WATER INSTITUTE SYMPOSIUM

# Coastal Resilience, Nature-Based Solutions, Ecosystem Conservation and Connectivity

Moderator:

Afsheen Sadaf (Ph.D.)
University of Florida

February 2024

# Program & Presenters

February 2024

| | |
|---|---|
| | **Dr. Afsheen Sadaf** |
| 5 minutes | **Introduction & Overview** |
| 15 MINUTES | **#1 Dr. Jules Bruck** University of Florida<br>Coastal Resilience & Nature Based Solutions- A DEED Project |
| 15 MINUTES | **#2 Dr. Afsheen Sadaf**<br>University of Florida Coastal Resilience through Nature-Based Solutions–A GIS Suitability Analysis Model for Living Shorelines at APG, Maryland |
| 15 MINUTES | **#3 Martha Ryan** University of Delaware<br>Improving the Surface Water Quality of Coastal Basins with Resilient Land Cover Scenarios |
| 15 MINUTES | **#4 Mojtaba Tahmasebi**<br>University of Florida Impacts of Land Use and Land Cover Changes on Soil Organic Carbon in Aberdeen Proving Ground |
| 15 MINUTES | **#5 Y. Peter Sheng** University of Florida<br>Mangroves Provide Significant Flood Protection Service in A Changing Climate |
| 10 MINUTES | **Q&A - Discussion** |

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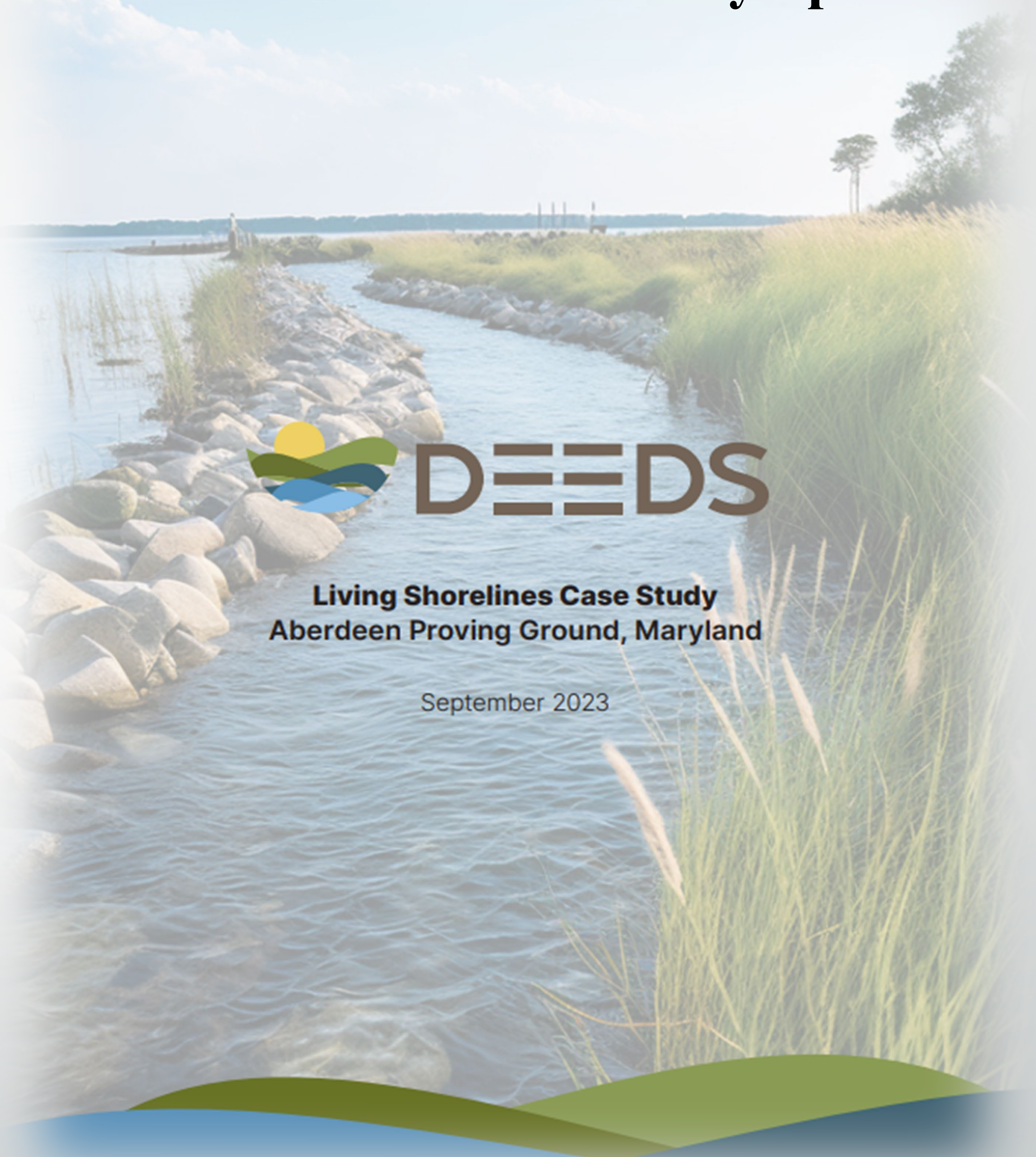
WATER INSTITUTE SYMPOSIUM

2024 UF Water Institute Symposium

# Coastal Resilience through Nature-Based Solutions – A GIS Suitability Analysis Model for Living Shorelines at Aberdeen Proving Ground, Maryland




University of Delaware

UF University of Florida

Partnership for the Delaware Estuary

EA Engineering, Science, and Technology, Inc., PBC

LSU

ERDC Engineer Research & Development Center

EWN Engineering With Nature

# Research Team (Bruck Lab)

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Mojtaba Tahmasebi

LA Graduate Student, Department of Landscape Architecture, College of Design, Construction & Planning, University of Florida, USA

## $2.6 billion in resilience funding for NOAA

### FACT SHEET: Biden-Harris Administration Makes Historic Investments to Build Community Climate Resilience

BRIEFING ROOM › STATEMENTS AND RELEASES

Over the past two years, more than 100 million Americans have been personally affected by an extreme weather event. The record-shattering heat wave that hit Puerto Rico earlier this month, recent wildfire smoke that blanketed the Midwest and East Coast, and devastating storms in California, are just the latest evidence that climate change is not a far-off threat. It's a crisis that's here now. President Joe Biden and Vice President Kamala Harris understand that to protect lives and livelihoods, we need to both slash emissions *and* give Americans the tools they need to prepare for the growing impacts of climate change.

# **DEEDS Project**| Aberdeen Proving Ground Maryland - *The multi-year project funded by the Department of Defense*

## Developing Engineering practices using Ecosystem Design Solutions for Future Army

## Building Coastal Community Resilience with Nature-based Shoreline Solutions

## *Install and evaluate shellfish-based living shorelines to understand ways to enhance community resilience to changing environment.*

**Project Focus**

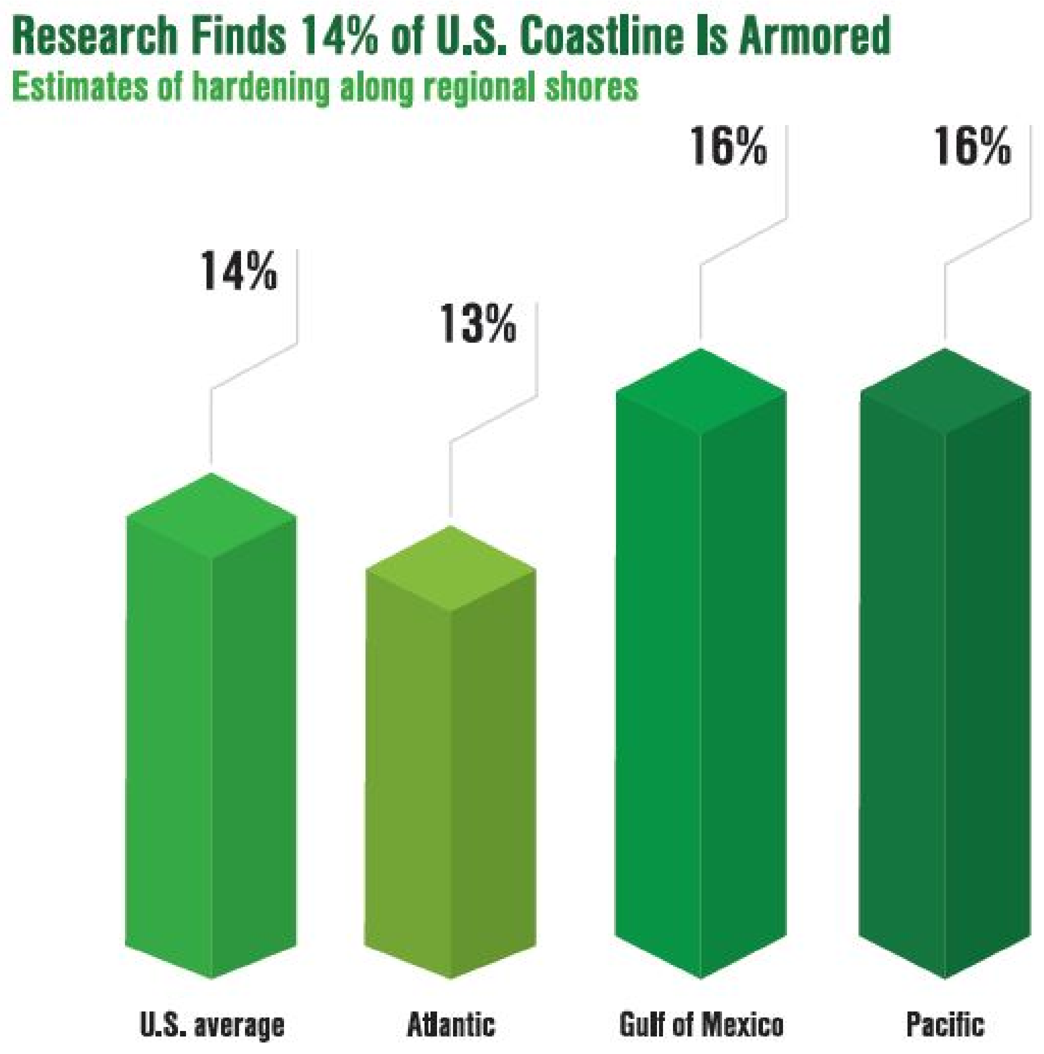
- **Site Selection**: Ecological, physical, and social/infrastructural attributes required for successful NNBS treatments. Use a transdisciplinary approach to site selection. Select sites from 5 different areas based on preliminary monitoring data, GIS analysis, and assessment of risk and vulnerability
- Work with stakeholders to understand community needs and concerns.
- Design and permit 2 site-specific projects.
- Install and monitor 2 projects.
- Use agent-based modeling and future land use planning scenarios to develop community resilience plans.

# Shorelines Hardening and Coastal Management in US and Maryland

## Hard shoreline is Dead shoreline!

- Current rate of shoreline hardening in continental US is 200 km of shoreline a year.
- 22,842 km (14%) of 160,168 km of tidal shoreline is hardened in the continental US.
- Assuming that there will be no restrictions in place on shoreline hardening, 1/3rd of the contiguous US shorelines is expected to be armored.
- So far only **eight states** have restricted shoreline hardening (North Carolina, South Carolina, Maine, Virginia, and Rhode Island etc).

- 11265.41 km out of (12121.6 km) of shoreline and 70 % of coastal population are susceptible to flooding in **Maryland.** (erosion from tides, storms, and sea level rise)
- Maryland already has over **1610 km** (1,000 miles) of hardened shorelines representing only ¼th of the surveyed shorelines (Berman and Rudnicky, 2008), Coastal Resources Management at the Virginia Institute of Marine Science (CCRM 2004)




Source: Rachel Gittman et al., 2015 Engineering Away Our Natural Defenses: An Analysis of Shoreline Hardening in the U.S. Frontiers in Ecology and the Environment 13(6): 301-307, doi:10.1890/150065.

# Introduction
## Coastal Resilience and Living Shorelines

a) Bulkhead

b) Riprap

Source: https://coastalscience.noaa.gov/news/living-shoreline-research-featured-estuaries-coasts-special-issue/

- Armoring, hard armoring, engineered structures, shoreline hardening and hardening structures are some of interchangeable terms used for traditional methods used for coastal or shoreline protection such as revetments, seawalls, bulkheads, break waters, riprap, and pier pilings etc.

- Negative Impacts on ecological and environmental processes such as permanent habitat loss, poor water quality, disruption in the terrestrial, estuarine, and marine ecosystems connection, causing seaward erosion, reduction in sediments sources, as well as change in ecological and environmental nature of streams and rivers (Berman and Rudnicky, 2008; Mitsova et al., 2016; Dobbs et al., 2017; Boland and O'Keife, 2018; Nunez et al., 2022).

Coastal habitats, coastal infrastructure and coastal population are more vulnerable due to continuous increase in sea level rise (SLR), wave and storm surge, erosion, and natural disasters like hurricanes.

# Introduction
## Coastal Resilience and Living Shorelines

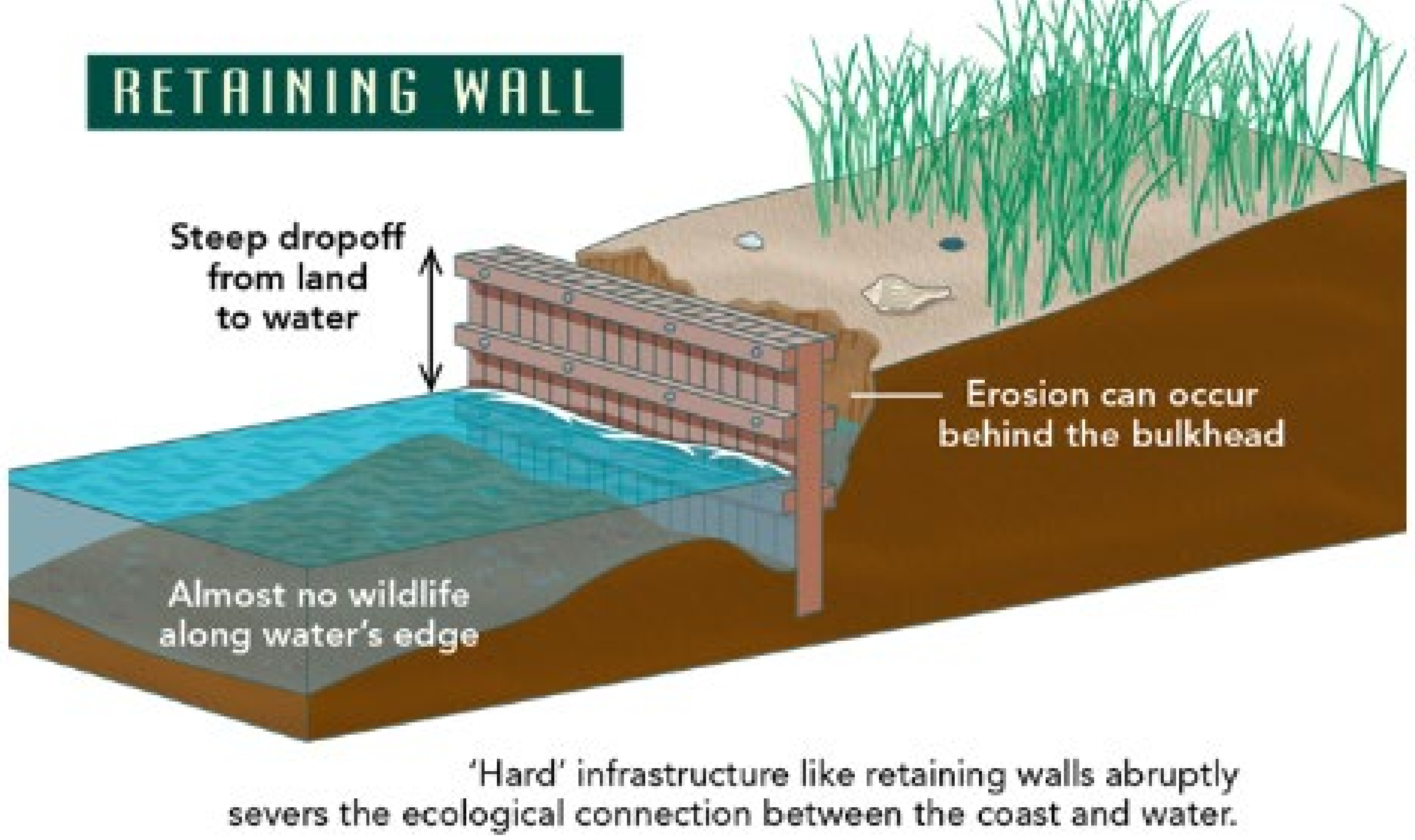
Reef Balls

(Jacksonville, FL)


Source: https://wmap.blogs.delaware.gov/2021/03/22/living-shoreline-permitting-dos-and-donts/

- “Soft Stabilization”, “Non-Structural”, “Soft Structural”, “Living Shorelines”, and “Nature-Based Solutions” as an alternative strategy to include natural habitats into a shoreline protection and design.
- Marsh plantings or sea grass provide comparable advantages by using natural vegetation and/or living resources such as shellfish, oyster reefs etc. (Dobbs et al., 2017; Nunez et al., 2022).
- Living Shorelines and vegetated shorelines perform better in low energy environments and provide numerous ecological, environmental, social and cost-related benefits like improving water quality, maintaining biodiversity, enhancing ecosystem and habitats, acting as natural barriers to absorb wave and storm energy, establishing natural connection between upland and water interface while maintaining aesthetical value of coast, developing erosion control effectively, low-cost of construction and maintenance and improving recreational opportunities in surrounding space.

