Public Working Meeting for Information Only

Virginia Coastal Resilience Master Plan

Capturing the "Total" Flood Hazard

December 1, 2021 10am - 12pm

Virginia Department of Conservation & Recreation

Agenda

Welcome and Convening Language - Rear Admiral Phillips, SACAP

"Total" Future Flood Hazard Overview - Matt Dalon, DCR

Pluvial/Rainfall-Driven Flood Hazard - Seth Lawler, Dewberry

Fluvial/Riverine Flood Hazard - Mat Mampara, Dewberry

Compound Flood Hazard - Shubra Misra, TWIG

Coastal Erosion/Landscape Changes - Brain Batten, Ioannis Georgiou, and Chris Esposito, Dewberry/TWIG

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Public Meeting Information

- Meeting is being recorded
- Meeting information available through the Commonwealth calendar
  - Agenda
  - Read Ahead Materials
  - Presentations
  - Meeting Minutes

- Visit the SNHR Website
  - *virginia.gov/coastalresilience*
- DCR Master Plan Website
  - Coming Soon
- If you have any questions or comments, please send a message to:
  - resilientcoastVA@governor.virginia.gov
  - matt.dalon@dcr.virginia.gov
  - ann.phillips@governor.virginia.gov

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Virginia Coastal Resilience Master Plan Overview

Virginia Department of Conservation & Recreation

Virginia Focus ~
Coastal Resilience Master Planning Process

Commonwealth of Virginia
Office of the Governor

Executive Order

NUMBER TWENTY-FOUR (2018)

INCREASING VIRGINIA'S RESILIENCE TO SEA LEVEL RISE AND NATURAL HAZARDS

Importance of the Initiative

Sea level rise, land subsidence, higher average temperatures, more frequent and intense weather events, severe drought, and increased development, have increased risk and will continue to increase and exacerbate risk from natural hazards across the Commonwealth of Virginia. The number of federally declared disasters has steadily increased nationally and in Virginia. The number has experienced a 250 percent increase in federally declared disasters over the past 20 years, including declarations for flooding, hurricanes, severe storms, and wildfire.

The best available science predicts that this trend will continue to worsen. A recent report from the United Nations Intergovernmental Panel on Climate Change states that the world is likely to experience dramatic increases in coastal flooding and severe weather events. Additional studies show that water levels in the Hampton Roads region are now 18 inches higher than they were a century ago, and that they are expected to gain up to five more feet, while the land sinks as much as 7.5 inches, by 2100. That combined rise is faster than anywhere else on the East Coast. The most recent National Climate Assessment reported that the intensity, frequency, and duration of North Atlantic hurricanes, as well as the frequency of the strongest hurricanes, have all increased.

This increase in extreme weather events and natural disasters will continue to have a profound impact on Virginia. It threatens public health and safety, our environment and natural resources, and the economic wellbeing of the Commonwealth, including our ports, military installations, transportation infrastructure, tourism assets, farms, and forests. We must act now to protect lives and property from multiple threats and reduce taxpayer exposure through fiscally responsible planning.

Commonwealth of Virginia
Office of the Governor

Executive Order

NUMBER FORTY-FIVE

FLOODPLAIN MANAGEMENT REQUIREMENTS AND PLANNING STANDARDS FOR STATE AGENCIES, INSTITUTIONS, AND PROPERTY

Importance of the Initiative

Executive Order 24 "Increasing Virginia's Resilience to Sea Level Rise and Natural Hazards," issued in November 2018, set the Commonwealth on a course towards addressing its risk and resilience to natural hazards, including flooding. A key element of that Order required an analysis of flooding and flood preparedness in the Commonwealth. Based on that analysis, the Commonwealth must establish new policies and directives to ensure that necessary actions are taken to protect state property from the risk of floods.

Background

Flooding remains the most common and costly natural disaster in Virginia and the United States. With more than 100,000 miles of streams and rivers, as well as 10,000 miles of estuarine and coastal shoreline, Virginia's flood risk is statewide, comes in many forms, and is increasing because of climate change and increased development in flood-prone areas. In 1987, in order to improve Virginia's flood protection programs and to consolidate all related programs in one agency, responsibility for coordination of all state floodplain programs was transferred from the State Water Control Board to the Department of Conservation and Recreation (DCR). Section 10.1-602 of the *Code of Virginia* names DCR as the manager of the state's floodplain program and the designated coordinating agency of the National Flood Insurance Program (NFIP). The Code stipulates that the Director of DCR or his designee shall serve as the State Coordinator for the NFIP.

DCR's Floodplain Management Program was created to minimize Virginia's flood hazards. In particular, it aims to prevent loss of life, reduce property damage, and conserve natural and beneficial values of state rivers and coastal floodplains. To achieve these goals, DCR promotes

VIRGINIA COASTAL RESILIENCE MASTER PLANNING FRAMEWORK

Principles and Strategies for Coastal Flood Protection and Adaptation

OFFICE OF GOVERNOR RALPH S. NORTHAM
COMMONWEALTH OF VIRGINIA
OCTOBER 2020

Guiding Principles:

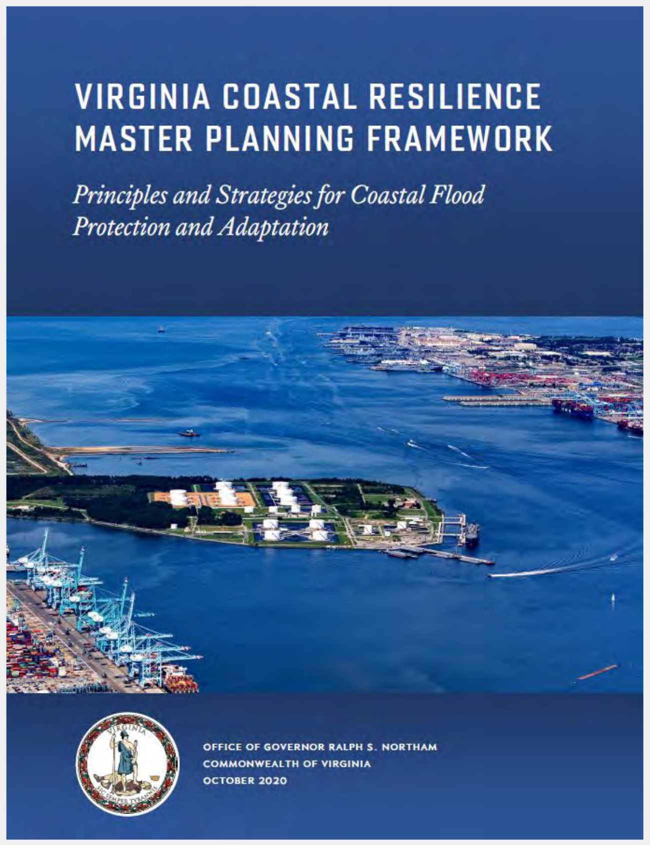
- **Acknowledge climate change and its consequences, and base decision-making on the best available science.**

- **Identify and address socioeconomic inequities and work to enhance equity through coastal adaptation and protection efforts.**

- **Recognize the importance of protecting and enhancing green infrastructure like natural coastal barriers and fish and wildlife habitat by prioritizing nature-based solutions.**

- **Utilize community and regional scale planning to the maximum extent possible, seeking region-specific approaches tailored to the needs of individual communities.**

- **Understand fiscal realities and focus on the most cost-effective solutions for protection and adaptation of our communities, businesses and critical infrastructure.**



Goals:

1. Identify and prioritize projects to increase the resilience of coastal communities, including both built and natural assets at risk due to flooding and sea level rise

2. Establish a financing strategy, informed by regional differences and equity considerations

3. Incorporate and promote climate change projections into Commonwealth's programs addressing coastal adaptation and protection

4. Coordinate state, federal, regional, and local coastal region adaptation and protection efforts

Virginia Coastal Resilience Master Plan Adaptive Management

Virginia Department of Conservation & Recreation

“Total” Future Flood Hazard Overview

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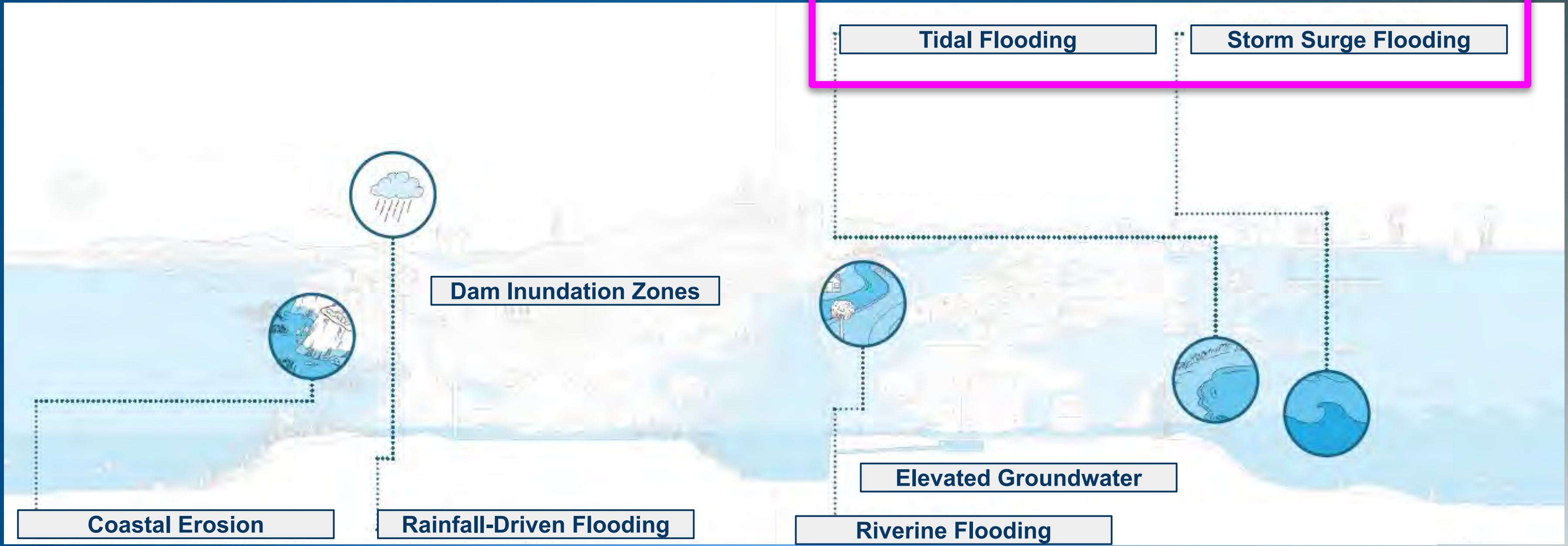
Characterize Hazards - Objective

Develop consumable, current and future, flood hazard products in support of local, regional, and state planning efforts to build flood resilience.

