment Budgets
- Monitoring Shore Protection
- Defining Coastal Regions

- Coastal Engineering Index
- Coastal Resilience
- Critical Species Detection and Modeling
  - Sea turtle nesting habitat
  - Oysters*
  - Salmonid

* ECO-PCX model certification