Source: https://www.delawarelivingshorelines.org/what-is-a-living-shoreline

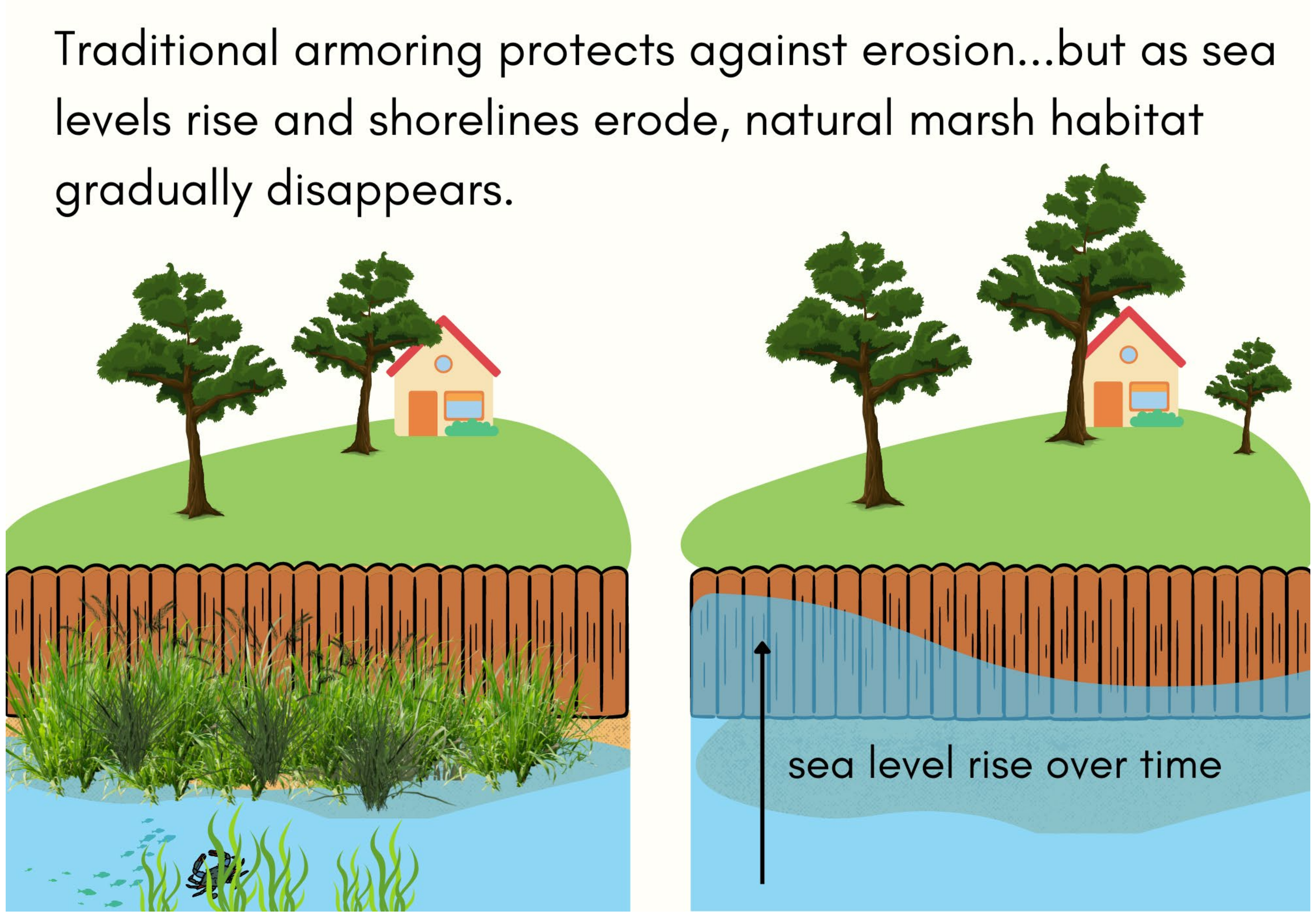




# Living Shorelines vs Hard Armoring

Nature Based Solutions (NBS), Living Shoreline (LS), Green Infrastructure (GI), Ecological Engineering (EE), Engineering with Nature (EWN) are related terms used for coastal protection through natural means which tend to improve ecosystem function and enhance coastal resilience along estuaries, riverbanks, deltas, tributaries, bays, and other sheltered shorelines. (Pontee, 2022 and NOAA, 2015)

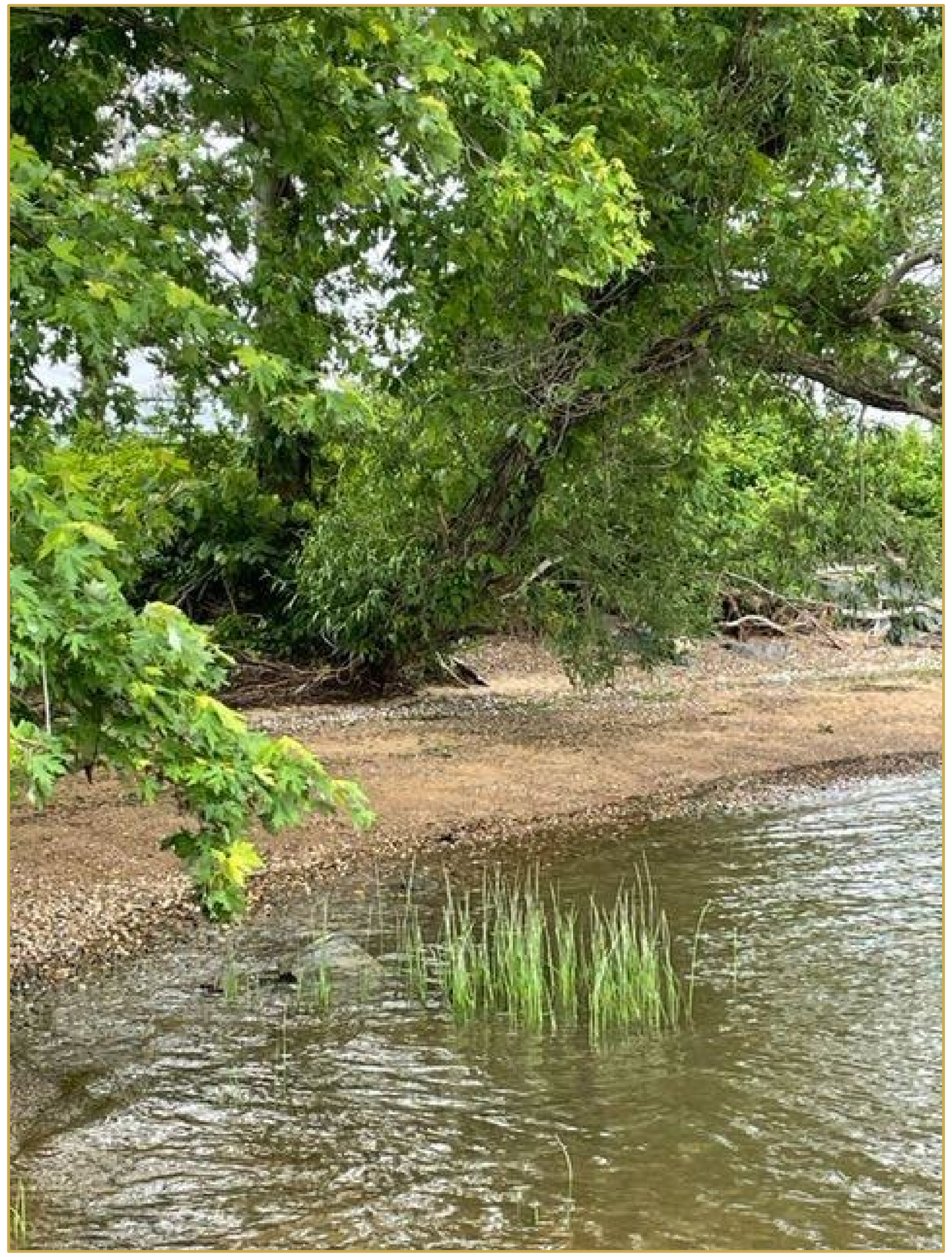
Source: https://wmblogs.wm.edu/mbreinsel/student-summer-research-spotlight-living-shorelines/




For this study we adapt the shoreline definition based on CCRM and Burke (2005) which states; **"a shoreline management practice that provides erosion control benefits; protects, restores or enhances natural shoreline habitat; and maintains coastal processes through the strategic placement of plants, stone, sand fill and other structural and organic materials** (e.g., bio-logs, oyster reefs, etc.)".

# **Study Area** | Aberdeen Proving Ground, Maryland


The Aberdeen Proving Grounds (APG) covers 153.7 km2 (59.36 mi2) of land, approximately 12.9% of the land area of Hartford County and **401 km2 of coastline** (Maryland Department of Natural Resources).



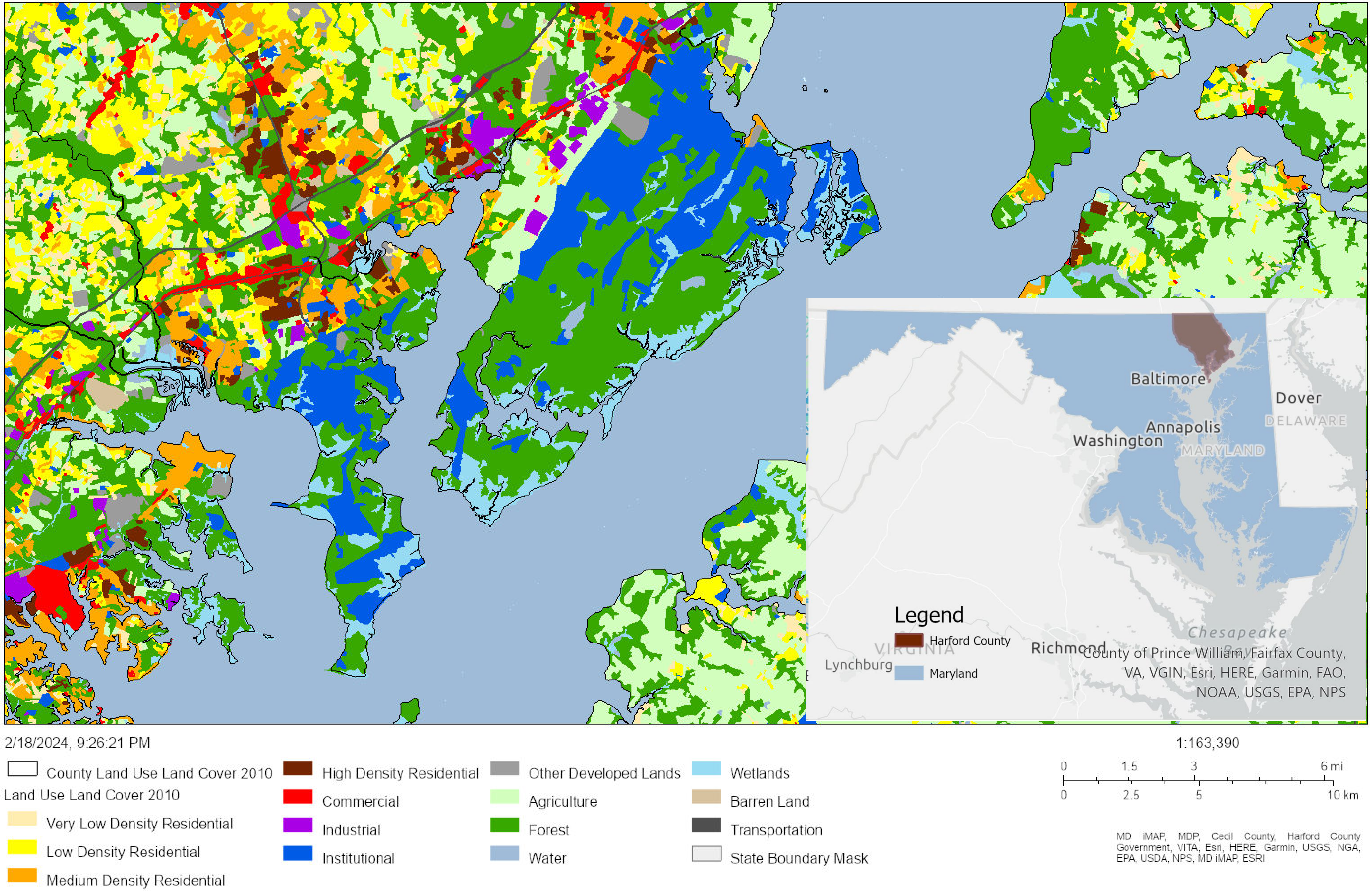
# Historical Significance of Aberdeen Proving Ground, Maryland

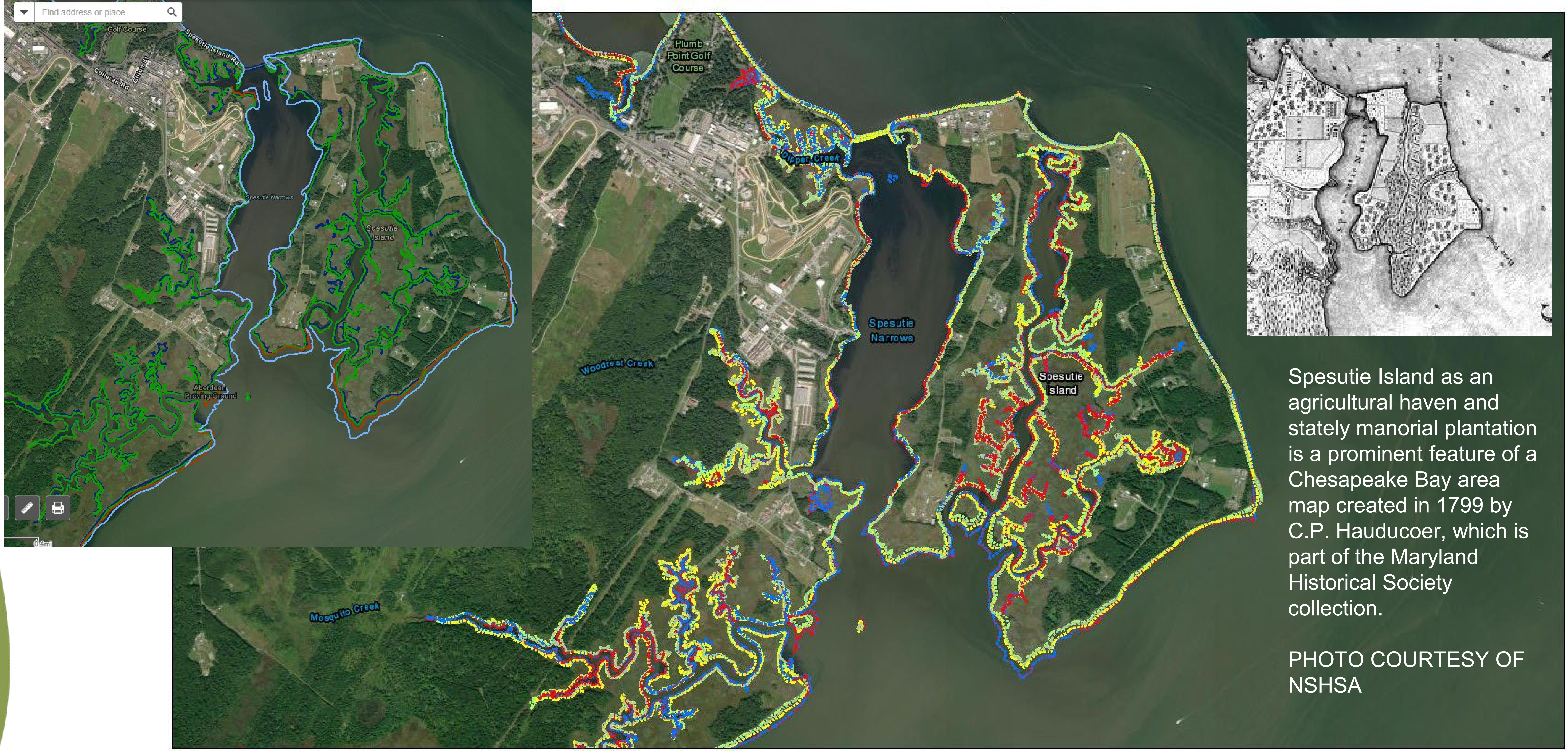
- The APG land was acquired by the U.S. Army in 1917 making it **one of the oldest active proving grounds in the U.S**.
- **Many wartimes technological advances were developed at APG** through the years, and the site has a continuous history of innovation, construction, and testing.
- The first known European settlement in the region (now APG) was established on what was originally called Bearson's Island, which is today's **Spesutie Island**.
- The mainland of APG was known for its rich soil and abundant wildlife, waterfowl, and fish - making it notable for agriculture and hunting which sustained generations of families in the region.
- Over time, the Army developed APG to host railways, hospitals, artillery schools, laboratories, and testing facilities for testing bombs and various forms of weaponry.


# GIS Suitability Analysis Model for Living Shorelines & Hybrid Solutions

*Determining Site suitability for Living Shorelines (LS) to protect landscapes that are vulnerable to rising sea levels, high rates of erosion, and wetland deterioration.*

**Land use in APG -** state land, wetland, forested land, habitat to sensitive species/critical areas, green areas (hub and corridors) and SAV. APG also claims to have many properties with historical importance with respect to WW1 and WW2. Although there are no residential properties or communities which are vulnerable at this site.






Spesutie Island as an agricultural haven and stately manorial plantation is a prominent feature of a Chesapeake Bay area map created in 1799 by C.P. Hauducoer, which is part of the Maryland Historical Society collection.

PHOTO COURTESY OF NSHSA

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Limited Area Shorelines by Decade

1930
1940
1950
1960
1970
1990
2000
2010

1:36,112

0 1,500 3,000 6,000 ft

0 500 1,000 2,000 m

VITA, Esri, HERE, Garmin, Maxar, MD iMAP, DNR

# APG Shoreline Change

# Risk Assessment

**Shoreline Change (between 1930 to 2010)**

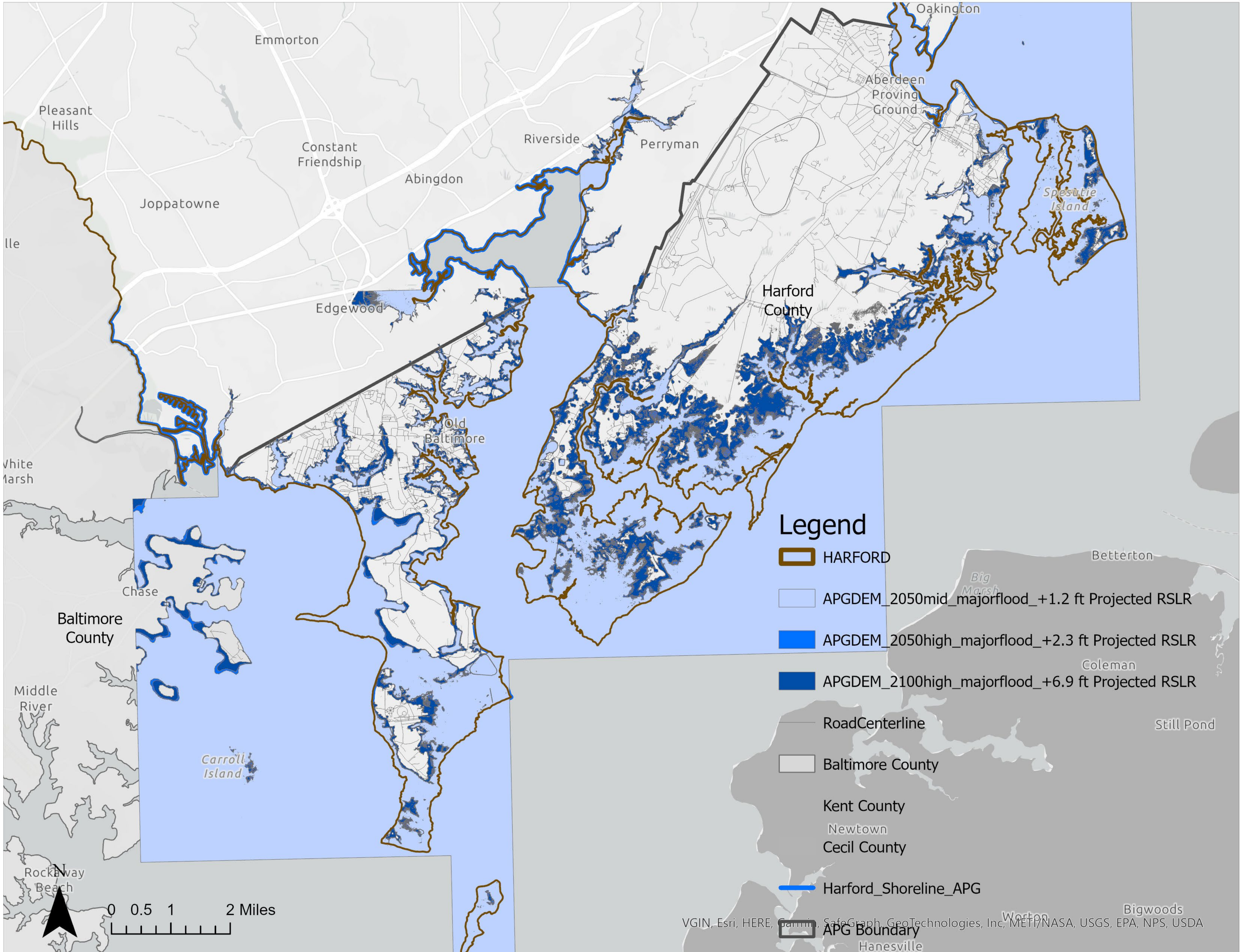
We started by pinpointing potential risks and opportunities prior to implementing GIS models and then developing diverse design solution typologies.