"Total" Flood Hazard

Virginia Coastal Resilience Master Plan
Phase One, December 2021



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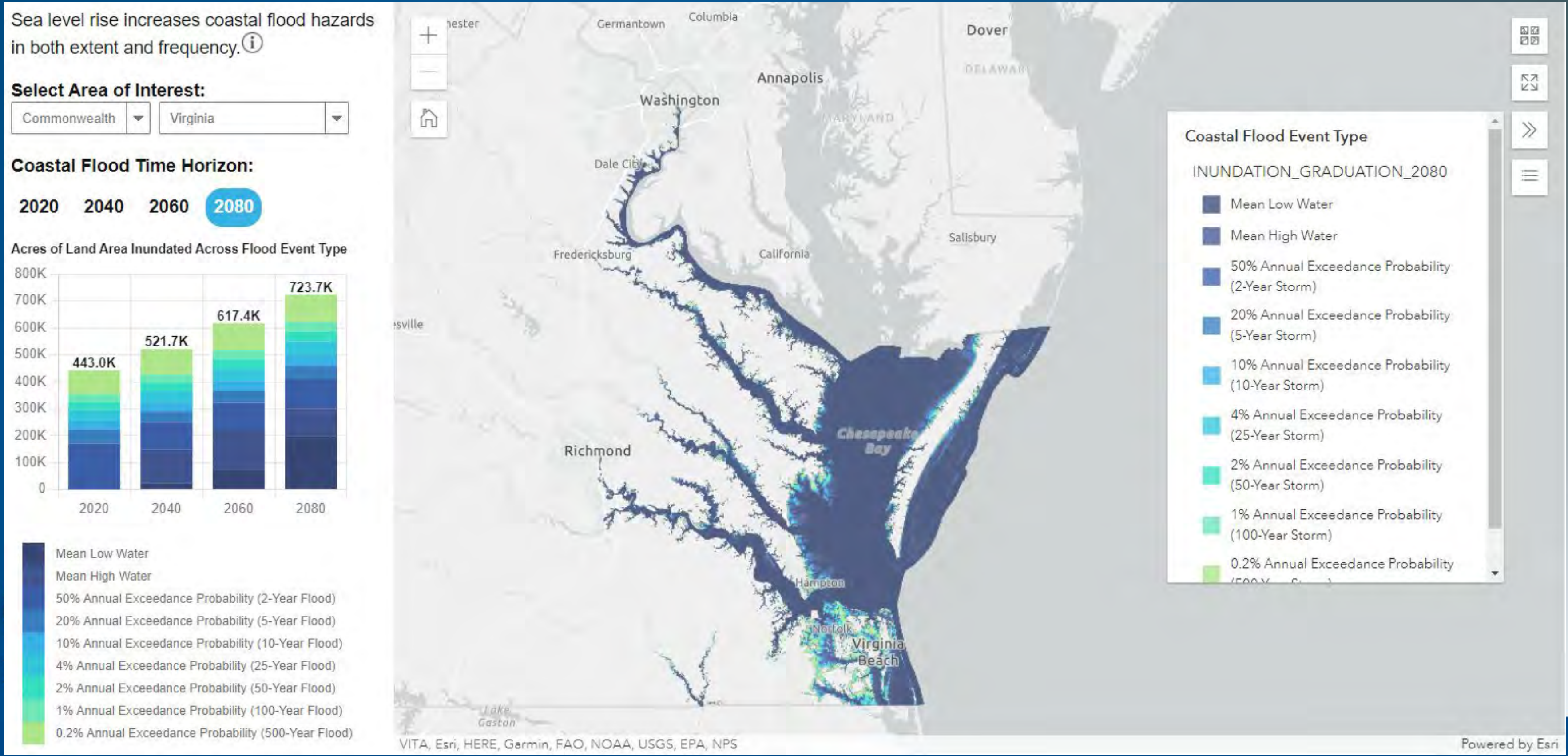
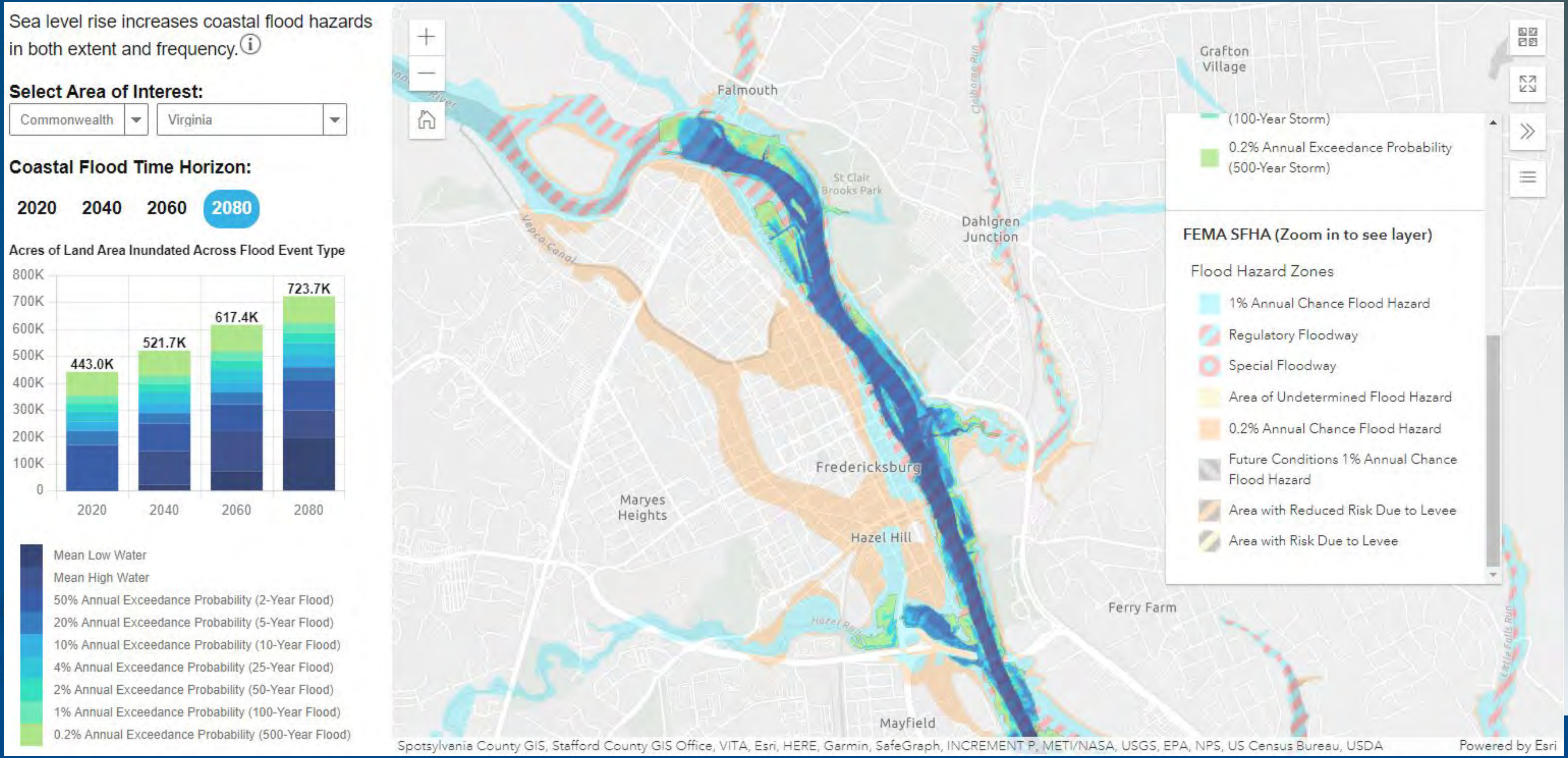
Compound Flooding

Virginia Coastal Flood Hazard



Coastal Flood Hazard ≠ Total Flood Hazard



Master Plan Centralized Survey Results
Flood Hazard Priority by Master Planning Region

Hampton Roads (HRPDC)	Rural Coastal (NNPDC, MPPDC, A-NPDC)	Fall Line South (Crater PDC, PlanRVA)	Fall Line North (NVRC, GWRC)
1. **Rainfall-Driven Flooding**	1. **Rainfall-Driven Flooding**	1. **Rainfall-Driven Flooding**	1. **Rainfall-Driven Flooding**
2. Storm Surge Impacts	2. Tidal Flooding	2. Riverine Flooding	2. Riverine Flooding
3. Tidal Flooding	3. Coastal Erosion	3. Tidal Flooding	3. Coastal Erosion
4. Riverine Flooding	4. Storm Surge Impacts	4. Storm Surge Impacts	3. Tidal Flooding
5. Coastal Erosion	5. Groundwater Impacts	5. Coastal Erosion	5. Storm Surge Impacts
6. Groundwater Impacts	6. Riverine Flooding	6. Groundwater Impacts	6. Groundwater Impacts

Planning for the “Total” Future Flood Hazard

WHAT - Flood Component

Rainfall-Driven | Riverine | Compound | Erosion | Groundwater

WHERE - Scale

Local | Regional | State

WHEN - Timing

Short-Term | Long-Term

**** COORDINATION WITH LOCAL, REGIONAL, AND STATE STAKEHOLDERS ****

Draft Future Flood Condition Modeling Plan

Short-Term (2022-2023)	**Long-Term (2023-2025)**
Rainfall-Driven • HEC-RAS 2D Pluvial Flood Model • Current and Future Conditions • Multiple Durations and Recurrence Intervals Riverine • Non-Stationarity Analysis Compound Flooding • Regional Compound Flooding Potential Coastal Erosion/Landscape Changes • Simplified Coastal Erosion Prediction • Landscape Evolution Planning	Rainfall-Driven • Process Improvements Riverine • HEC-RAS 2D Fluvial Flood Model • Current and Future Conditions • Multiple Recurrence Intervals Compound Flooding • Develop Joint Flood Hazard with AEPs Coastal Erosion/Landscape Changes • Landscape Evolution Modeling

Questions?

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Flood Factors

- Climate Change
  - Rainfall amount and storm distribution
  - Type of precipitation
  - Sea level rise
  - Tailwater elevations
- Population change
- Demographic change
- Land use/development change
  - Drainage area size, shape, and orientation
  - Storage potential
  - Watershed development potential
  - Type of soil
  - Slopes of terrain and stream(s)
  - Antecedent moisture condition
  - Ground cover

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Virginia Coastal Resilience Master Plan

Future Conditions Modeling Options

12/1/2021

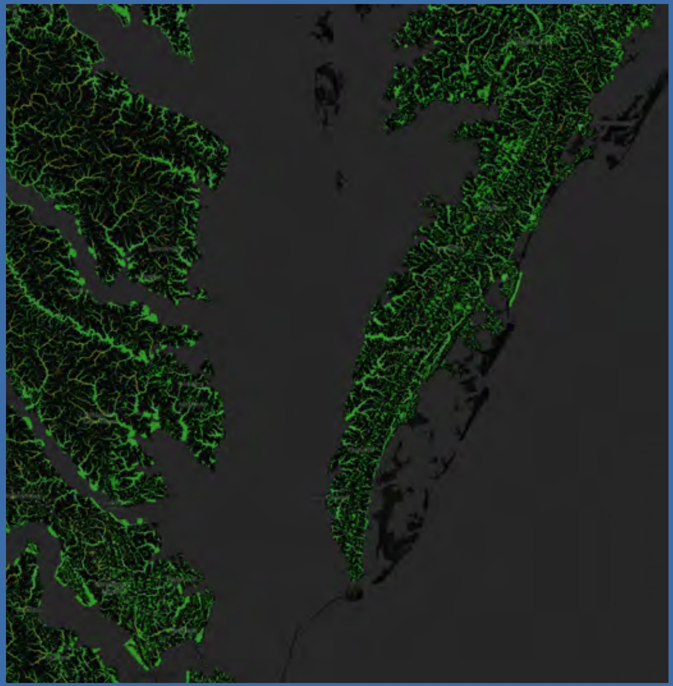
Overview

- Short-Term Activities
  - Pluvial
  - Fluvial
  - Compound Flooding Potential
  - Coastal Erosion
    - Simple Shoreline Retreat
    - Coastal Landscape Change

Pluvial

Need for Pluvial and Key Requirements

- Need
  - FEMA estimates ~40% of flood damage occurs from pluvial events
  - Existing data is limited as focus has been on riverine and coastal sources
  - Existing data is not accessible
- Requirements
  - High-resolution Topography
  - Meteorological Data
  - Land Use Information
  - 2D models subject to multiple constraints
  - Computing Resources



Goal:

Develop defendable and reusable pluvial hazard information using a consistent, detailed, and modern approach.