Shorelines by Decade
Maryland Department of Natural Resources

# Risk Assessment

## SLR

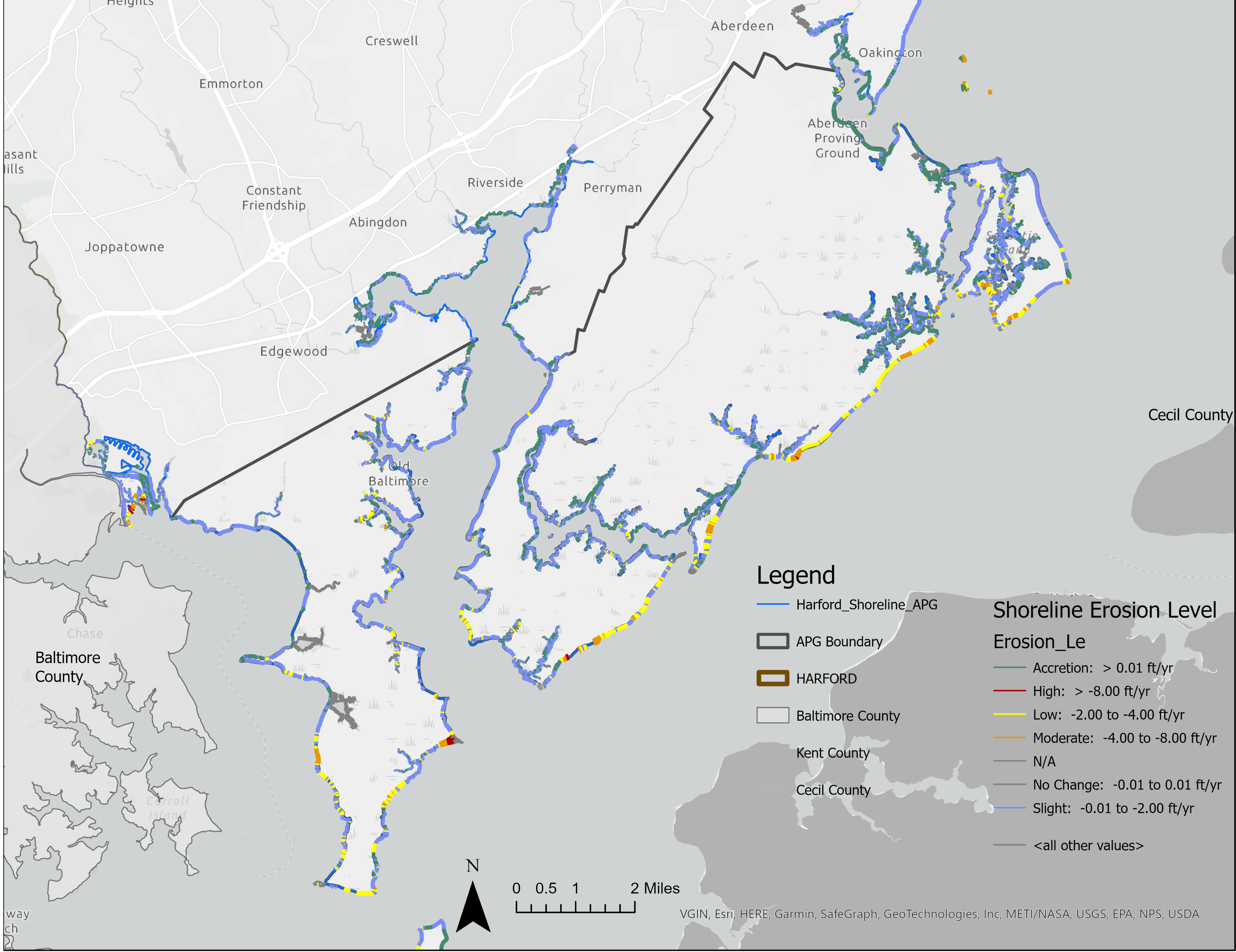
For + 1.2 & +2.3 ft projected RSLR scenario of 2050 (mid & high), the coastal edge of APG and Spesutie Island will be submerged in the water. (Boesch, 2018)



# Risk Assessment

## Coastal Erosion

Erosion Level falls between
Slight -0.01_-2.0
(Low -2_-4) to
Moderate -4_-8
at the coastal edge of APG and Spesutie Island.



# Risk Assessment

**Sensitive Species** and **Natural Habitats** protection is crucial for coastal benefits.

Living Shorelines (all natural) support and protect existing natural habitats and sensitive species

## Sensitive Species Chesapeake Bay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Forest Interior Dwelling Species habitat Areas
Sensitive Shorebirds Areas - Coastal Bays
Natural Heritage Areas
Waterfowl Areas
Sensitive Species Project Review Areas
MD Amphibian and Reptile Atlas Grid

Sensitive Horseshoe Crab Areas - Coastal Bays
Chesapeake Bay Terrapin Habitat
beach
cross connector
cross connector / vegetated
structure

vegetated
waters edge
Sensitive Terrapin Habitat - Coastal Bays
Chesapeake Bay Horseshoe Crab Habitat
beach
structure

vegetated
waters edge
Fish Blockage Locations

1:144,448

0 5,000 10,000 20,000 ft

0 2,000 4,000 8,000 m

MD iMAP, DNR, Map data © OpenStreetMap contributors, CC-BY-SA

Maryland Coastal Atlas Map
Maryland Department of Natural Resources

# Risk Assessment

## **Sensitive Species** and **Natural Habitats** in Chesapeake Bay

**American Eel**
*Anguilla rostrata*

**Shenandoah Salamander**
*Plethodon shenandoah*

**North Atlantic Right Whale**
*Eubalaena glacialis*

**Dwarf Wedgemussel**
*Alasmidonta heterodon*

**Puritan Tiger Beetle**
*Cicindela puritana*

**Virginia Big-Eared Bat**
*Corynorhinus townsendii virginianus*

**Atlantic Sturgeon**
*Acipenser oxyhyncus*

**Hooded Merganser**
*Lophodytes cucullatus*

**Leatherback Sea Turtle**
*Dermochelys coriacea*

**River Herring**
*Alosa aestivalis*

**Piping Plover**
*Charadrius melodus*

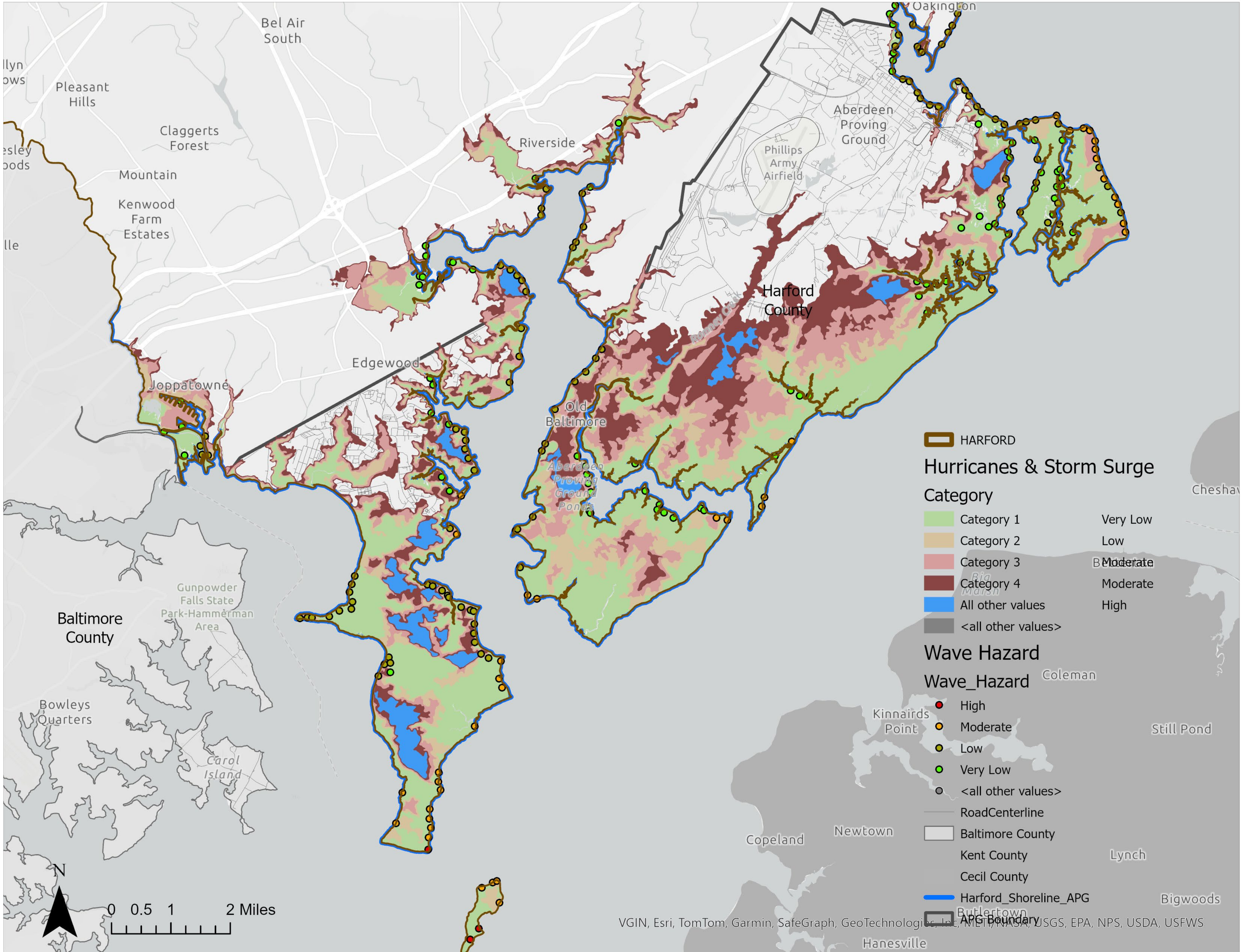
**Shortnose Sturgeon**
*Acipenser breviostrum*

Compiled by Donner Bryce (UF)

# Risk Assessment

## Storm Surge & Wave Hazard

Coastal edge of APG and Spesutie Island mostly has Moderate to V low Wave hazard values and projected to Category 1 Hurricane & Storm Surge.



# Methodology

## GIS Suitability Analysis Model for Living Shorelines & Hybrid Solutions

### Research Questions

- “How two comparatively unique suitability analysis modeling methods for shorelines can be run and compared for their model input and model output, model validation, data preparation, data execution, and merits/demerits of their overall use while determining shoreline suitability for living shorelines and hybrid solutions.”

### Method and Data Preparation

- Arc GIS Pro 3.1.0.

1) **GIS Model -Weighted Sum Method (Traditional)** assess the suitability of each model parameter independently and later combines all layers with assigned weighting.
2) **GIS Model -Suitability Modeler Method (Novel)**. a single tool “Suitability Modeler” in Arc GIS which includes reclassifying and calculating site suitability within a single tool.

- Both methods adopt a comparatively unique approach to calculate final suitability layer.

# GIS Model through Weighted Sum & Suitability Modeler Method

Data Collection:

**Downloading Feature and Raster Datasets**

Data Processing:

**Projecting all data to the planar PCS "NAD 1983 StatePlane Maryland FIPS 1900 (Meters)"**

Data Processing:

**Converting all data to raster dataset 10 mX10 m Cell size**

Data Processing:

**Assigning a common scale from 1 to 3**

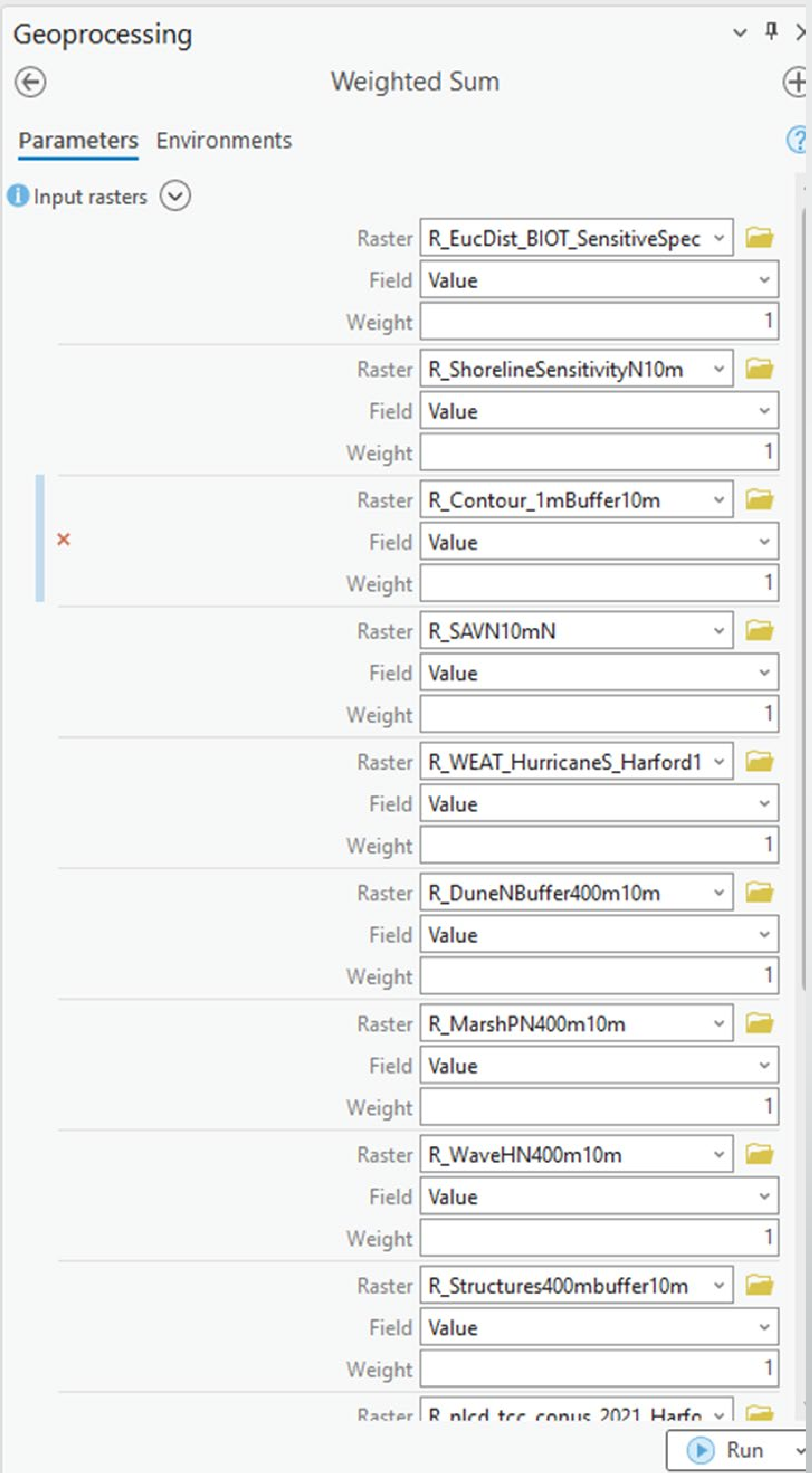
Data Processing:

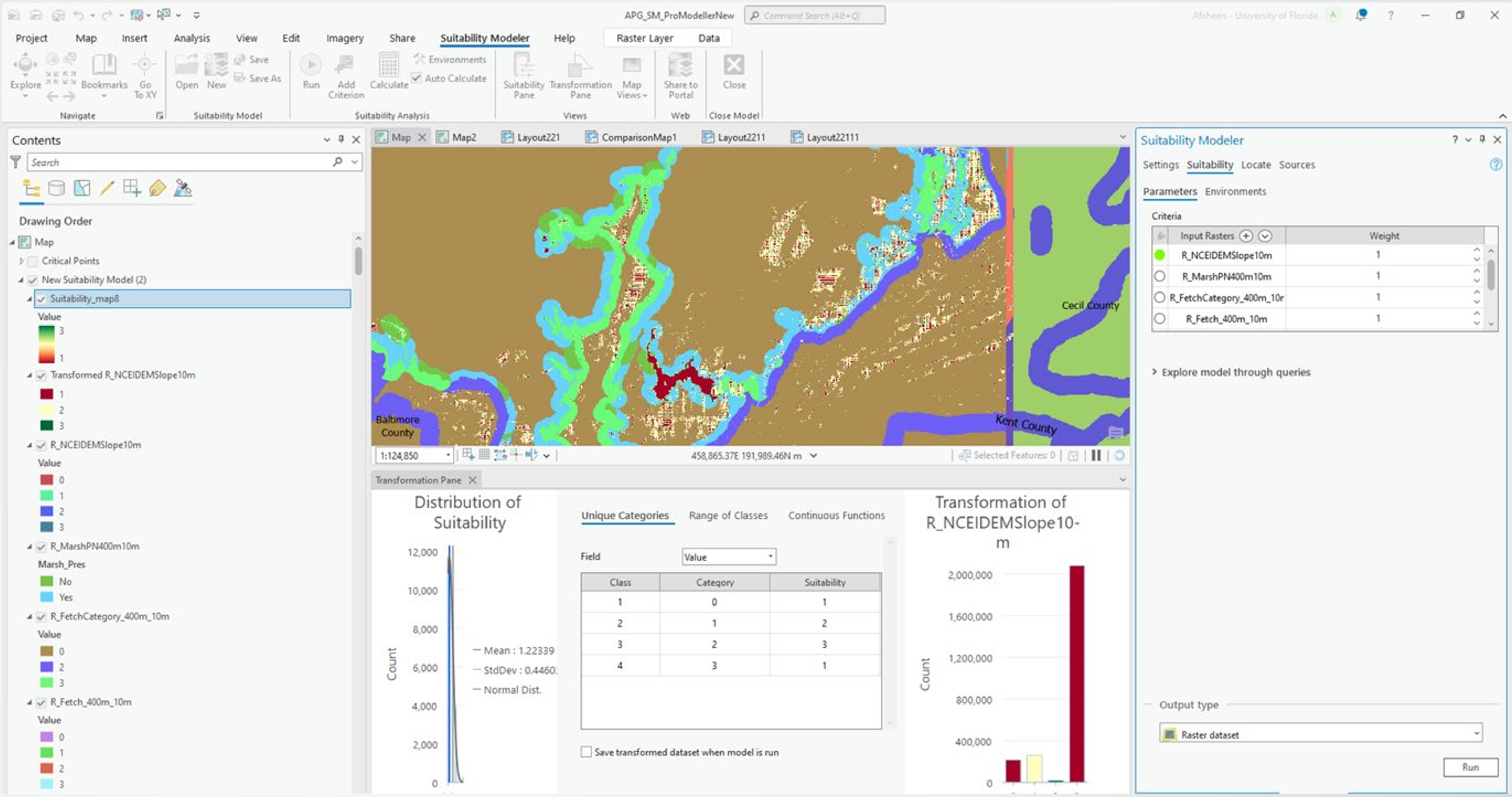
**Assigning weight to each converted layer**

**Running the Suitability Model by two GIS methods/Tools**

Data Processing:

**Buffering Shoreline Layer to 100 m & used it as a mask to run the model**



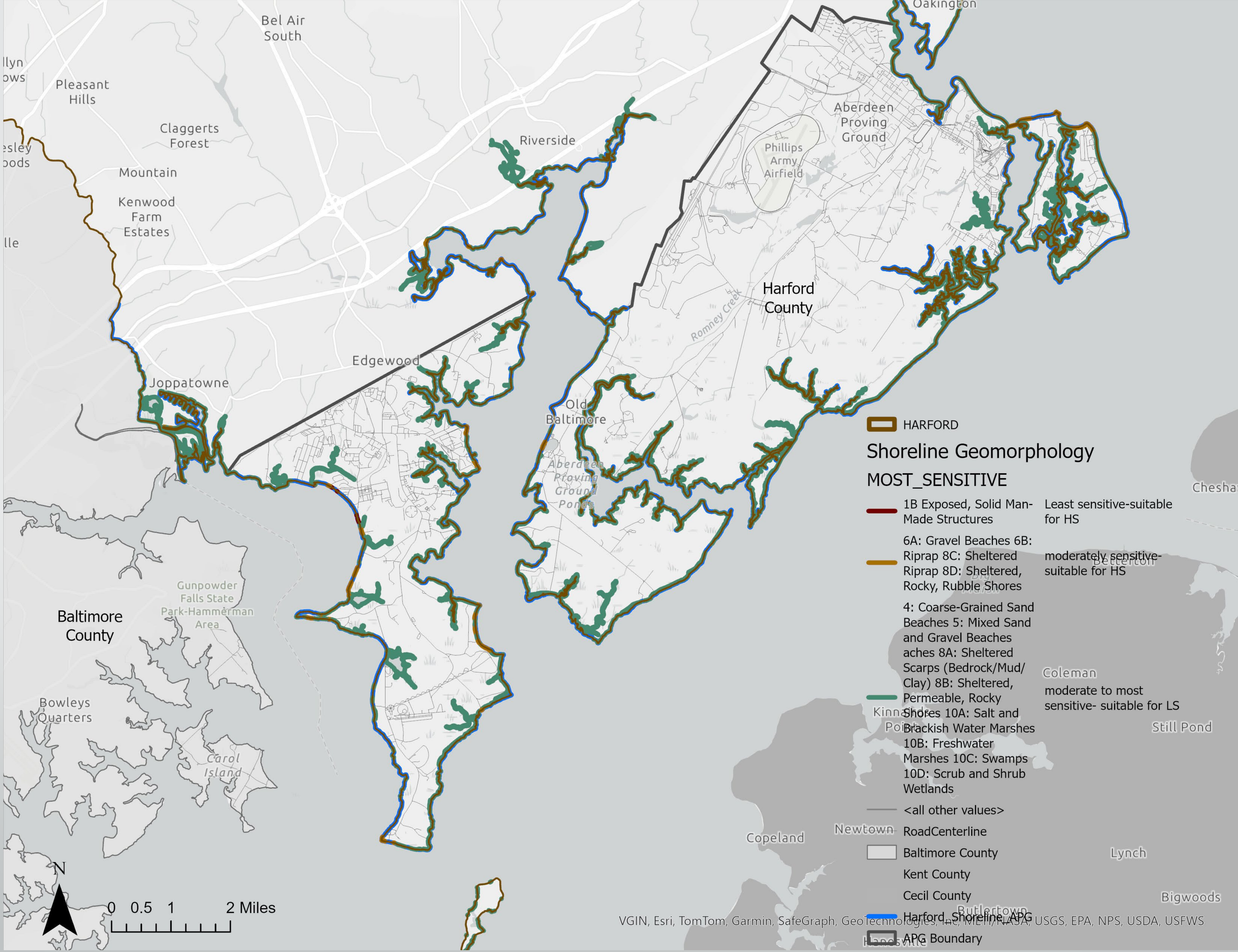

# 1- GIS Model Weighted Sum Method (Traditional)

# 2- GIS Model through Suitability Modeler Method (Novel).

# GIS Model Variables

## Physical (10)

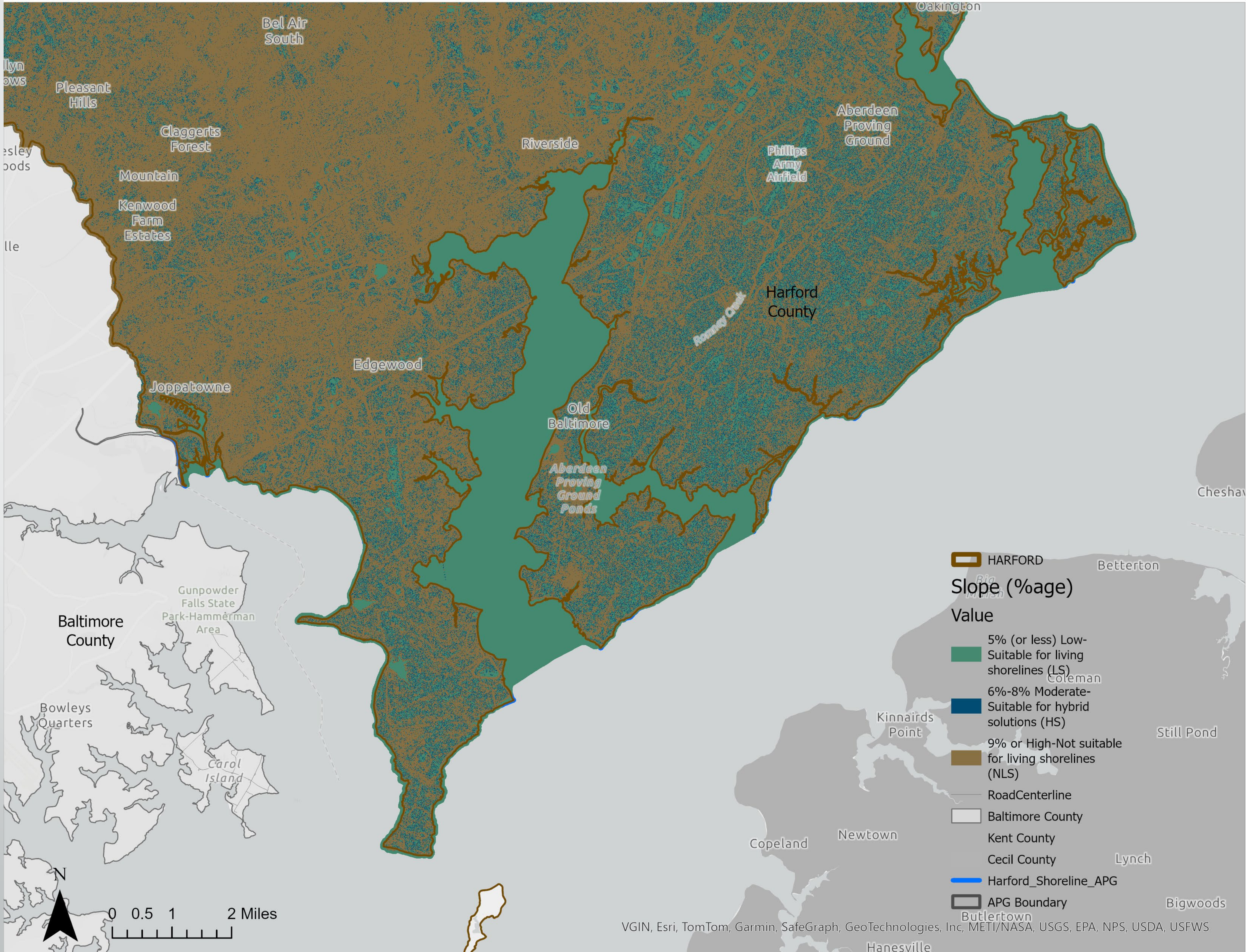
## Shoreline Sensitivity/ Geomorphology



# GIS Model Variables

## Physical (10)

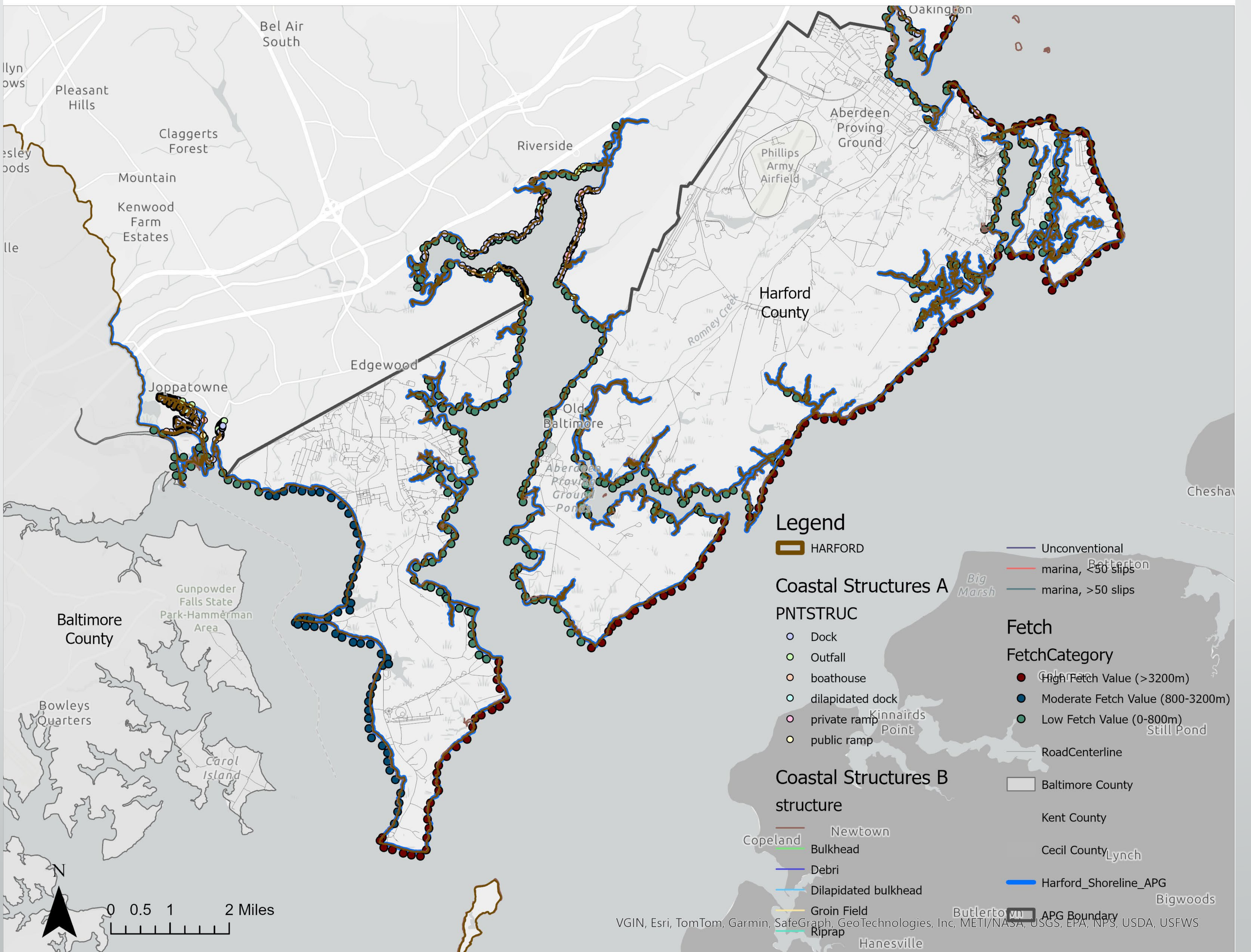
## Nearshore Slope



# GIS Model Variables

## Physical (10)

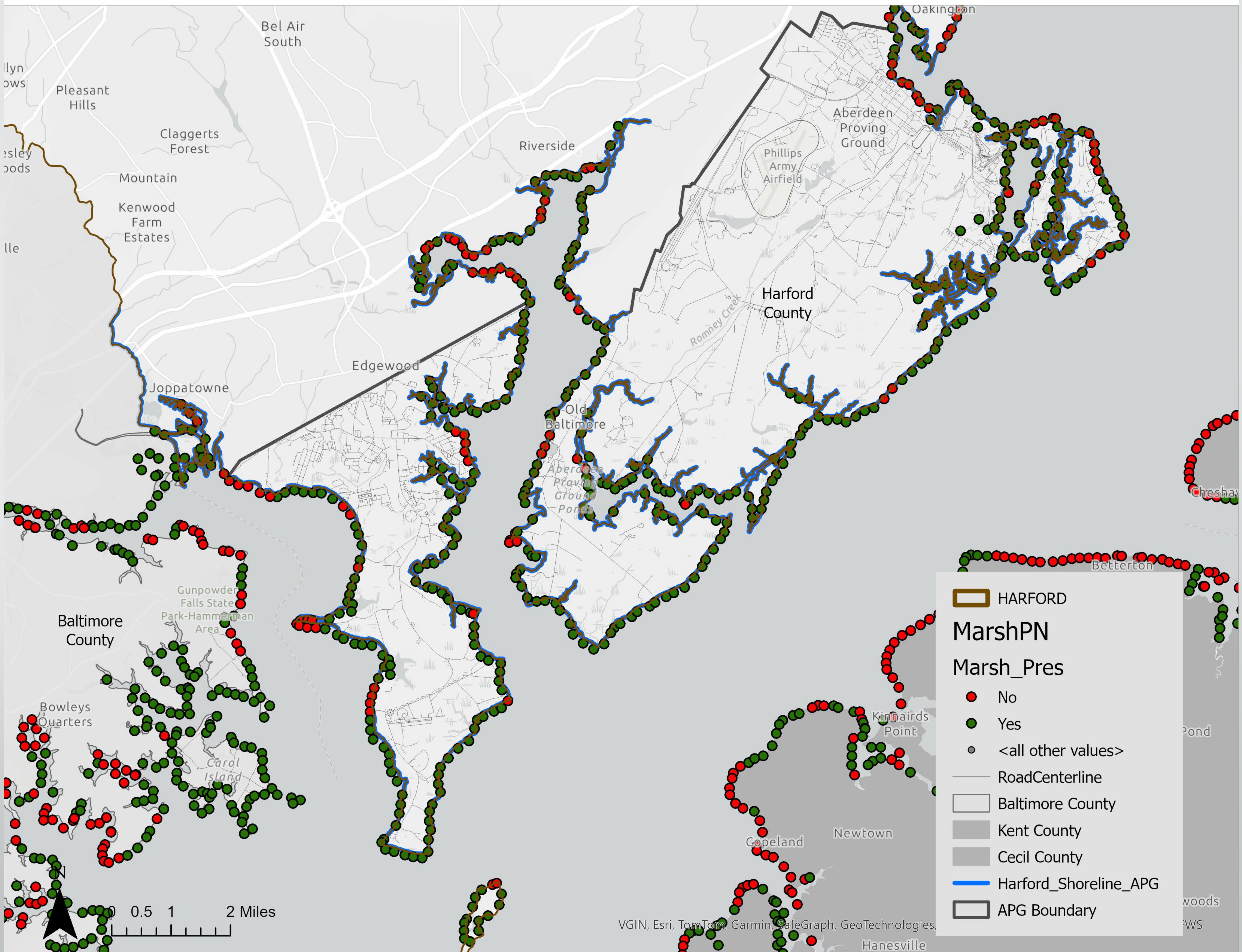
## Coastal Structure & Fetch categories



# GIS Model Variables

**Physical (10)**

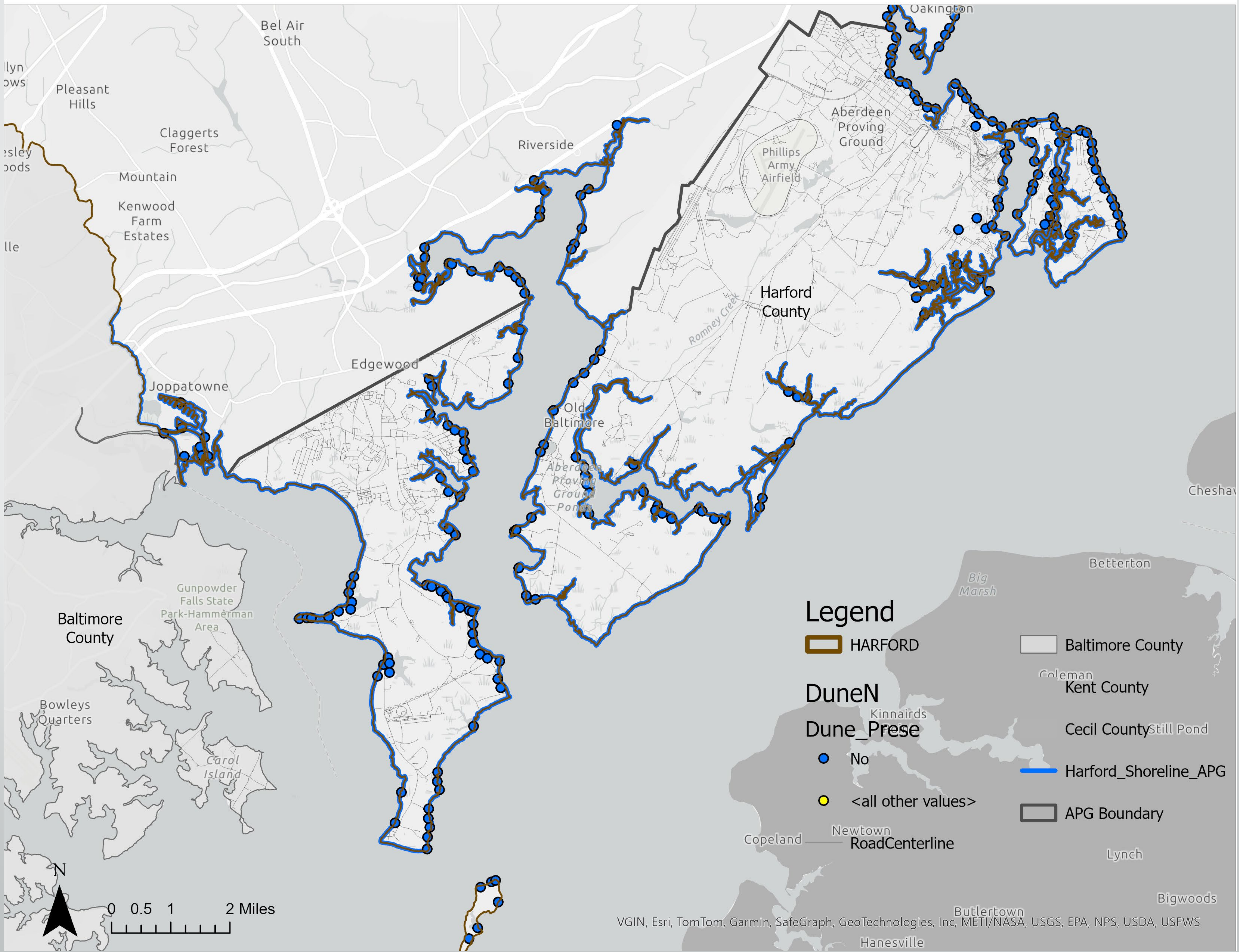
**Marsh Presence**



# GIS Model Variables

**Physical (10)**

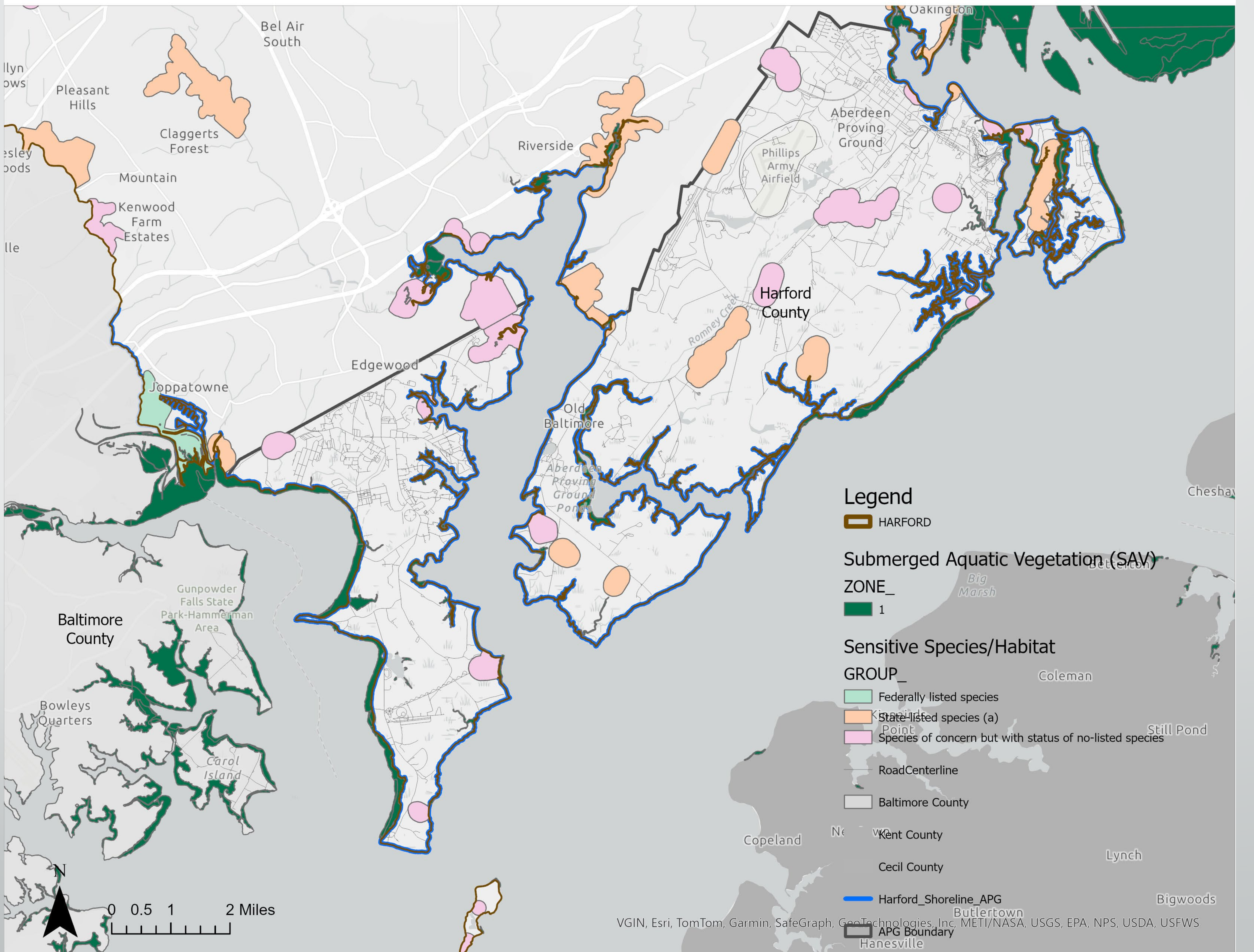
**Dune Presence**



# GIS Model Variables

## Ecological (3)

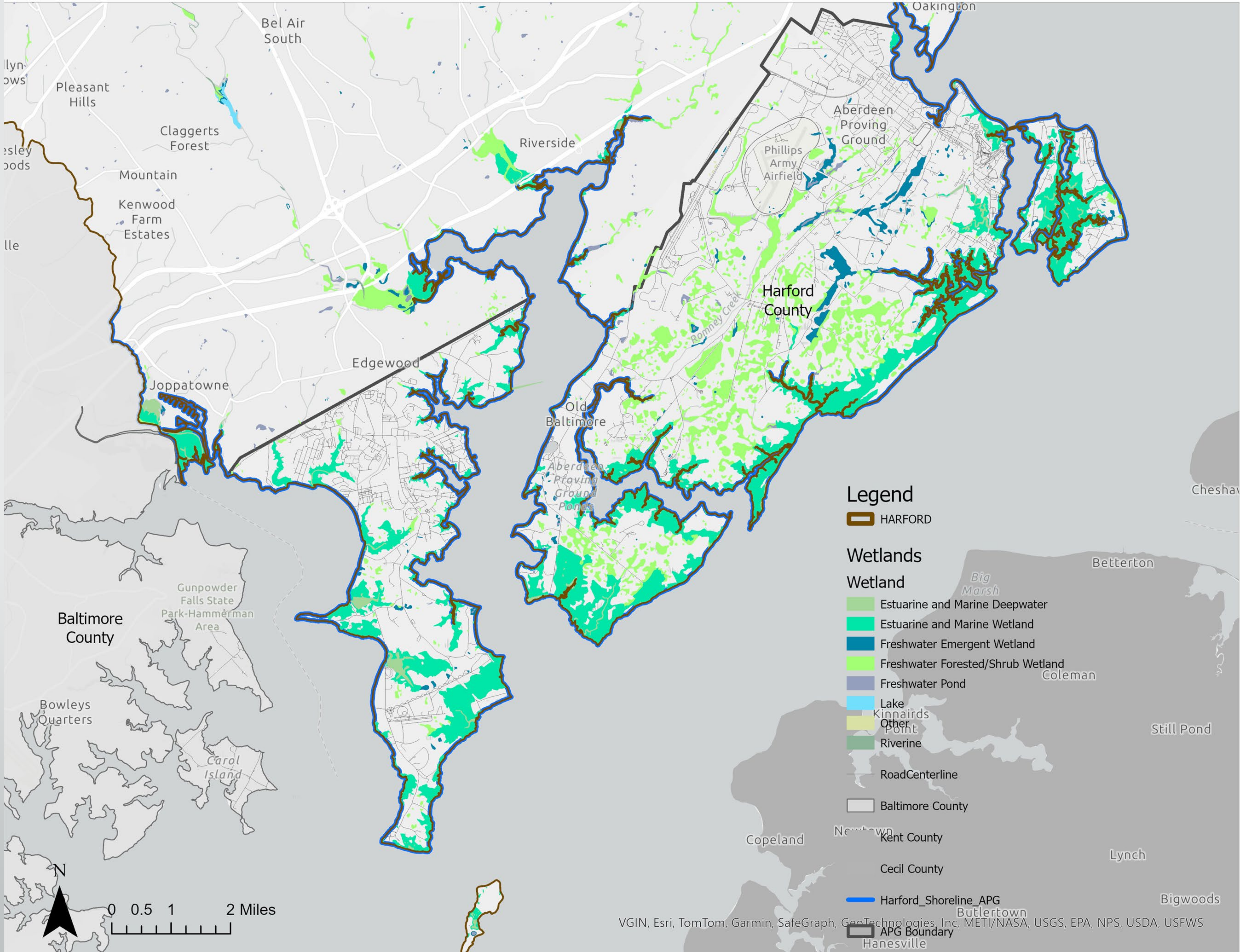
### SAV & Sensitive Species



# GIS Model Variables

## Ecological (3)

### Wetlands



# Analysis and Model Development GIS Suitability Analysis Model for Living Shorelines & Hybrid Solutions

**Suitability Index**

- 13 data variables were input in the model including 10 physical variables (Shoreline Sensitivity, Slope, Tree Canopy, Bathymetry Contour -1, Dune Absent, Marsh Present, Fetch, Strom Surge, Wave Hazard, Structures Absent) and 3 ecological variables (Habitat/Sensitive Species, Wetlands, Submerged Aquatic Vegetation (SAV)).
- This Suitability Index weighting was based on the methodology related to parameters weighing from a regionally specific integrative tool called the "**Living Shoreline Feasibility Model (LSFM)**" developed by the Partnership for the Delaware Estuary to spatialize model output.