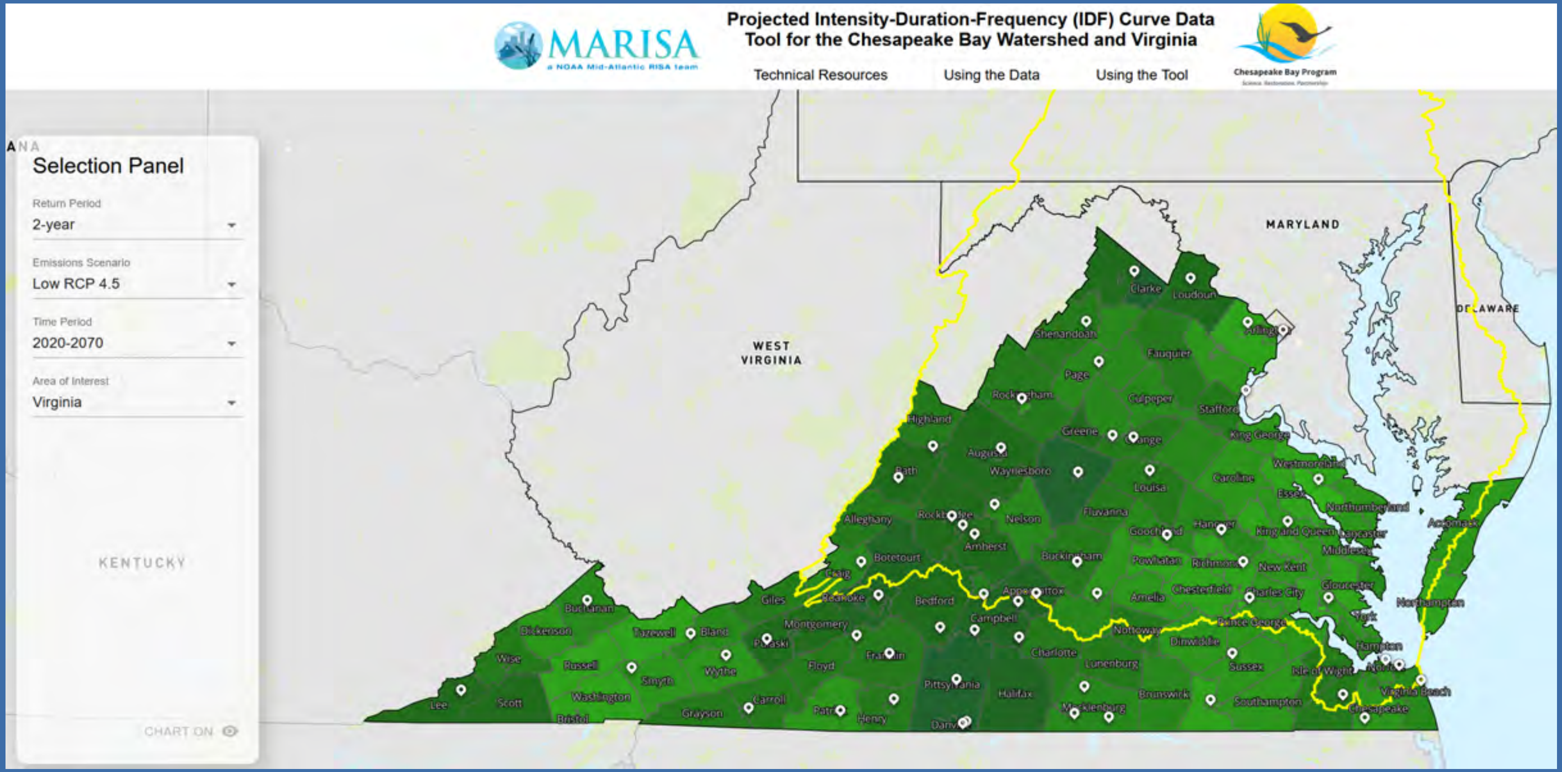
Pluvial: Proposed Approach

- Iterative approach to modeling
- HEC-RAS 2D hydraulic models
- Multiple frequency/climate scenarios
- Flexible basin sizing
- Automated mesh development
- Leverage available datasets to improve hydraulic pathways

Pluvial: Event Selection

~48 simulations per basin

- 3 Storm Durations
  - 2-hr, 6-hr, 24-hr
- 4 Storm Frequencies
  - 10-yr, 50-yr, 100-yr, 500-yr
- 2 Tidal Conditions
  - MLW (typical low tide)
  - MHW (typical high tide)
- 2 Climate Scenarios
  - Current Conditions
  - 8.5 RCP Future Conditions



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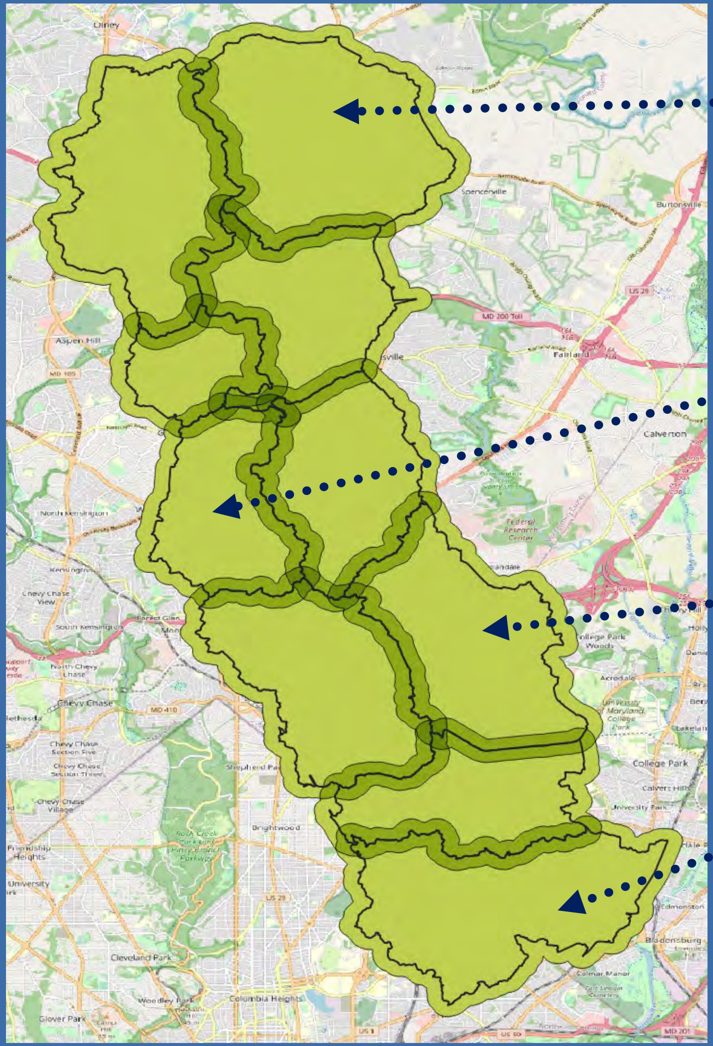
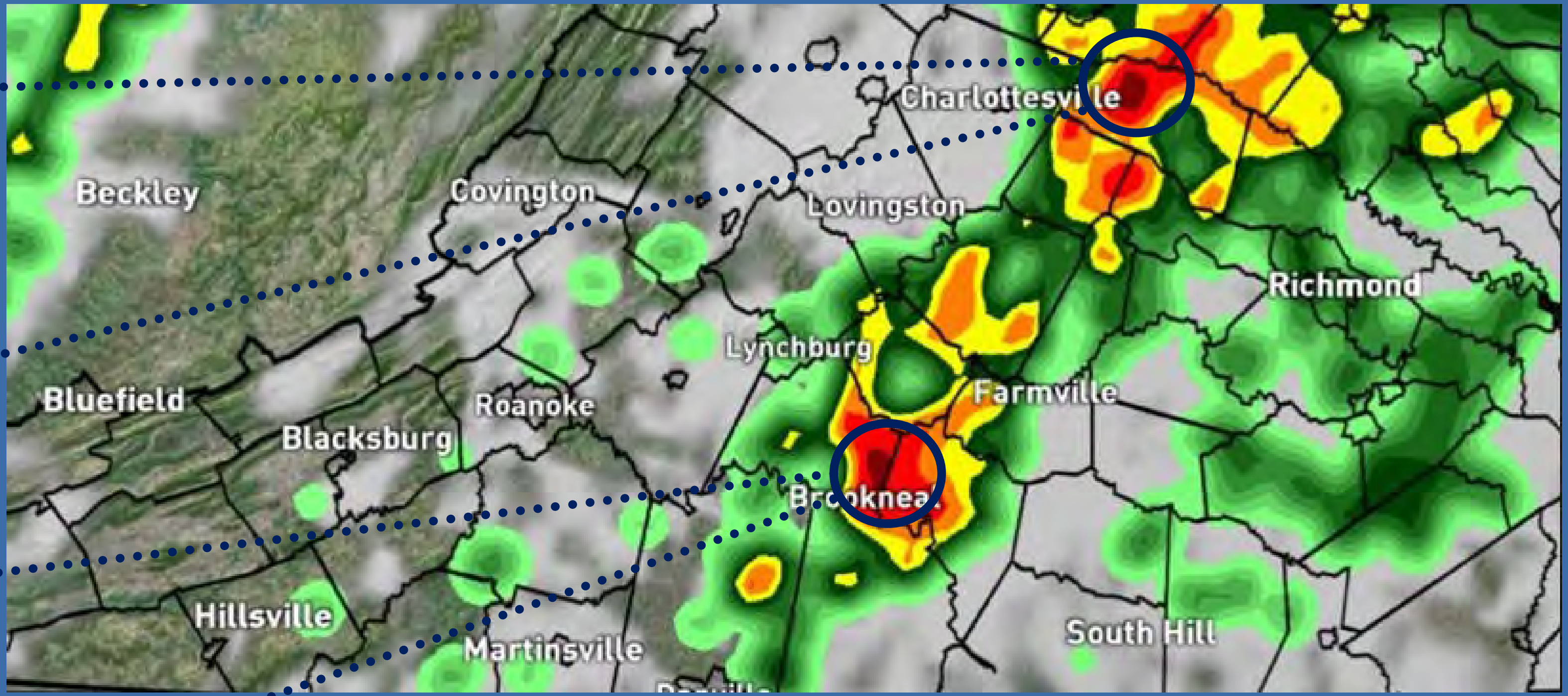
Pluvial: Basin Sizing





- HUC12’s divided into smaller subbasins ~5-7 mi^2
- Process provides ability to develop basin appropriate drainage

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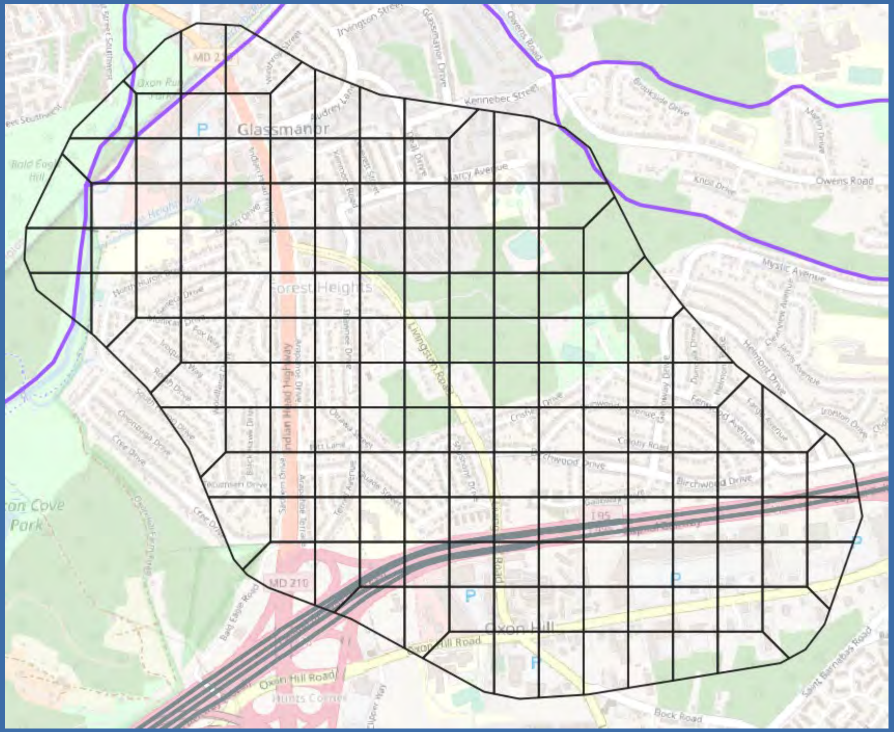
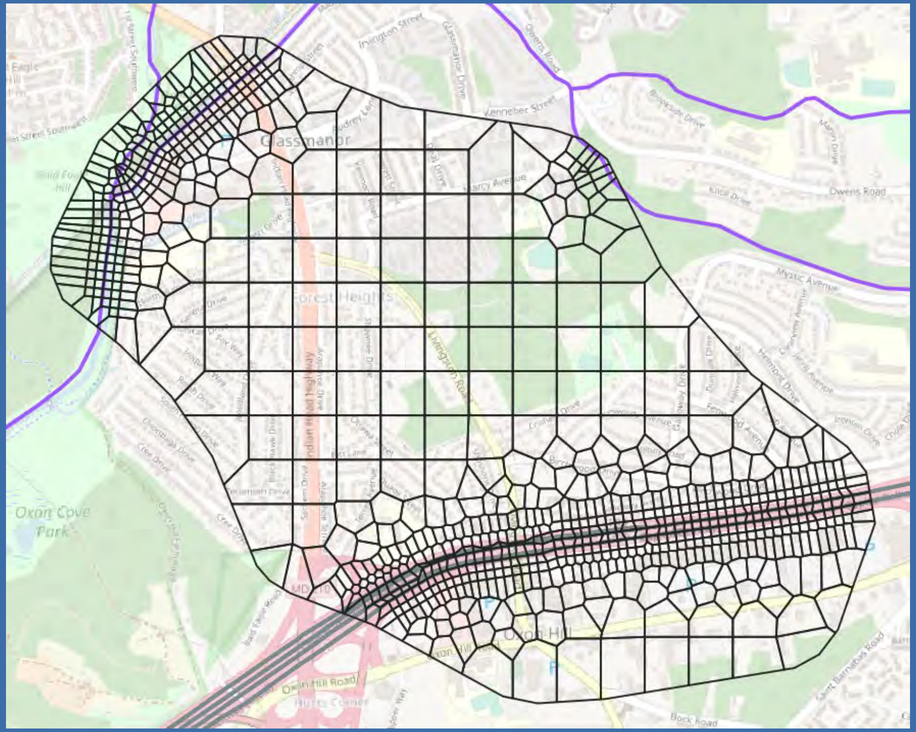
Pluvial: Integrating Existing Data