- The site suitability was modelled for three outcomes: **suitable for living shorelines (LS), suitable for hybrid solutions (HS),** and **not suitable for living shorelines (NLS)** through a scale with assigned values of 1 (not suitable for LS), 2 (suitable for HS), and 3 (suitable for LS).
- Data with no values was classified as 0 and included into not suitable for LS category to consider the unavailability of the data for potential suitability.

**Living Shorelines** or **soft stabilization techniques** include vegetation with native plants, riparian, marsh, and SAV, or installation of natural materials such as biodegradable bio-logs (coconut-fiber logs, coir-logs), fiber mats or constructing with other natural, living or shell-based structures such as oyster reefs, reef balls, rock sills, or anchored large wood etc.

**Hybrid Solutions** combine natural vegetation with hard design approaches like living breakwaters, sills, rocks, beach nourishment with or without vegetation etc.

# Suitability Modeling at APG

## Weighted Sum Method Without Weight

### Model Parameters:

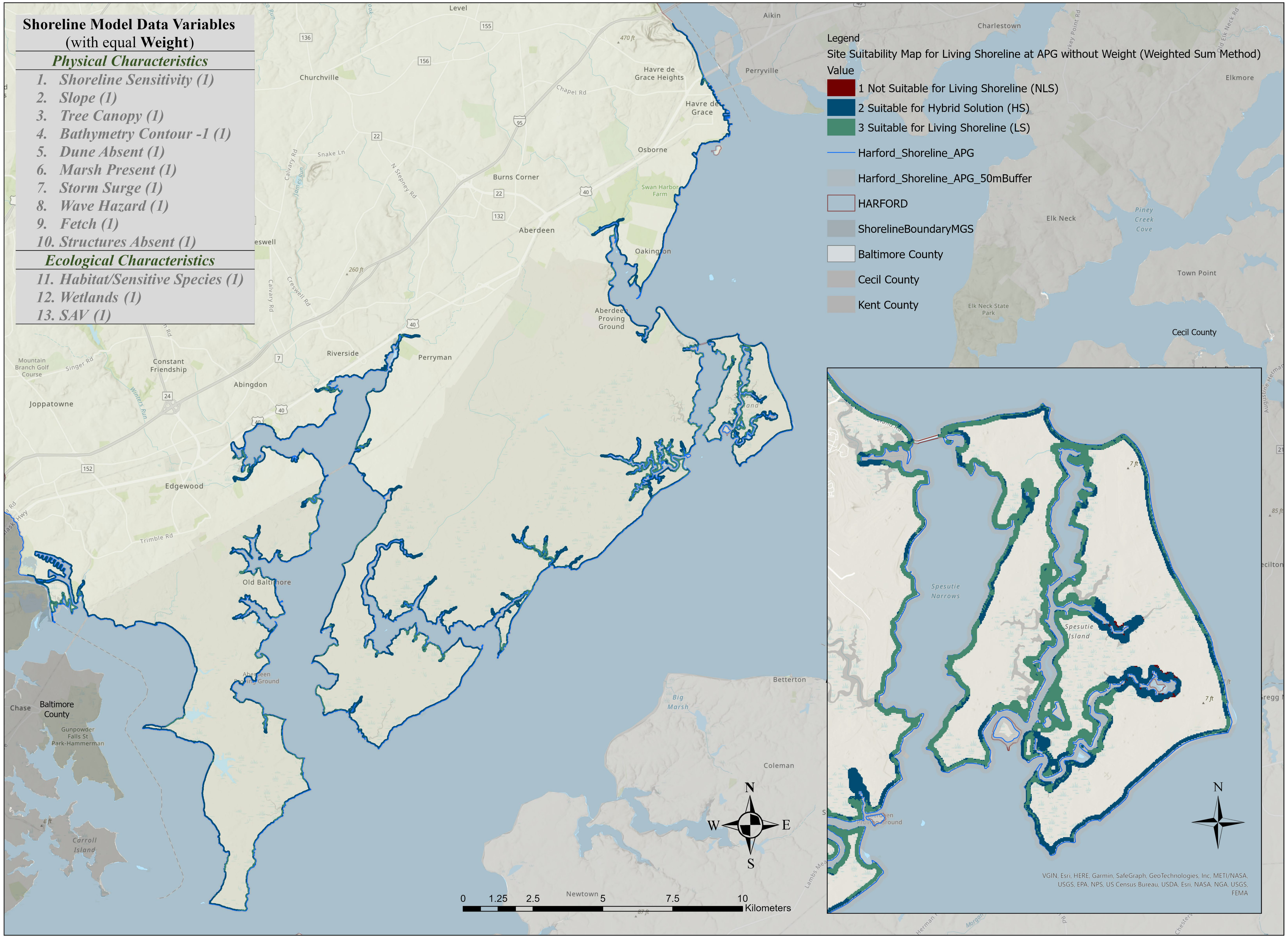
Shoreline Model Data Variables (with unequal Weight)

Physical Characteristics

- Shoreline Sensitivity (3)
- Slope (1)
- Tree Canopy (1)
- Bathymetry Contour -1 (1)
- Dune Absent (1)
- Marsh Present (1)
- Storm Surge (3)
- Wave Hazard (3)
- Fetch (3)
- Structures Absent (3)

Ecological Characteristics

- Habitat/Sensitive Species
- Wetlands (1)
- SAV (1)




Site Suitability Map for Living Shoreline at Aberdeen Proving Ground Maryland - DEED Project

# Suitability Modeling at APG

## Weighted Sum Method With Weight

### Model Parameters:

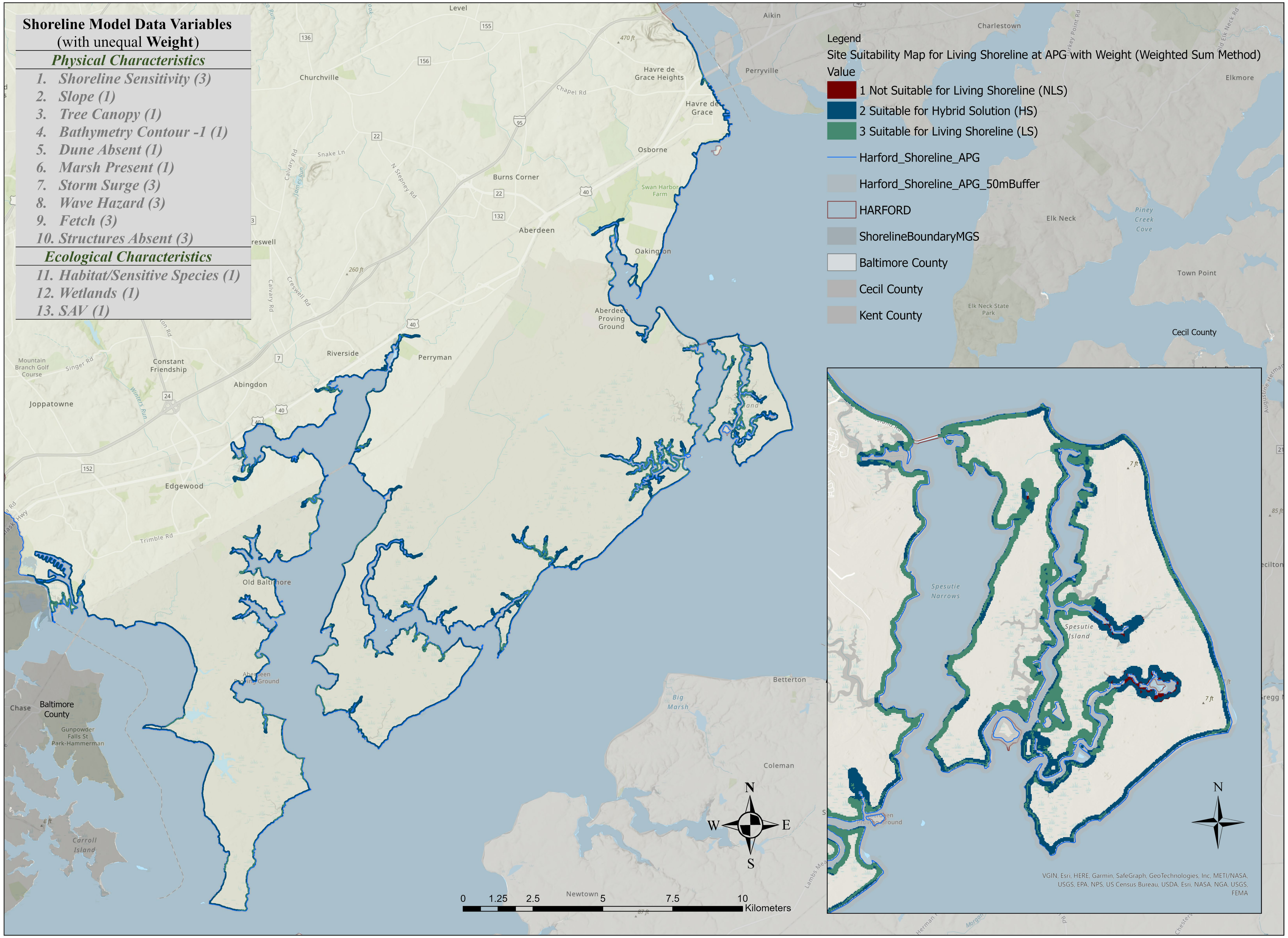
Shoreline Model Data Varial
(with unequal Weight)