Automated break lines enable tightened, oriented mesh near NHD stream lines and near TIGER road lines.



Raw mesh



Mesh improved via breaklines along streams and roads

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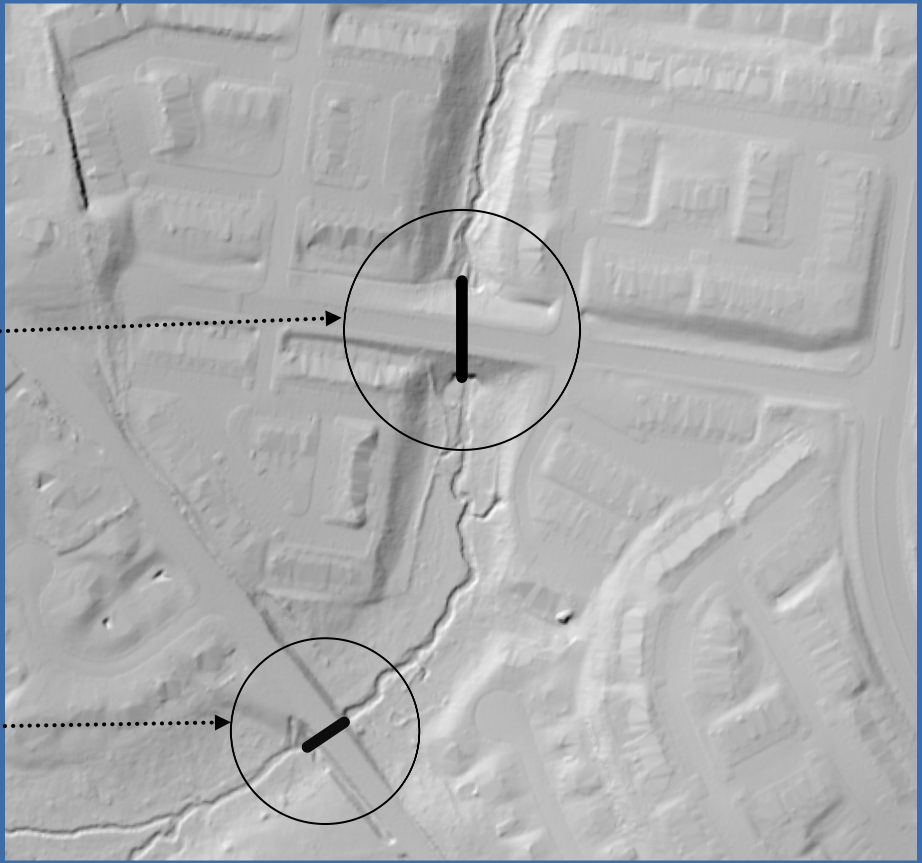
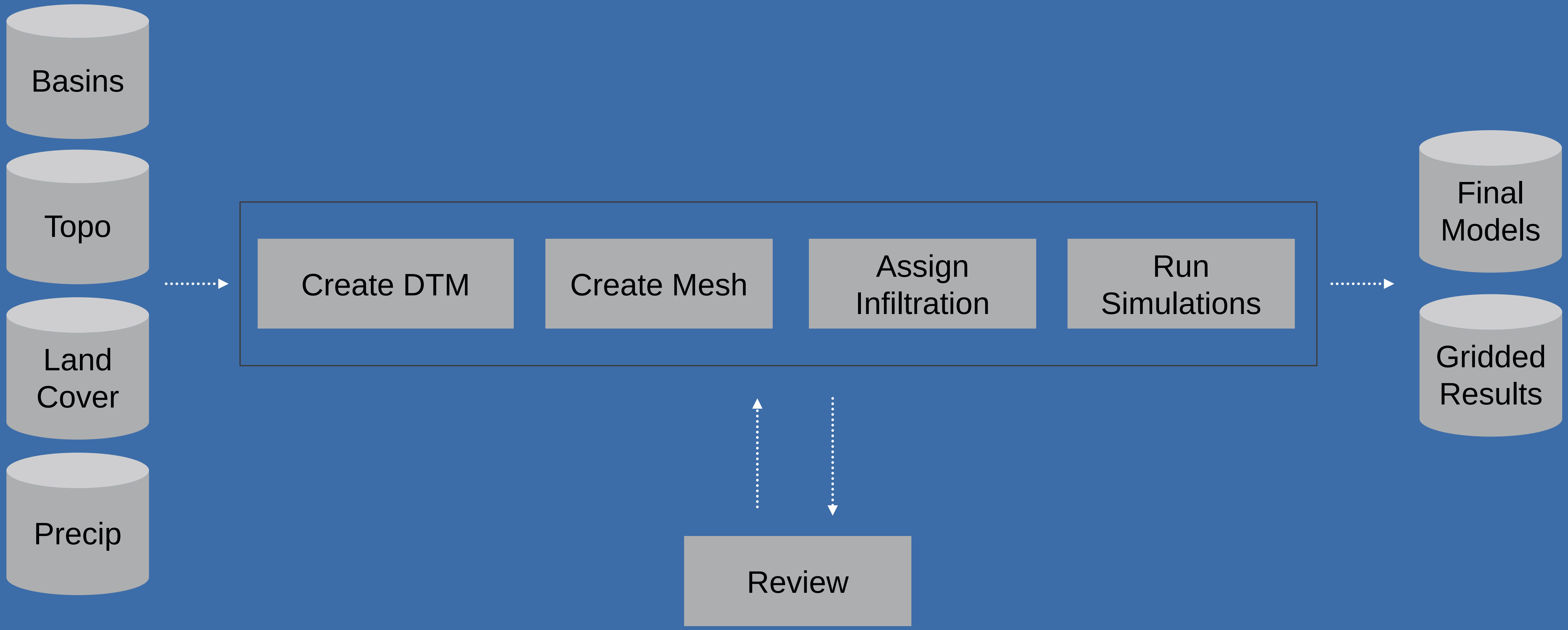
Pluvial: Hydraulic pathways

Raw DEM



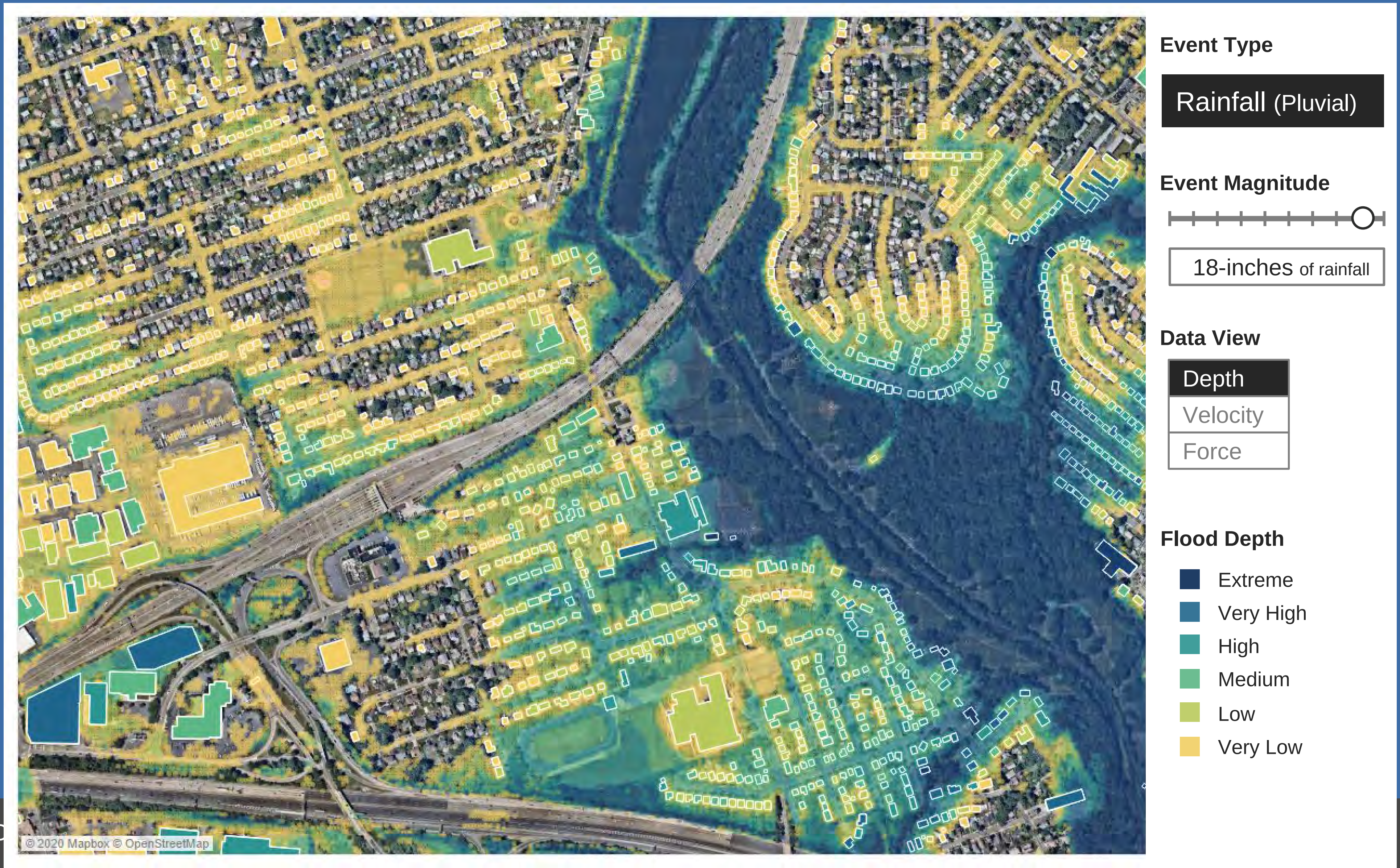
Proposed burn lines along streams

Framework: Pilot & Production



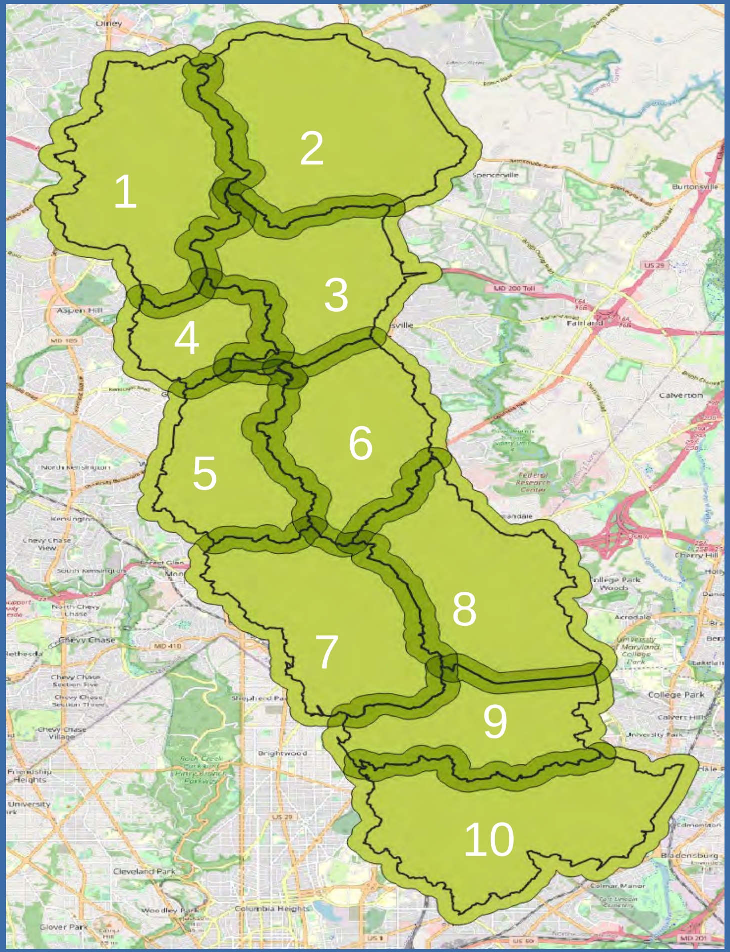
Pilot representative sample of the ~3K Basins

Pluvial: Products



Pluvial: Update Data

- Rerun when new frequency data is available
- Connectivity of subbasin models
- Addition of hydraulic structures
- Additional scenarios
- Compound flooding scenarios



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Example Existing Data/Methods in Virginia

- No state-wide resource
- No direct federal resources
- Available at the locality level
- Currentness and detail depends on local resources and investments

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Potential Long-term Enhancements

- Pluvial
  - Enhance the 2022 pluvial models and derived products
    - Develop need-based prioritization for enhancements
    - Update topographic data, if needed
    - Add additional storm durations and climate scenarios, if needed
    - Improve forcing data
    - Enhanced precipitation statistics, i.e., stochastic storm transposition
    - Incorporate new features into models
    - Build more sophisticated custom applications for interacting with results
    - Create graduated probabilistic future condition products for CRMP end-use

Fluvial Non-Stationarity

Needs

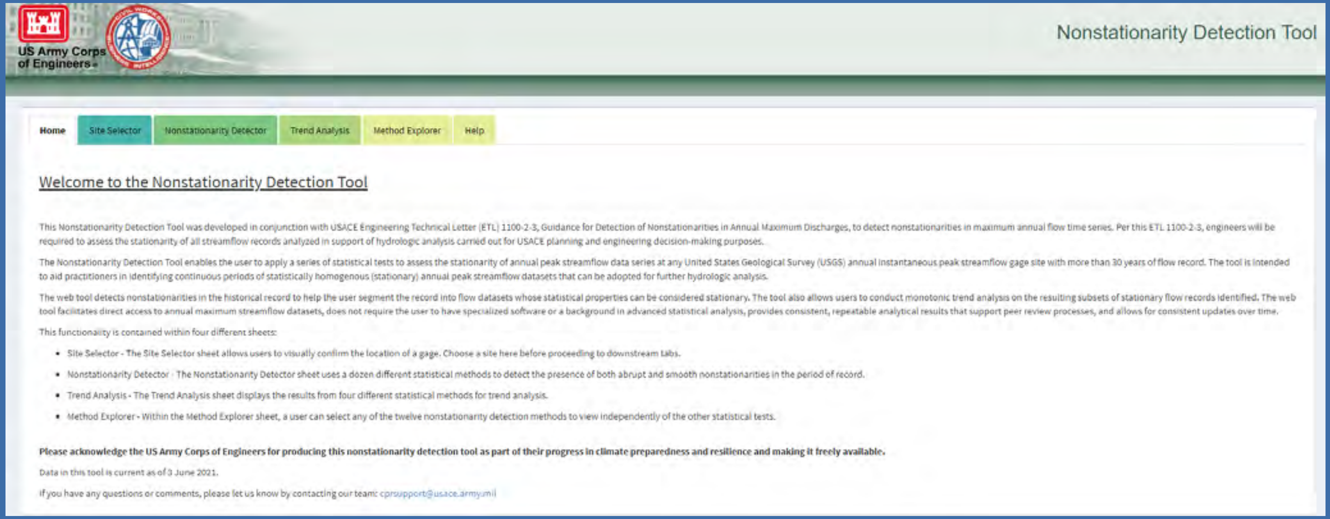
- The magnitude and intensity of precipitation events have increased
- Where, and how much are these increases are translating into increased fluvial flood events?

Goal:

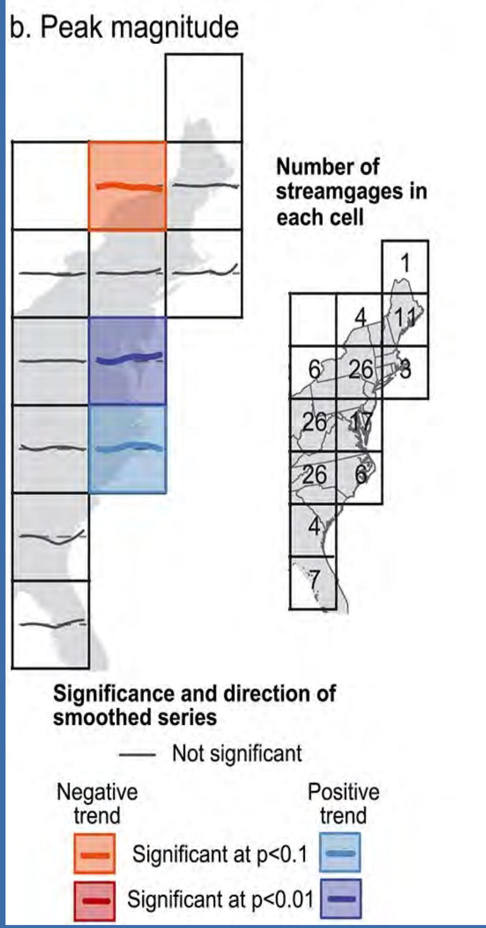
Apply proven techniques to detect and quantify trends in fluvial hazards to a) inform scoping and prioritization of longer-term analyses, and b) provide valuable information to aid design and resilience activities.

Example Existing Data/Methods

- Archfield, S.A., et al (2016)
- USACE Climate Preparedness and Resilience Tools



Trends (1940 to 2013): Peak Daily Streamflow of Flood Events
Ref: Archfield, S.A. et al (2016), "Fragmented patterns of flood change across the United States". https://doi.org/10.1002/2016GL070590.



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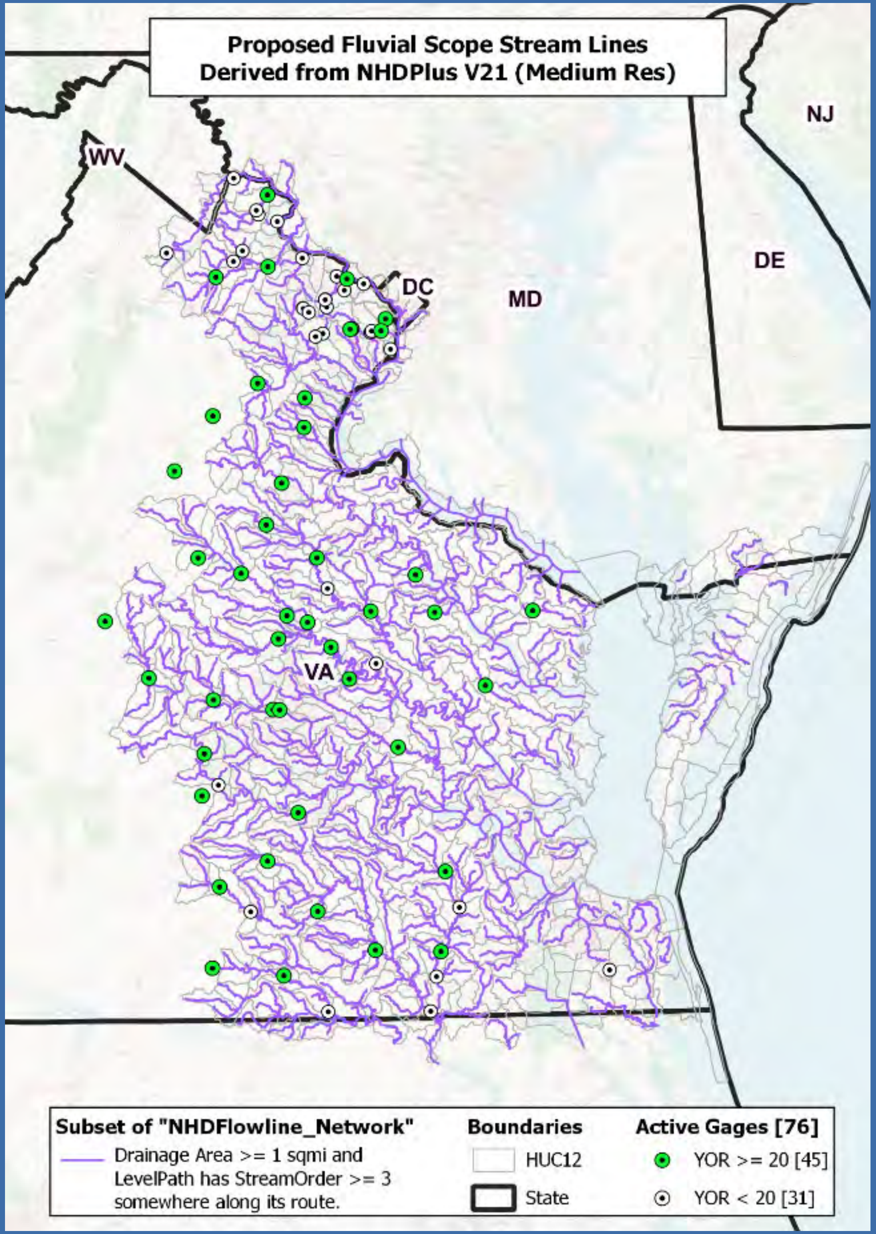
Activities

- Identify candidate USGS stream gages
- Evaluate gages
  - quality of the data
  - historic changes in collection
  - natural phenomena
  - data gaps
- Reviewing raw data
  - identify variability and changes, spatial patterns
- Apply Test Statistics- following ETL1100-2-3, “Guidance for Detection of Non-Stationarities in Annual Maximum Discharge”
- Identify implications
- Develop report on needs, methods, and results



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Benefits

- Establish foundation to understanding fluvial flood hazard trends
- Support scoping and prioritizing fluvial reaches for updated hydrologic and hydraulic analyses, as part of the longer term, 2026 efforts.
- Inform water resources management, engineering, and resilience activities

Potential Long-term Enhancements

- Fluvial
  - Determine priority reaches for fluvial model development
  - Prepare data for fluvial hazard characterization
  - Develop fluvial hydrologic input datasets
  - Develop unsteady-state, HEC-RAS 2D fluvial flood models for each fluvial model domain
  - Extract and host meaningful results from fluvial models

Compound Flood Potential

Needs

- Multiple independent or dependent flood hazards can occur simultaneously
- Co-occurrence can worsen flood conditions and impacts
- Existing information is limited about compound hazards
- Compound flood hazards projected to worsen in the future with climate change
- Both planning and engineering activities should consider full potential of combined flood hazards

Goal:

Perform a quantitative assessment of dependencies between coastal, fluvial, and pluvial hazards, for both existing and future conditions, to establish the dominance, relative importance, and geographic extents of combined flood hazards to fully inform modeling and mapping efforts.