Physical Characteristics

- Shoreline Sensitivity (3)
- Slope (1)
- Tree Canopy (1)
- Bathymetry Contour -1 (1
- Dune Absent (1)
- Marsh Present (1)
- Storm Surge (3)
- Wave Hazard (3)
- Fetch (3)
- Structures Absent (3)

Ecological Characteristics

- Habitat/Sensitive Species
- Wetlands (1)
- SAV (1)




Site Suitability Map for Living Shoreline at Aberdeen Proving Ground Maryland - DEED Project

# Suitability Modeling at APG

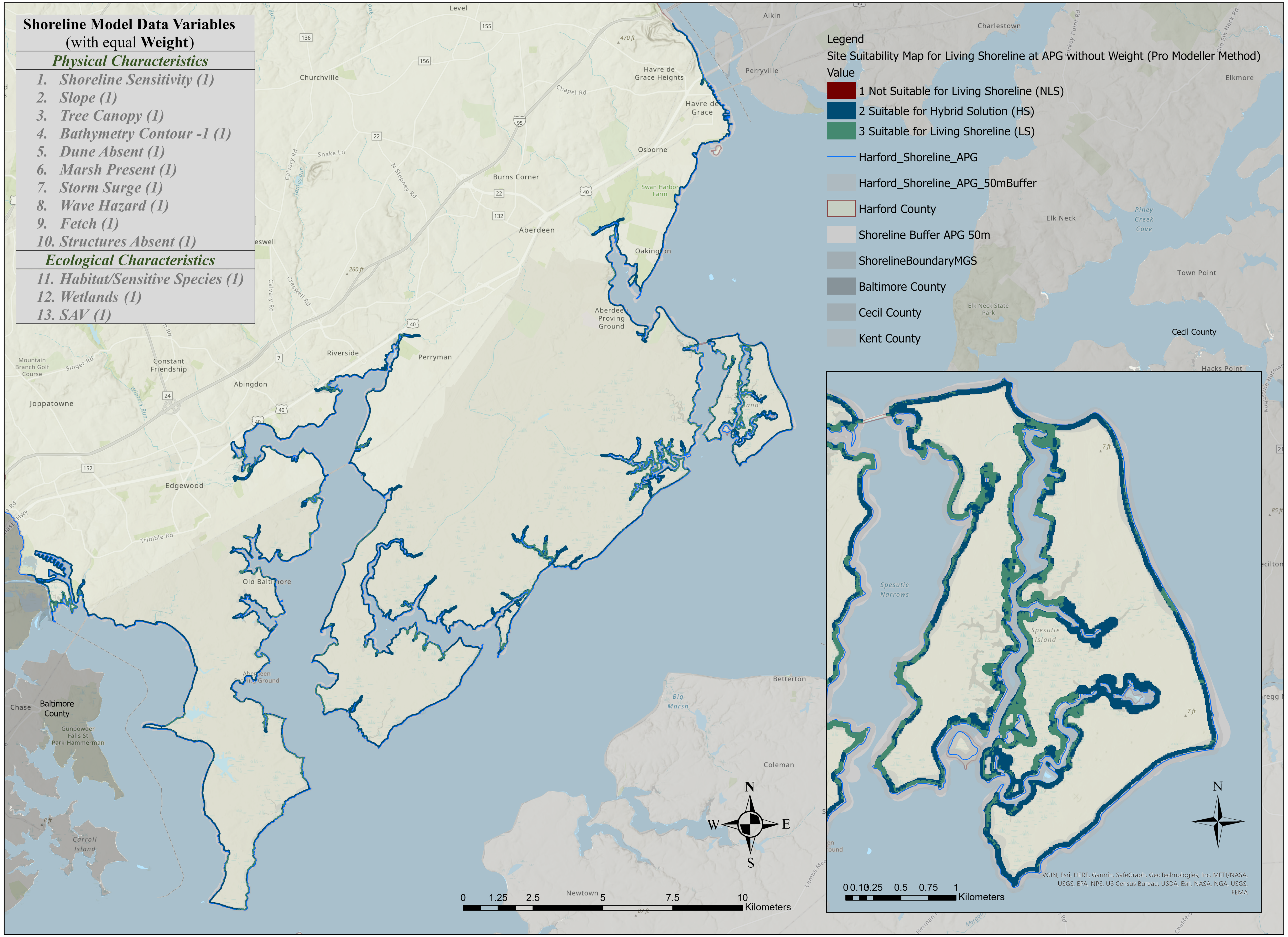
## Suitability Modeler Method Without Weight

Model Parameters:

Shoreline Model Data Variables
(with unequal Weight)

Physical Characteristics
- Shoreline Sensitivity (3)
- Slope (1)
- Tree Canopy (1)
- Bathymetry Contour -1 (1)
- Dune Absent (1)
- Marsh Present (1)
- Storm Surge (3)
- Wave Hazard (3)
- Fetch (3)
- Structures Absent (3)

Ecological Characteristics
- Habitat/Sensitive Species
- Wetlands (1)
- SAV (1)




Site Suitability Map for Living Shoreline at Aberdeen Proving Ground Maryland - DEED Project

# Suitability Modeling at APG

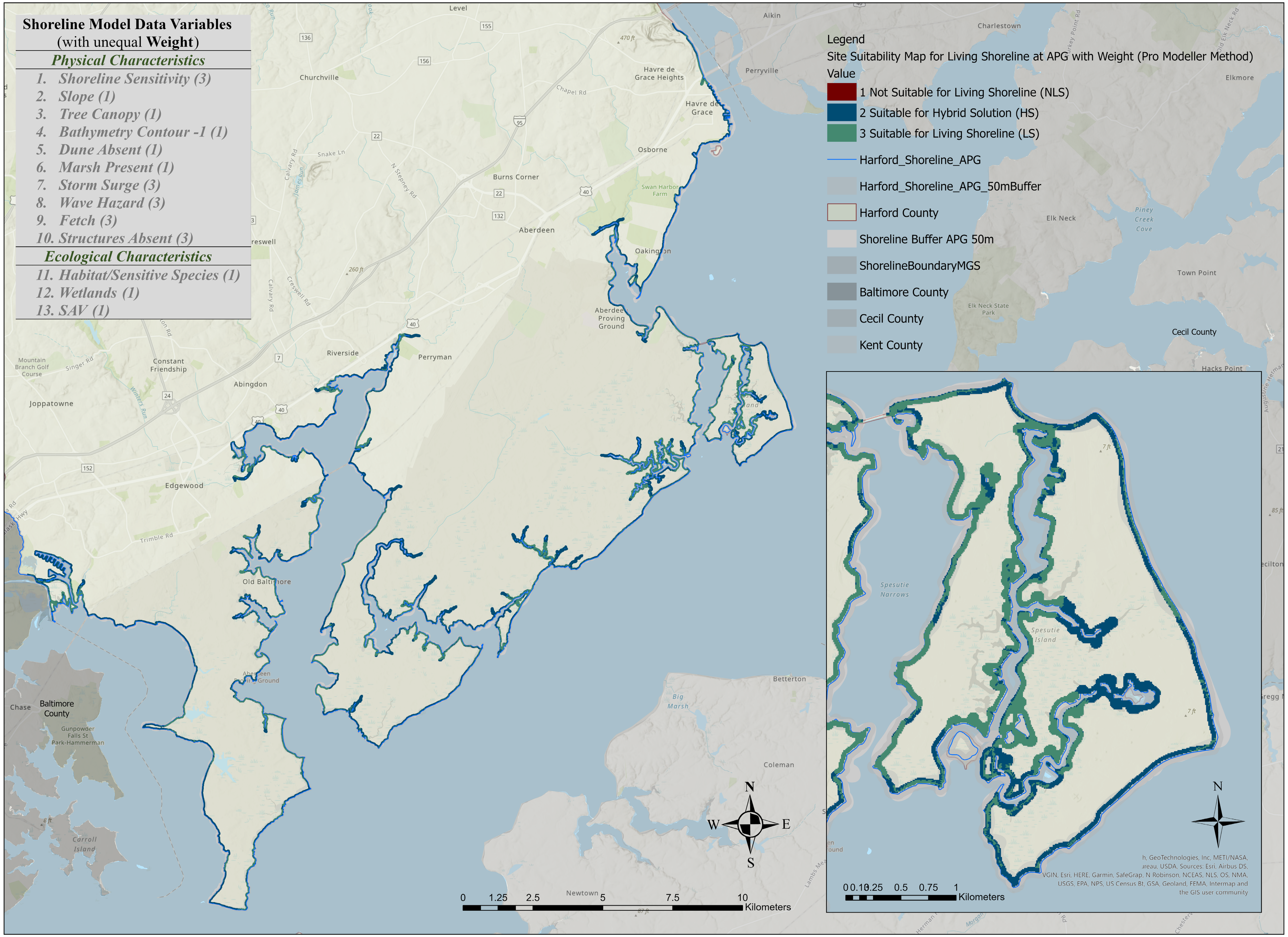
## Suitability Modeler Method With Weight

### Model Parameters:

Shoreline Model Data Variables (with unequal Weight)

Physical Characteristics
- Shoreline Sensitivity (3)
- Slope (1)
- Tree Canopy (1)
- Bathymetry Contour -1 (1)
- Dune Absent (1)
- Marsh Present (1)
- Storm Surge (3)
- Wave Hazard (3)
- Fetch (3)
- Structures Absent (3)

Ecological Characteristics
- Habitat/Sensitive Species
- Wetlands (1)
- SAV (1)




Site Suitability Map for Living Shoreline at Aberdeen Proving Ground Maryland - DEED Project

# Shoreline Suitability Model Result for Weighted Sum Method and Suitability Modeler Method

| Suitability Model Type | Shoreline Classification Type | | | Total Shoreline Length **401,000** m and model was run for **326,075** m |
|---|---|---|---|---|
| | LS (%) | HS (%) | NLS (%) | |
| Weighted Sum Method | | | | |
| Equal Weight | 36.6 % | 57.8 % | 5.6 % | 100 % |
| Unequal Weight | 36.1 % | 60.0 % | 3.8 % | 100 % |
| Pro Modeler Method | | | | |
| Equal Weight | 20.8 % | 61.1 % | Less than 1 % | 100 % |
| Unequal Weight | 38.2 % | 61.7 % | Less than 1 % | 100 % |

# Results

- The unequal and equal weighting in both methods represent difference of classification in each category.
- The model calculates a little more shoreline area for not suitable for living shorelines (NLS) in weighted sum method than suitability modeler method.
- The unequal and equal weighting in **weighted sum method** mark a negligible difference of 36.1 % vs 36.6 % respectively when classifying suitability for living shorelines (LS), 60 % vs 57.8 % respectively when classifying suitability for hybrid solutions (HS), and 3.8 % vs 5.6 % respectively when classifying suitability for not suitable for living shorelines (NLS).
- The unequal and equal weighting in **pro modeler method** mark larger difference of 38.2% vs 20.8 % respectively when classifying suitability for living shorelines (LS), a significant difference 61.7% vs 79.1 % respectively when classifying suitability for hybrid solutions (HS), and non-significant 0.02 % vs 0.03 % respectively when classifying suitability for not suitable for living shorelines (NLS).
- The unequal weighting in both methods (weighted sum and pro modeler respectively) calculates a non-significant difference in percentage 36.1 % vs 38.2% for shoreline edges that are suitable for living shorelines (LS) and 60 % vs 61.7% for shoreline edges that are suitable for hybrid solutions (HS).

# Model Validation Results - Confusion (Error) Matrix

## assess the accuracy and reliability of the shoreline suitability model

**Confusion Matrix with 300 Stratified Random Samples – each classified point was checked manually before running the CM**

**Overall, the model performs well for classification 3 and need improvement or further refinement for classification 1 due to data with 0 value (no data within the inside of channels).**

### Suitability Modeler Method-with weight

FP

| | OBJECTID * | ClassValue | C_1 | C_2 | C_3 | Total | U_Accuracy | Kappa |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | C_1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 2 | C_2 | 36 | 13 | 69 | 118 | 0.110169 | 0 |
| 3 | 3 | C_3 | 28 | 8 | 144 | 180 | 0.8 | 0 |
| 4 | 4 | Total | 64 | 21 | 213 | 298 | 0 | 0 |
| 5 | 5 | P_Accuracy | 0 | 0.619048 | 0.676056 | 0 | 0.526846 | 0 |
| 6 | 6 | Kappa | 0 | 0 | 0 | 0 | 0 | 0.12437 |

FN

Slight Agreement

### Weighted Sum Method-with weight

FP

| | OBJECTID * | ClassValue | C_1 | C_2 | C_3 | Total | U_Accuracy | Kappa |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | C_1 | 0 | 0 | 2 | 2 | 0 | 0 |
| 2 | 2 | C_2 | 33 | 14 | 28 | 75 | 0.186667 | 0 |
| 3 | 3 | C_3 | 31 | 7 | 183 | 221 | 0.828054 | 0 |
| 4 | 4 | Total | 64 | 21 | 213 | 298 | 0 | 0 |
| 5 | 5 | P_Accuracy | 0 | 0.666667 | 0.859155 | 0 | 0.661074 | 0 |
| 6 | 6 | Kappa | 0 | 0 | 0 | 0 | 0 | 0.248076 |

Fair Agreement

### Suitability Modeler Method-without weight

| | OBJECTID * | ClassValue | C_1 | C_2 | C_3 | Total | U_Accuracy | Kappa |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | C_1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 2 | C_2 | 36 | 13 | 70 | 119 | 0.109244 | 0 |
| 3 | 3 | C_3 | 28 | 8 | 145 | 181 | 0.801105 | 0 |
| 4 | 4 | Total | 64 | 21 | 215 | 300 | 0 | 0 |
| 5 | 5 | P_Accuracy | 0 | 0.619048 | 0.674419 | 0 | 0.526667 | 0 |
| 6 | 6 | Kappa | 0 | 0 | 0 | 0 | 0 | 0.123204 |

FN

Slight Agreement

### Weighted Sum Method- without weight

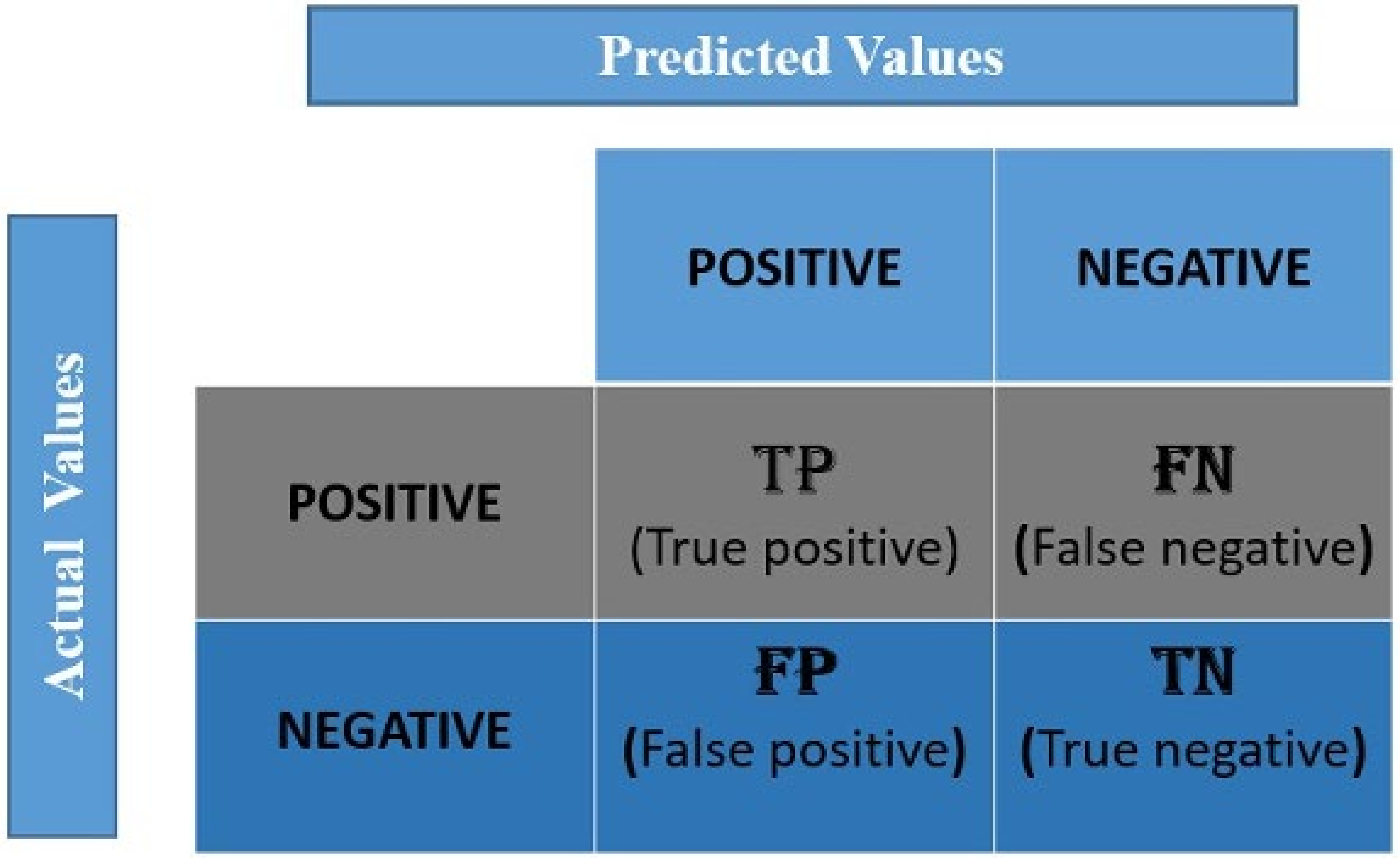
| | OBJECTID * | ClassValue | C_1 | C_2 | C_3 | Total | U_Accuracy | Kappa |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | C_1 | 0 | 0 | 7 | 7 | 0 | 0 |
| 2 | 2 | C_2 | 36 | 13 | 48 | 97 | 0.134021 | 0 |
| 3 | 3 | C_3 | 28 | 8 | 159 | 195 | 0.815385 | 0 |
| 4 | 4 | Total | 64 | 21 | 214 | 299 | 0 | 0 |
| 5 | 5 | P_Accuracy | 0 | 0.619048 | 0.742991 | 0 | 0.575251 | 0 |
| 6 | 6 | Kappa | 0 | 0 | 0 | 0 | 0 | 0.159629 |

Slight Agreement

# Model Validation – Confusion (Error) Matrix

## Reference

- CM (confusion matrix) computes errors of omission and commission and derives a **kappa index of agreement**, **Intersection over Union (IoU),** and an **overall accuracy** between the classified map and the reference data.
- Kappa index of agreement gives an overall assessment of the accuracy of the classification.
- **User's accuracy** shows **false positives** in which pixels are incorrectly classified as a known class when they should have been classified as something else.
- **Producer's accuracy** is a **false negative** in which pixels of a known class are classified as something other than that class.
- **Intersection over Union (IoU)** is the area of overlap between the predicted segmentation and the ground truth divided by the area of union between the predicted segmentation and the ground truth. The mean IoU value is computed for each class.




| Value Range | Cohen's Interpretation | McHugh's Interpretation |
|---|---|---|
| Below 0.20 | None to slight agreement | No agreement |
| .21–.39 | Fair agreement | Minimal agreement |
| .40–.59 | Moderate agreement | Weak agreement |
| .60–.79 | Substantial agreement | Moderate agreement |
| .80–.90 | Almost perfect agreement | Strong agreement |
| Above .90 | Almost perfect agreement | Almost perfect agreement |

# Conclusion

- **Model Output** Selecting unequal weighting for both methods is recommended instead of equal weighting based on the model parameters criticality and importance. This would also justify expert opinions as the equal weighting method is not recommended by most experts and studies.
- **Model Validation** Kappa Index validates output of **Weighted Sum with weight performed well** with 24.8 % (fair agreement) between classified and ground truth data.