Example Existing Data/Methods in Virginia

- VDOT:
  - Guidance for tailwater/stream relationships

9.4.9.2 Tailwater and Outfall Considerations

For most design applications, the tailwater will either be above the crown of the outlet or can be considered to be between the crown and critical depth. In determining the HGL, begin with the actual tailwater elevation or an elevation equal to 0.8 times the diameter of the outlet pipe (0.8D), whichever is higher.

When estimating tailwater depth on the receiving stream, the designer should consider the joint or coincidental probability of two events occurring at the same time. For the case of a tributary stream or a storm drain, its relative independence may be qualitatively evaluated by a comparison of its drainage area with that of the receiving stream. A short duration storm, which causes peak discharges on a small watershed, may not be critical for a larger watershed. Also, it may safely be assumed that if the same storm causes peak discharges on both watershed, the peaks will be out of phase. To aid in the evaluation of joint probabilities, refer to Table 9-4 Joint Probability Analyses.

Table 9-4 Joint Probability Analyses

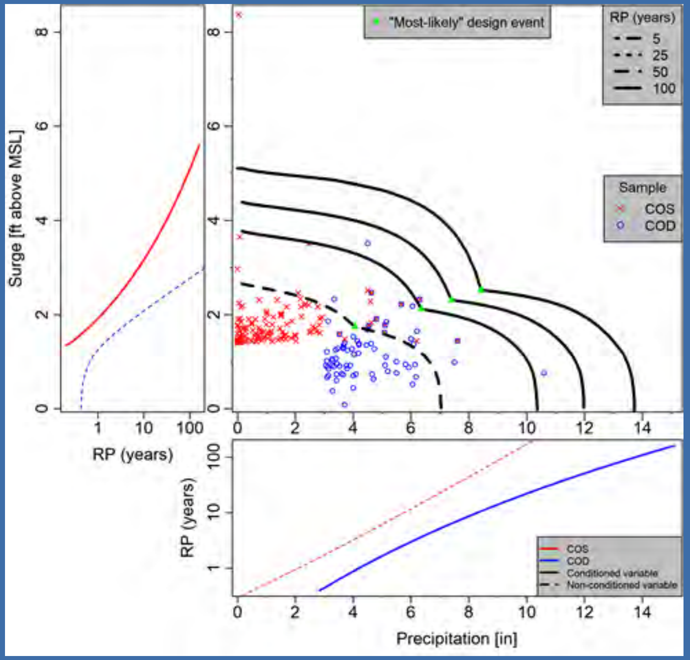
Watershed Area Ratio	Frequencies For Coincidental Occurrence			
	10-Year Design		100-Year Design	
	Main Stream	Tributary	Main Stream	Tributary
10 000 TO 1	1 10	10 1	2 100	100 2
1 000 TO 1	2 10	10 2	10 100	100 10
100 TO 1	5 10	10 5	25 100	100 25
10 TO 1	10 10	10 10	50 100	100 50
1 TO 1	10 10	10 10	100 100	100 100

VDOT Design Manual

- City of Virginia Beach:
  - Joint probability analysis of rainfall and coastal conditions
  - Included in stormwater modeling and design guidelines

Activities

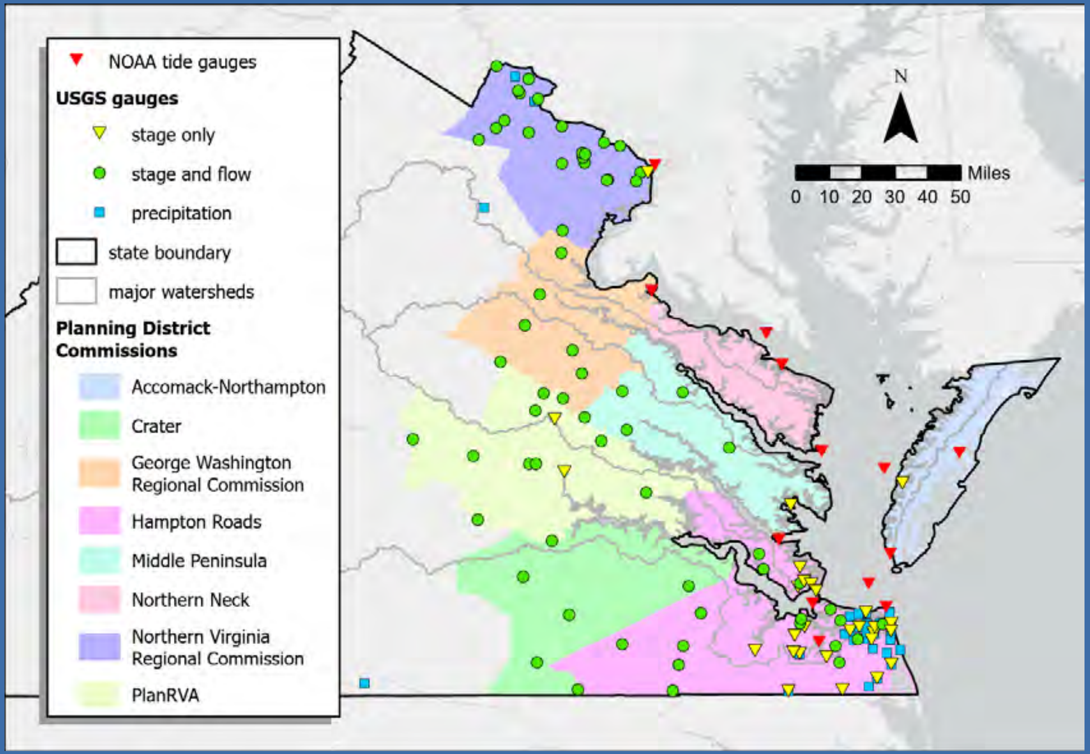
- Collect, review and process data
  - Inventory, review, process data, identify constraints, uncertainties
- Develop marginal distributions for the three flood hazards for current and future conditions
  - Apply sampling to identify relevant pairs (precipitation-surge, surge-discharge, and precipitation-discharge) and test distributions
- Quantify the dependence, including seasonality, between each pair of flood hazards
  - Derive dependence between hazards and identify uncertainties
- Compare the individual flood hazards and compound flooding potential across the CRMP study area
  - Identify joint distribution functions and derive joint annual exceedance probabilities



Inputs

- Historic observational gaged data and numerically modeled reanalysis/hindcast data
  - Precipitation, discharge, and coastal water levels (tide and surge) data

- Downscaled climatic data for future conditions (RCP 8.5 future condition (2020 – 2070), and RCP 8.5 (2050 – 2100))
  - Precipitation, discharge, and coastal water levels (tide and surge) data



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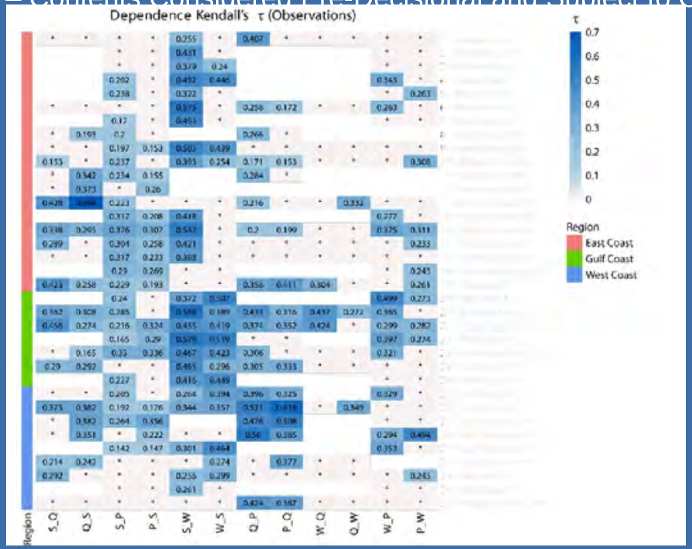
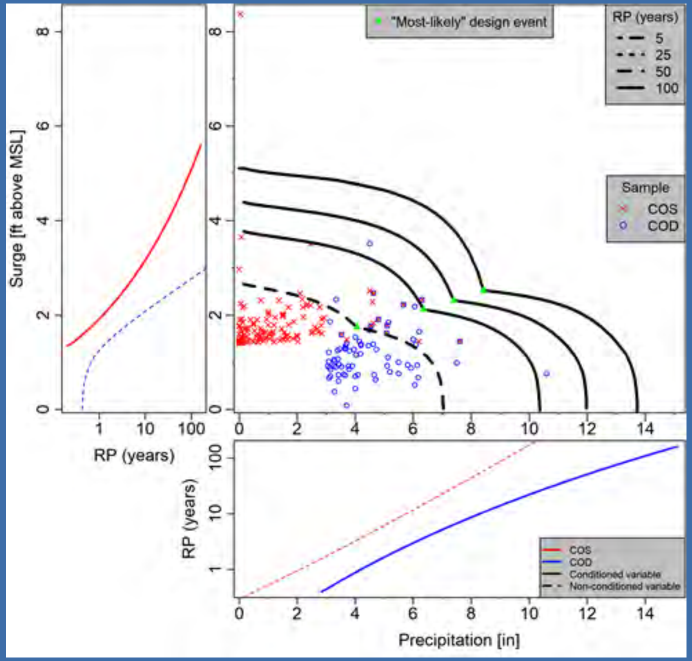
Outputs

- Marginal distributions for each of the three hazards and associated AEPs (50%, 20%, 10%, 4%, 2%, 1%, 0.2%)
- Pair-wise flood hazard dependency curves including seasonal dependence
- Compound flooding potential, including seasonal dependence
- Cross-comparison of eight PDC/RCs





Limitations

- Robustness and confidence in dependencies and AEPs will be directly influenced by duration of available historical and downscaled climatic data
- Data for future conditions from downscaled climatic models will likely be regional in nature although largely reflective of local conditions
- Provides for compound flooding potential, not detailed mapping of combined flood hazards (to be performed in 2026 CRMP iteration)

Benefits

- Provides understanding and quantification of the relative importance and geographical extent and variability of compound flood hazards
- Inform priorities and approach for modeling efforts for 2026 CRMP iteration
- Informs future resilience activities, in terms of modeling and design approaches

Potential Long-term Enhancements

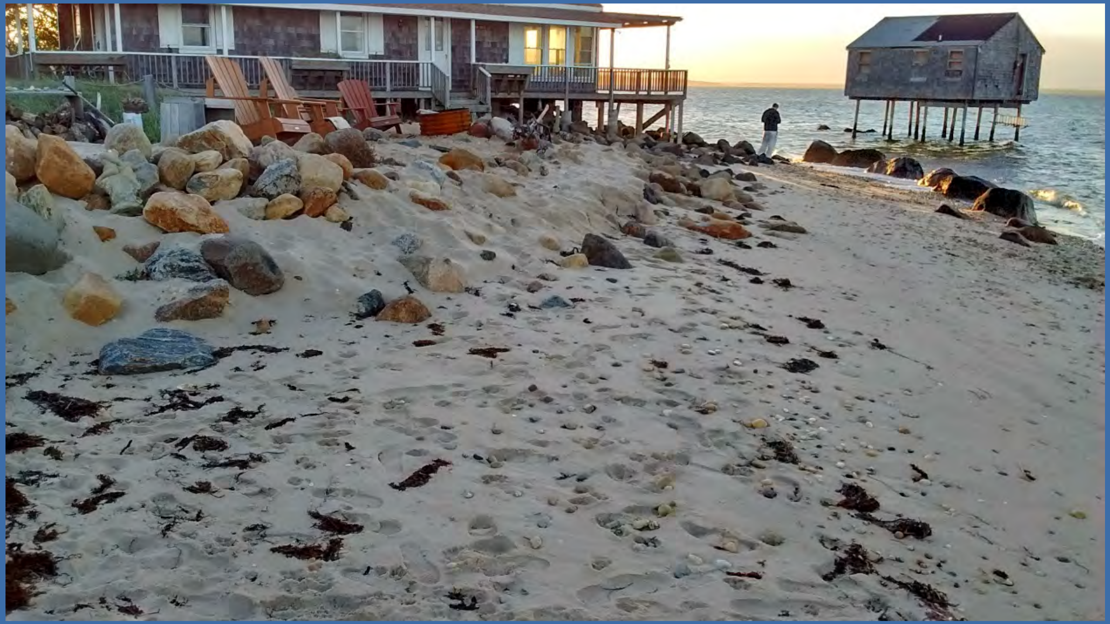
- Combined Coastal, Fluvial and Pluvial Modeling
  - Follow best-practice guidance emerging from Louisiana and Texas for robust state-wide total compound flood annual exceedance probabilities.
    - Determine antecedent conditions
    - Develop spatio-temporal rainfall grids for forcing pluvial models
    - Update storm suite to account for variability in (joint) rainfall from tropical events and antecedent baseflows and soil moisture
    - Develop optimal set of non-tropical storms
    - Develop and execute model simulations
    - Develop compound flooding hazards with associated annual exceedance probabilities

Coastal Erosion

Simple Shoreline Retreat

Needs

- Coastal retreat is the primary threat to areas of Virginia's coast
- Climate change and SLR accelerate coastal retreat
- Broad threat to Virginia's coast is unknown
- General lack of data to assist resilience planning

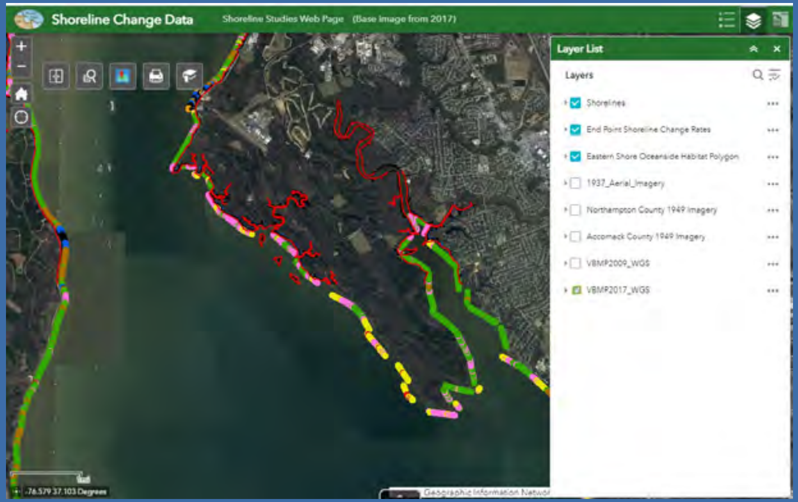


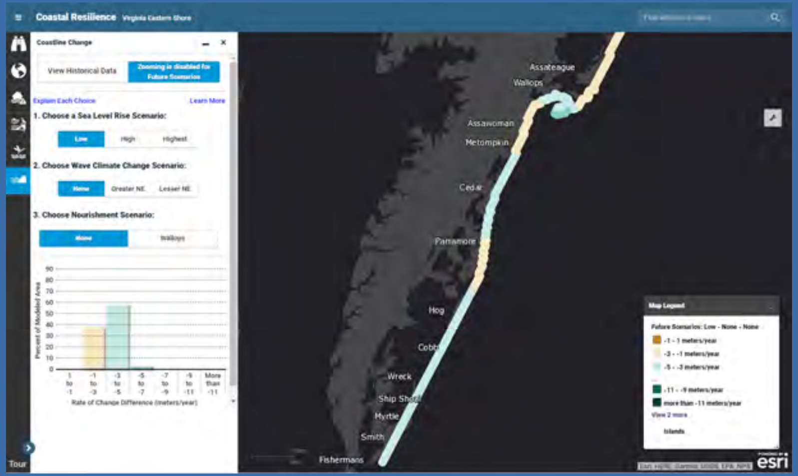
Goal:

Conduct a pilot study of simple shoreline retreat mapping, review data resources, and engage stakeholders to identify best value approach to assist resilience initiatives.

Example Existing Data/Methods in Virginia

- VIMS historic shoreline change analysis
  - Long-term shoreline change rates
  - 1930s to 2009*
    (some areas updated to 2017,
    others include 1949)
- TNC Virginia Eastern Shore
  - Future conditions
  - Model considering SLR, wave climate, nourishment scenarios





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Upcoming tools for Virginia

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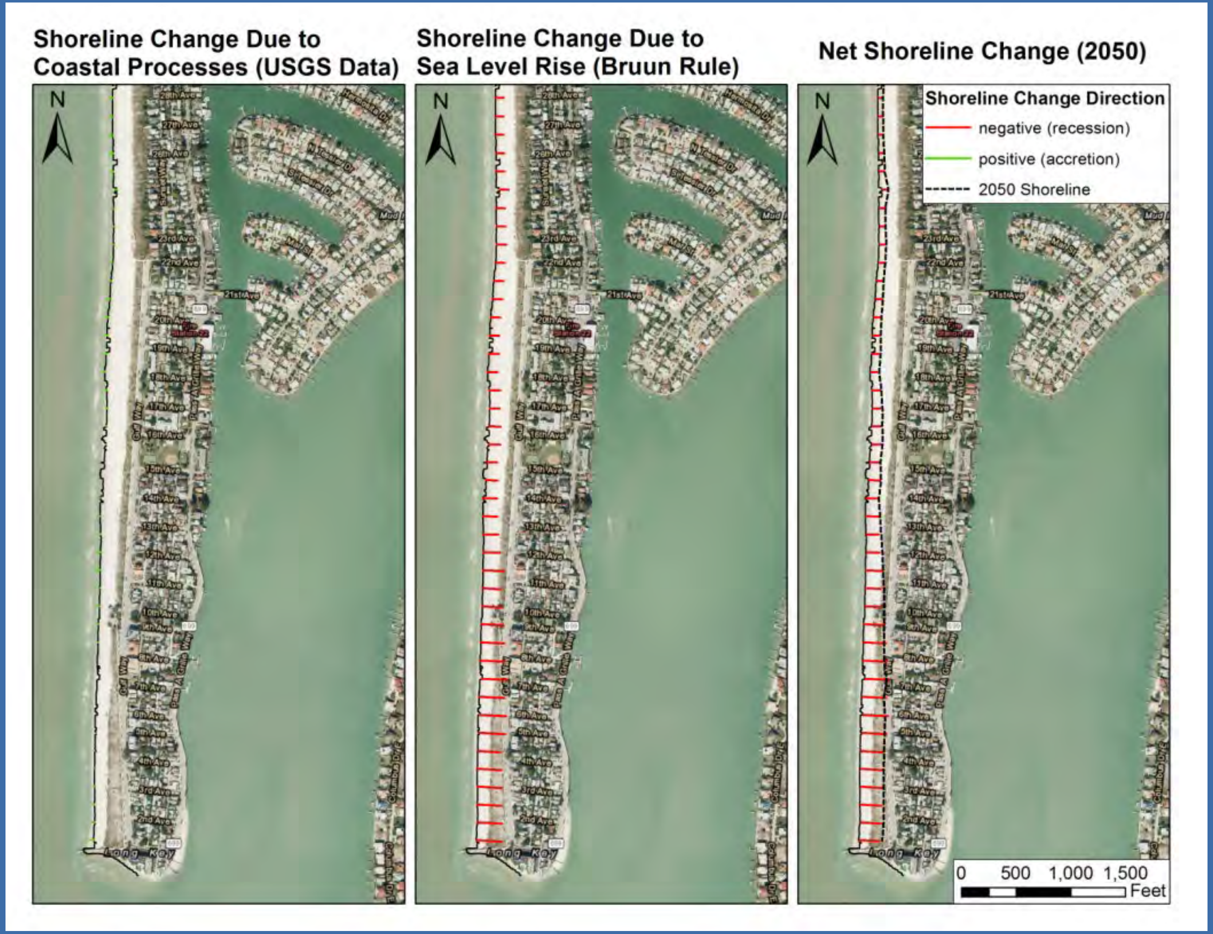
Activities

- Explore data resources and alternatives for applications
- Generate simple "retreat area" map product for pilot 50-miles of coast
- Stakeholder engagement



FEMA, Advisory Sea Level Rise Study: Hillsborough and Pinellas Counties, Florida

Outputs

- Mapped Zones of retreat
  - By time horizon, and/or SLR scenario
- Summary of stakeholder feedback
- Anticipated effort and/or alternatives for wider application

FEMA, Post-hurricane Maria recovery advisory product, Puerto Rico

NYSERDA, East Hampton, New York, Coastal Resilience Planning Pilot

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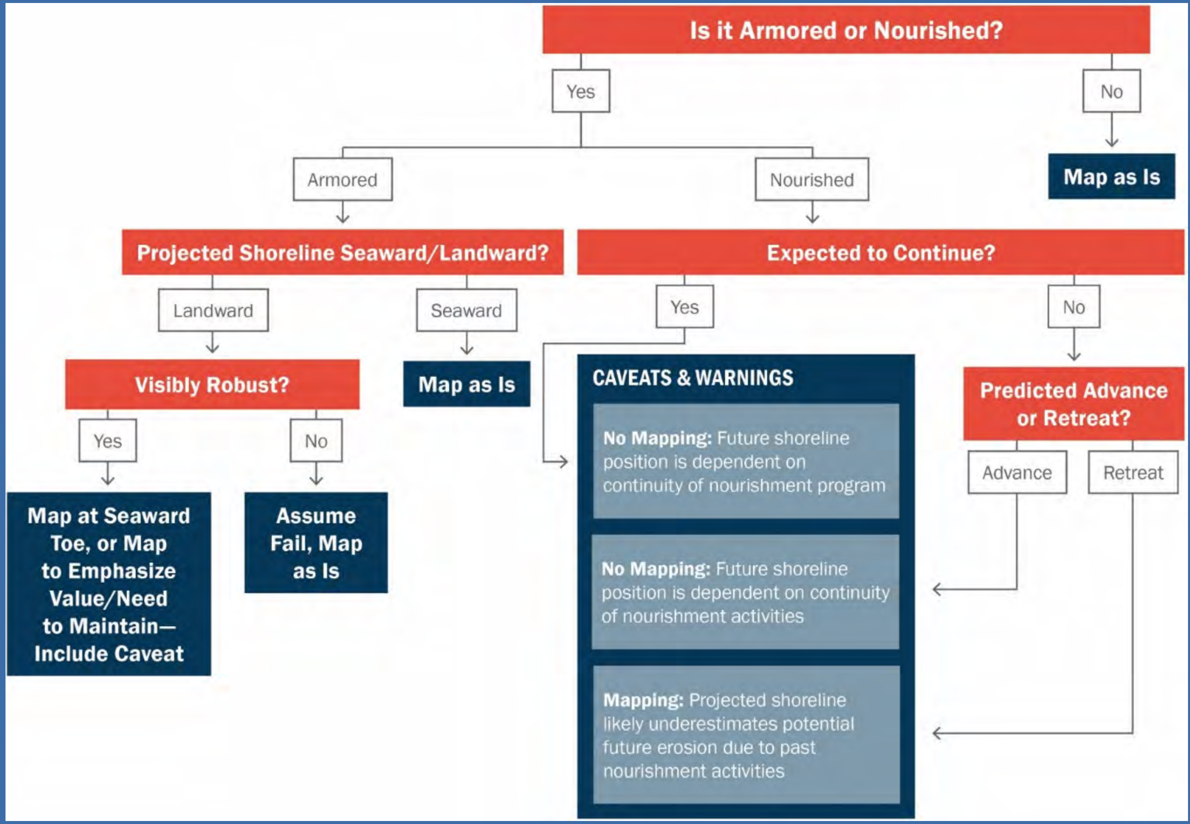
Limitations

- Scale of coast may limit complexity of method
  - Simple methods proposed
- Products rooted in historical trends and associated processes
- Anthropogenic influences and storms
- Consideration of other efforts essential