Weighted Sum without weight 15.9 % accuracy (slight agreement)

Suitability Modeler with weight 12.4 % accuracy (slight agreement)

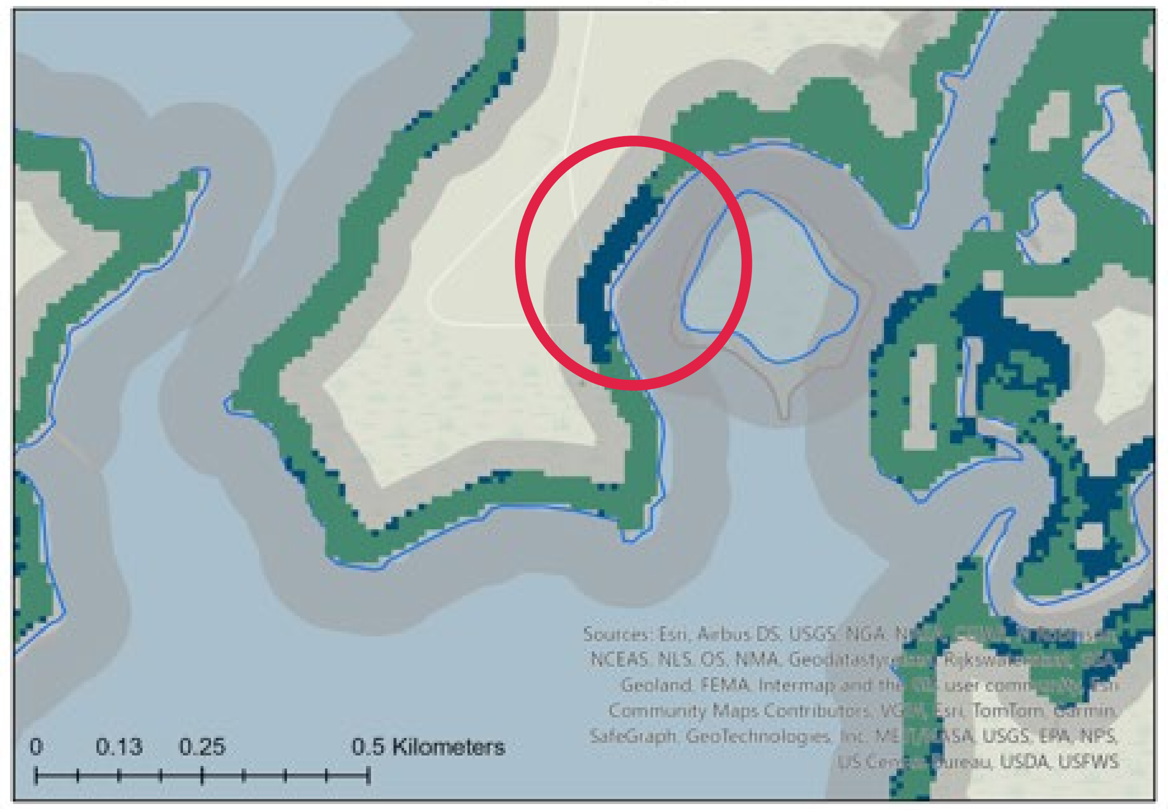
Suitability Modeler without weight 12.3 % accuracy (slight agreement)

- **Model Execution/ Pros & Cons** Weighted Sum offer more independence whereas Suitability Modeler in a unified tool and can be confusing for some users for variety of task performed in one window.
- This study also suggests having ground surveys to better understand the local site condition before planning for any LS and did not include any site surveys as a part of the project.
- We also recommend running the model with both methods (weighted sum and pro modeler) to compare the model outputs and to explore the advantages/disadvantages both have to offer.

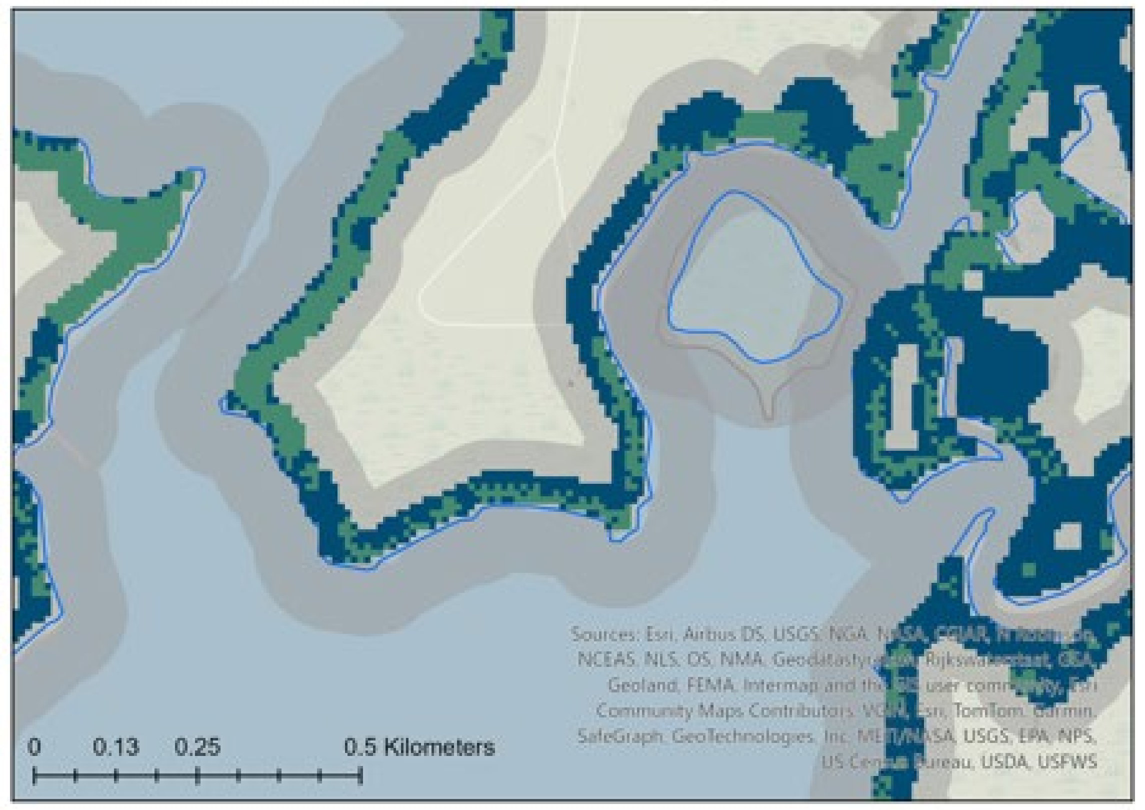
# Segments Analysis and Validation through LSFM

## Segment 1

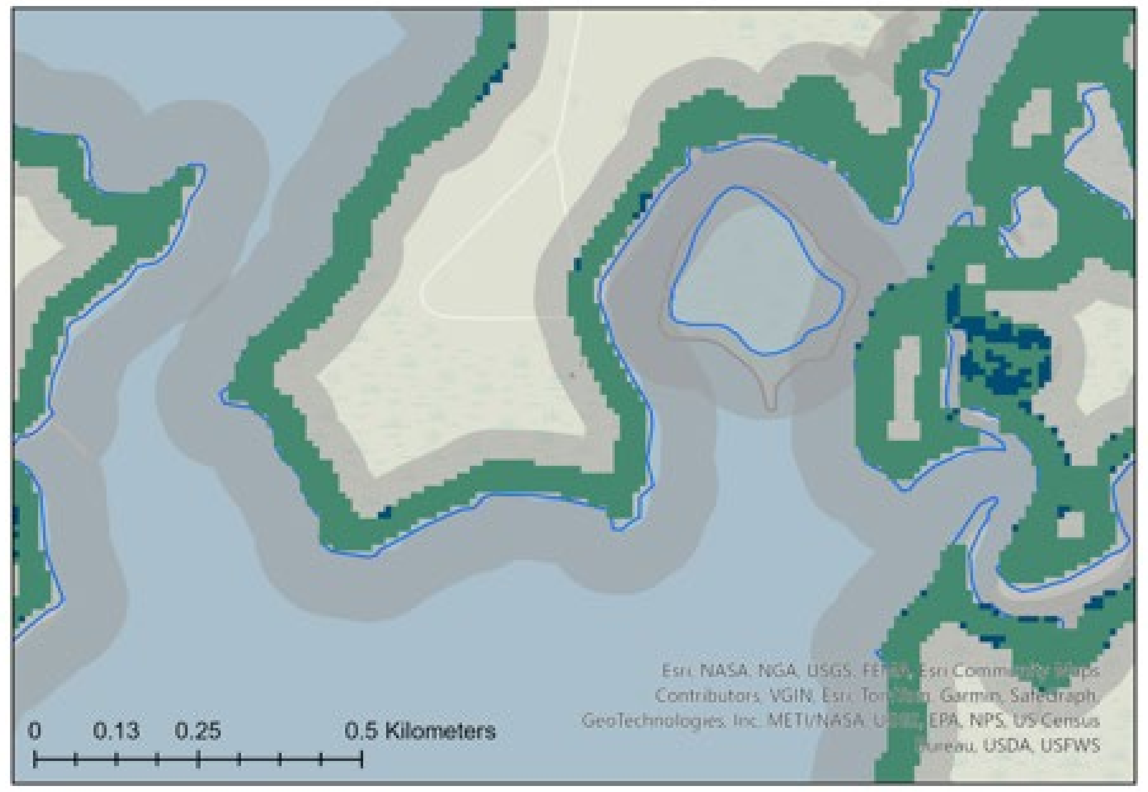
SM With Weight



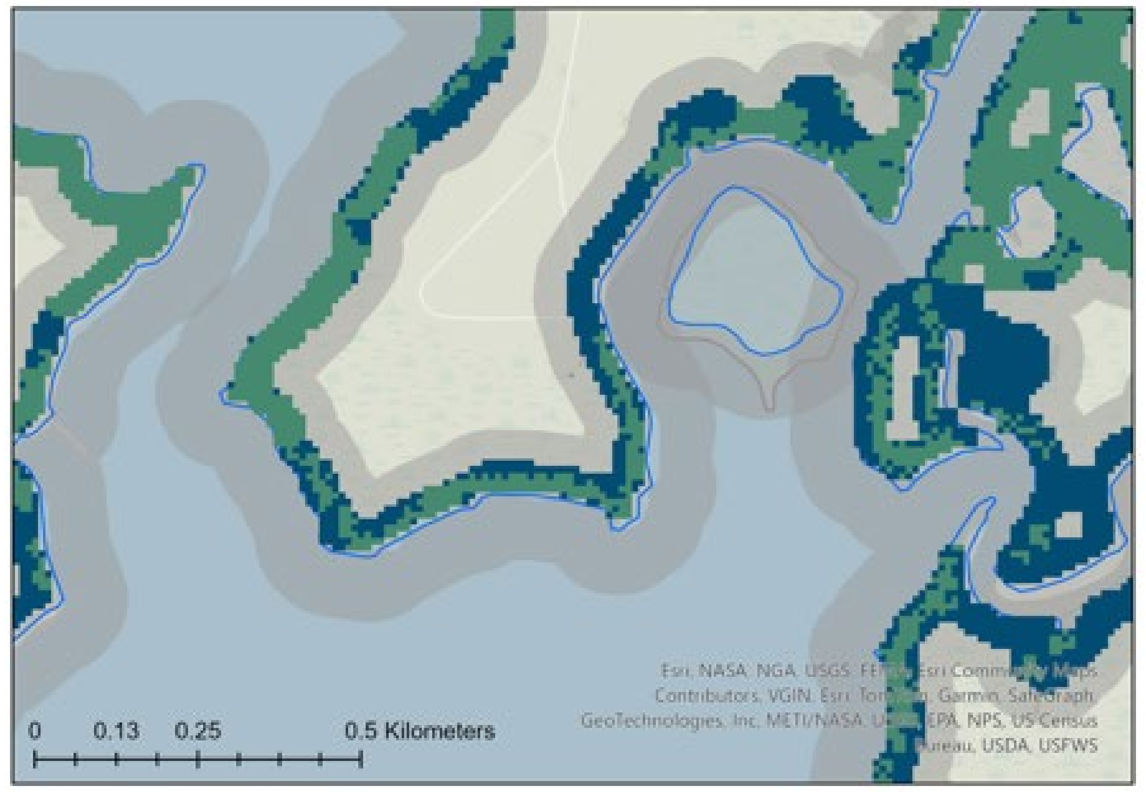

WS With Weight




SM Without Weight




WS Without Weight




LSFM Tool Score 126.5

PHYSICAL CONDITIONS (Total 85)

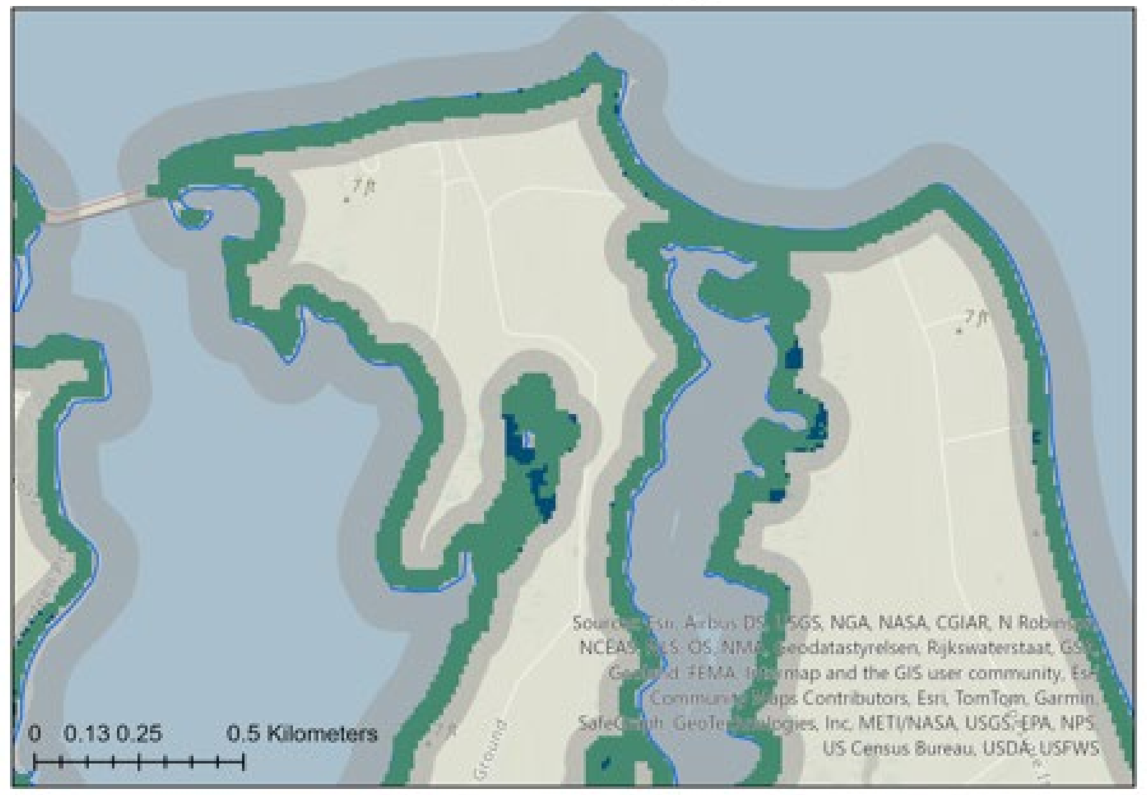
ECOLOGICAL CONDITIONS (Total 40)

## Segment 2

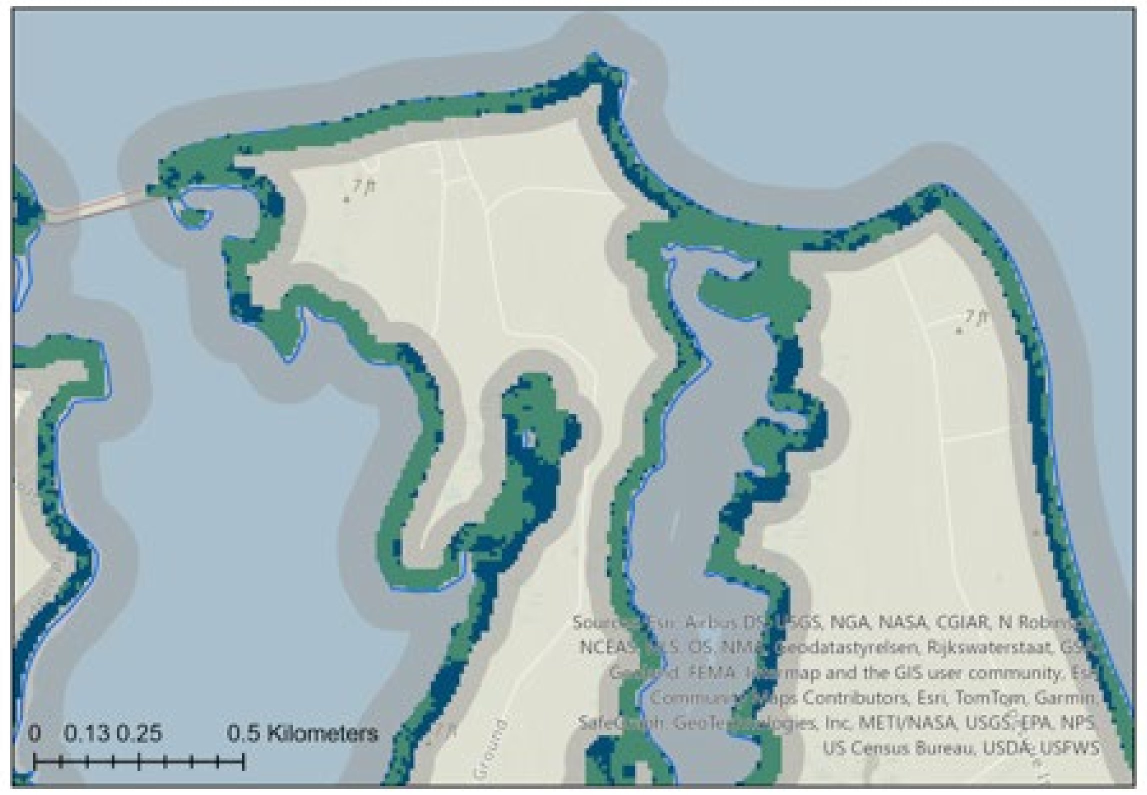
SM With Weight


WS With Weight


SM Without Weight




WS Without Weight



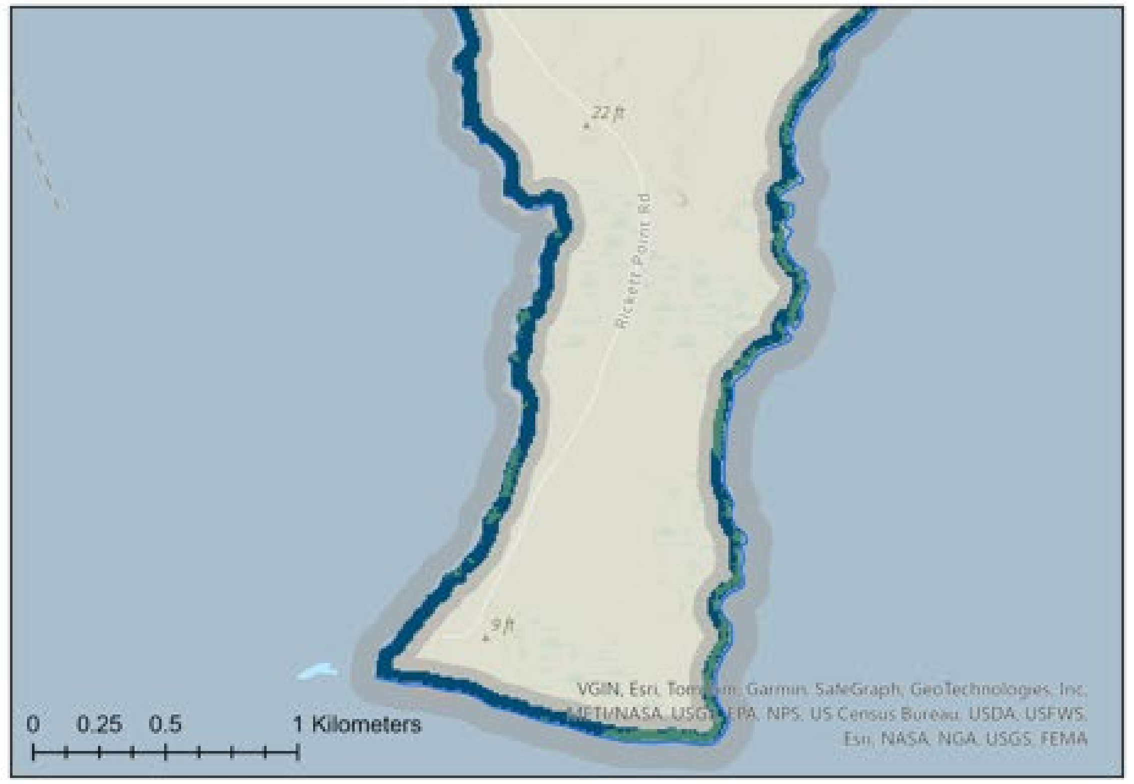

LSFM Tool Score 83

# Segments Analysis and Validation through LSFM

## Segment 3

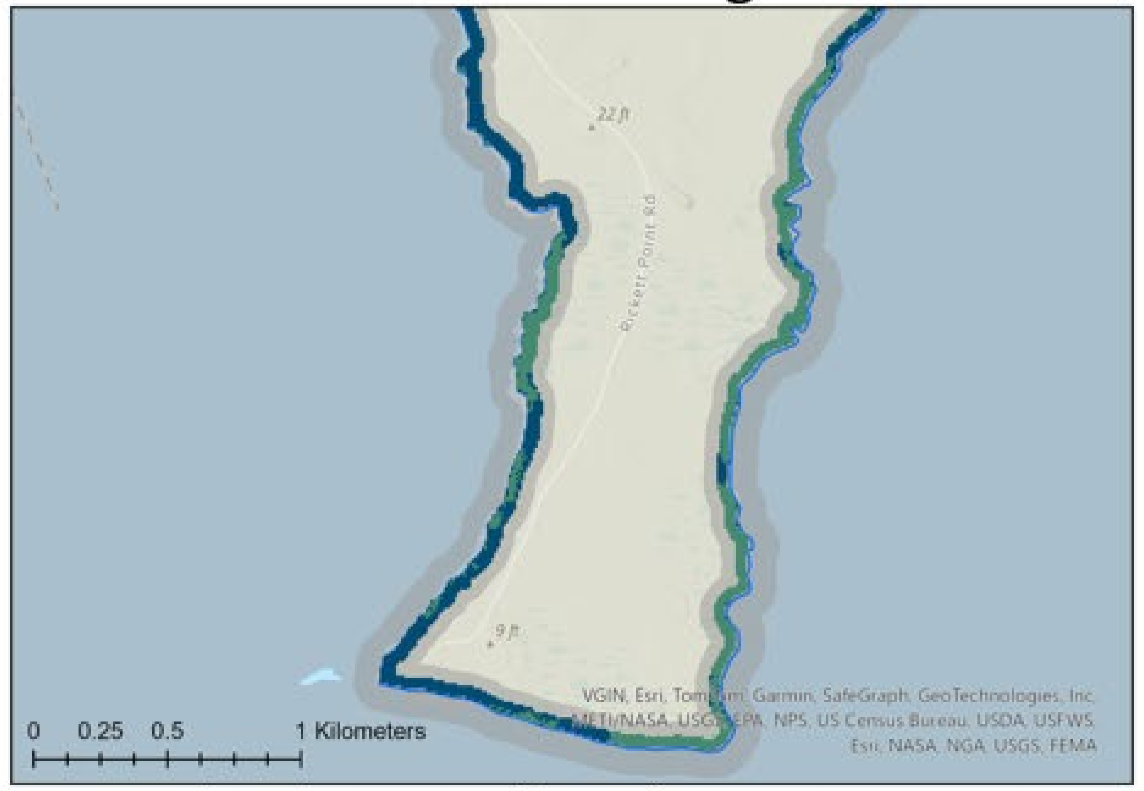
SM With Weight


WS With Weight




SM Without Weight


WS Without Weight



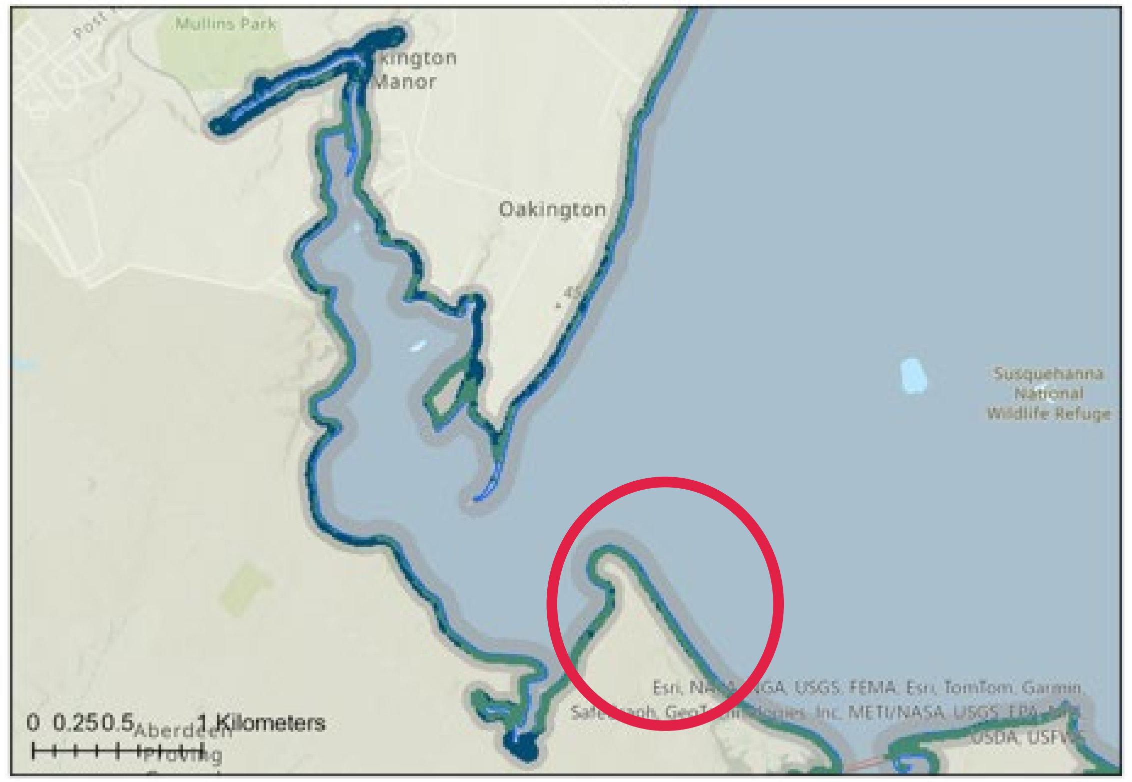

LSFM Tool Score 100.5

PHYSICAL CONDITIONS (Total 85)

ECOLOGICAL CONDITIONS (Total 40)

## Segment 4

SM With Weight




WS With Weight

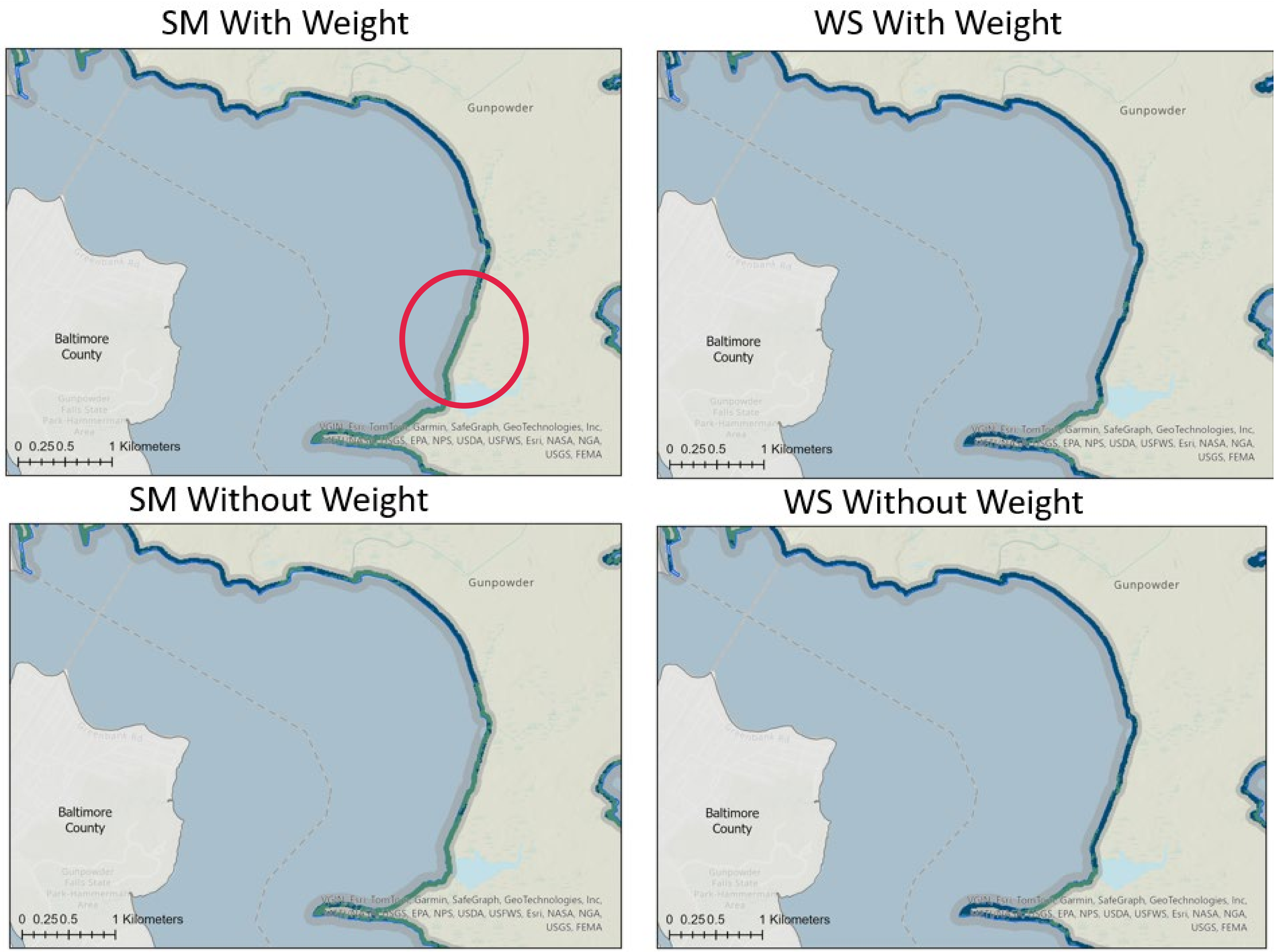

SM Without Weight


WS Without Weight


LSFM Tool Score 84

# Segments Analysis and Validation through LSFM

Segment 5




LSFM Tool Score 101.5

PHYSICAL CONDITIONS (Total 85)

ECOLOGICAL CONDITIONS (Total 40)

## LSFM Validation Results

- Higher score validates suitable for living shorelines
- Lower score validates suitable for living hybrid solutions

# Limitations, Challenges, Strengths, and Suggestions

- **Dependency on data precision, availability and analysis** - The model accuracy is entirely linked with **data precision, availability and analysis** and there are always chances of on-ground changes after data has been collected, particularly if data is not as current. This model, however, emphasizes the importance of current and accurate data, which have a tendency to alter the output.
- **physical changes caused by nature** - Most models fail to identify **site-specific anthropogenic conditions and/or any other environmental and physical changes caused by nature** including this one. This may include any structure, physical feature, or other unfavorable condition that the model cannot predict.
- **Errors in observation** - It's also a possibility that some environmental characteristics may not be readily or correctly observed in the field while collecting survey data or that there might be areas where the actual shoreline conditions may differ from the physical and ecological data run through the model. Therefore, this study also suggests **having a second round of ground surveys to better understand the local site condition before planning for any LS**, as some site surveys have been done by the research team in the start of this research project.

# Limitations, Challenges, Strengths, and Suggestions

- **Model Accuracy** - Another limitation of the suitability modeling is the **problem with no data**. When running the model, the data values must be assigned for areas where there is no available data. This process calculates the actual data values and assigns less scores for a potential site which can otherwise be suitable for either LS or HS. In this study there was no data available for the inner channel of shoreline's segments of APG, which miscalculated the result assigning these areas suitable for HS, whereas they should be classified as suitable for LS.

- **Policies and land regulations** - are another limitation and this study suggested that **LS-related regulations and policies** should be revised and updated as a part of usual municipal comprehensive planning exercises and be included as a section of the Harford County coastal resiliency plan. The Coastal Zone Management Act, or CZMA was passed in 1972 leading to Maryland's Coastal Zone Management Program (CMP) in 1978 which is now called "Chesapeake and Coastal Service (CCS)" – 2007.

- **Permitting and regulatory process -** For other study areas, the **mechanics and delay in permitting and regulatory process** can be discouraging and delay the design and installation process but APG site is a state-owned institutional land where this issue might not exist.

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## Websites for GIS Data, Maps & Reports


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- https://www.usgs.gov/centers/md-de-dc-water/data
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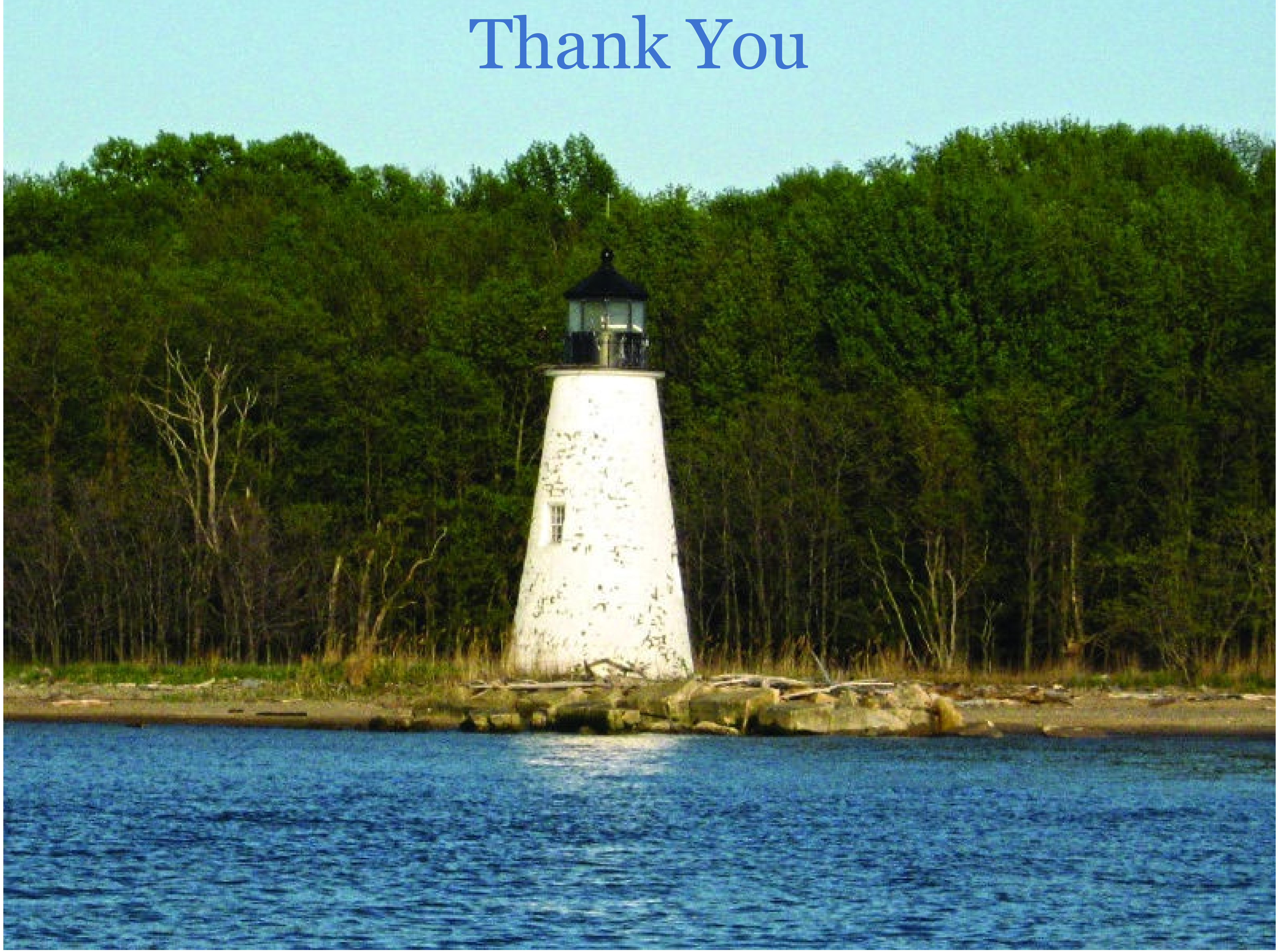
# Thank You



# Thank You