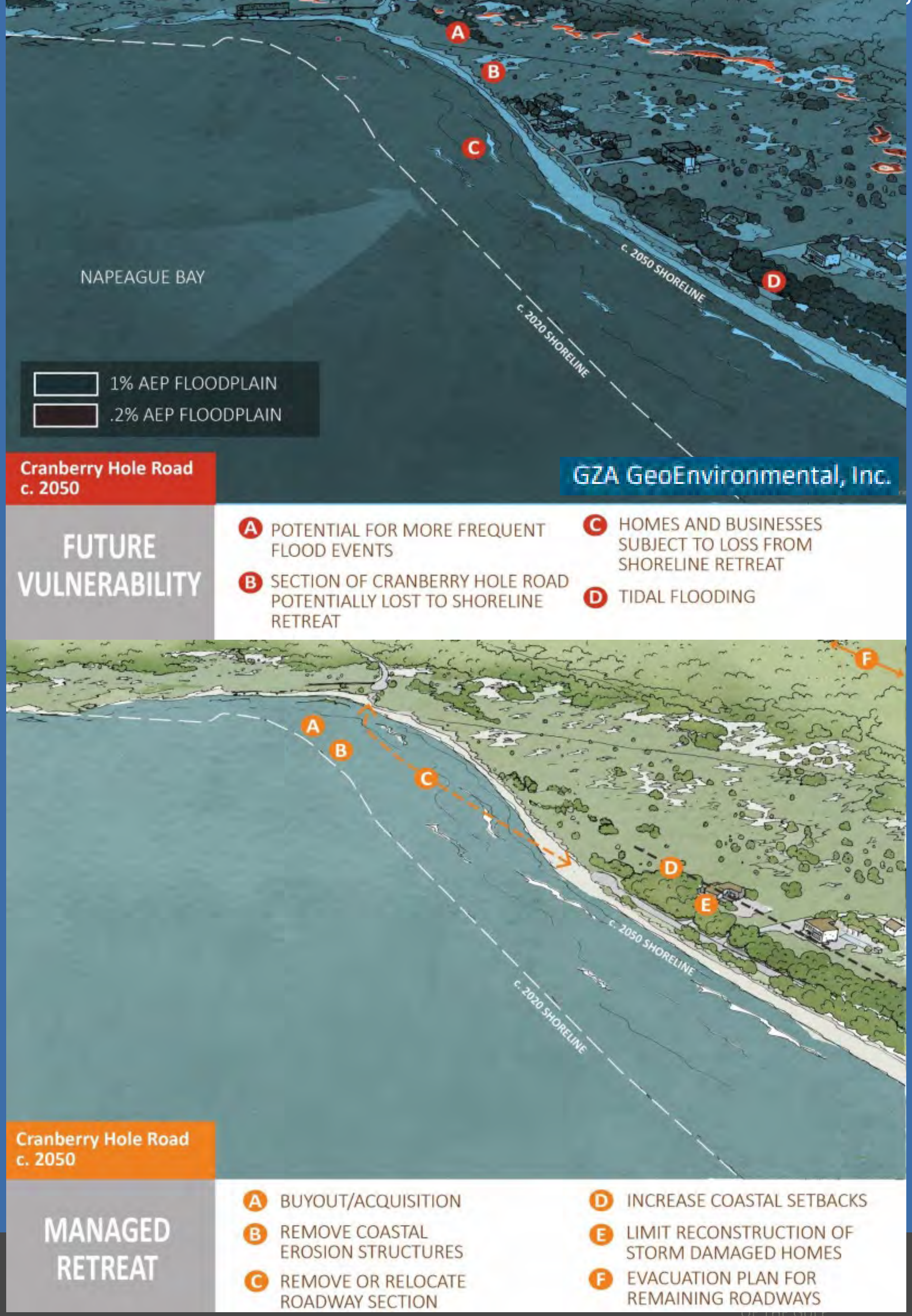


FEMA, Advisory Sea Level Rise Study: Hillsborough and Pinellas Counties, Florida

Benefits

- For many areas, more important hazard than flooding
- Provides a basic resource to aid resilience planning

East Hampton, New York, Coastal Assessment and Resiliency Plan

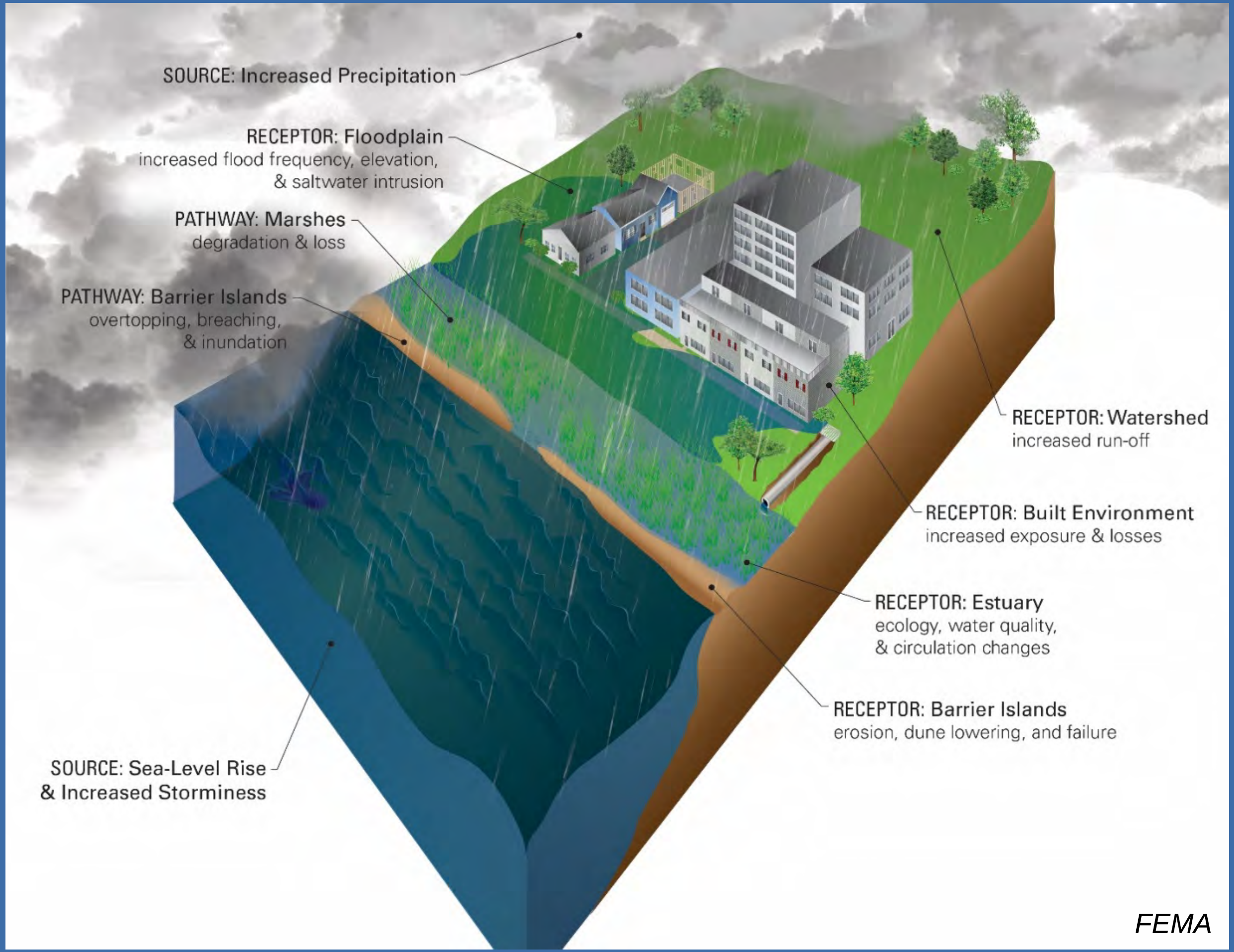


Coastal Erosion

Future Landscape Change

Needs

A thorough examination of future coastal flood hazards should include a coastal numerical modeling effort that considers future changes to the barrier islands and marshes that make up the coastal landscape, and can cause cascading changes



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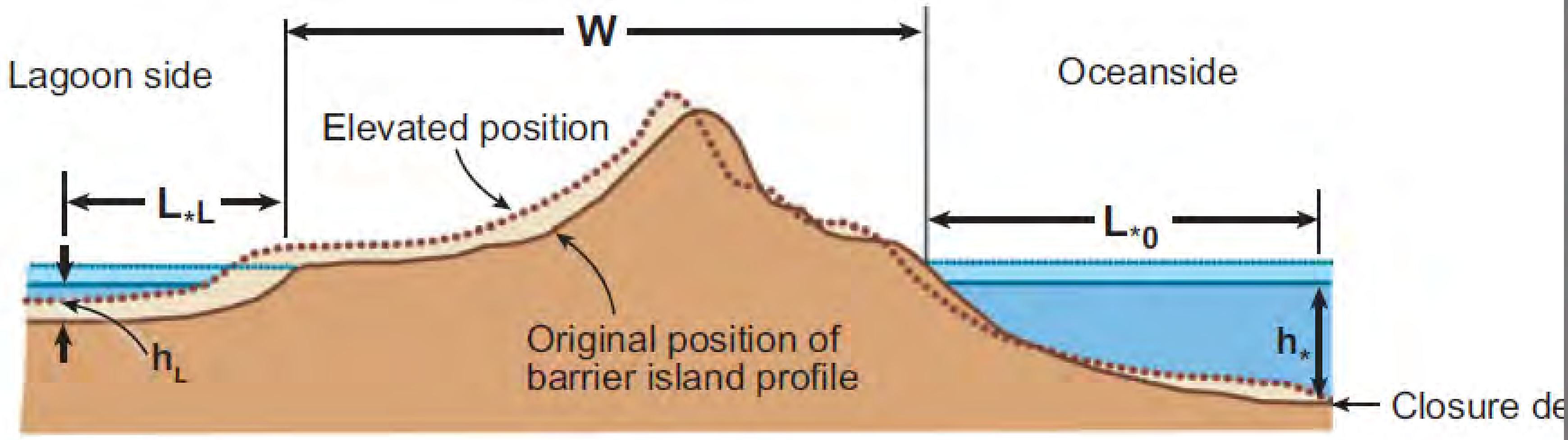
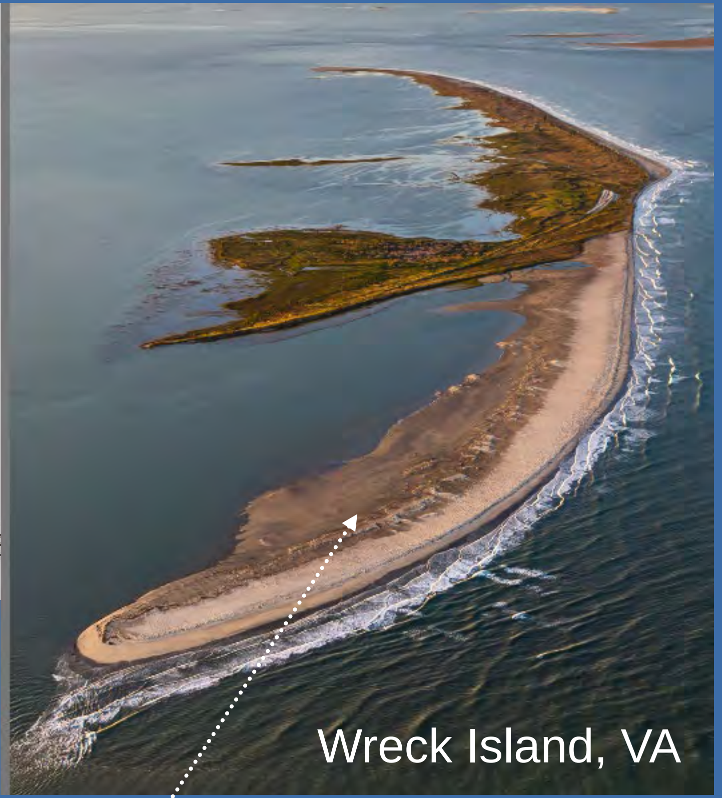
Barrier Island Dynamics modeling

The modified Bruun model (from FitzGerald et al., 2008; modified from Dean and Maurmeier, 1983)

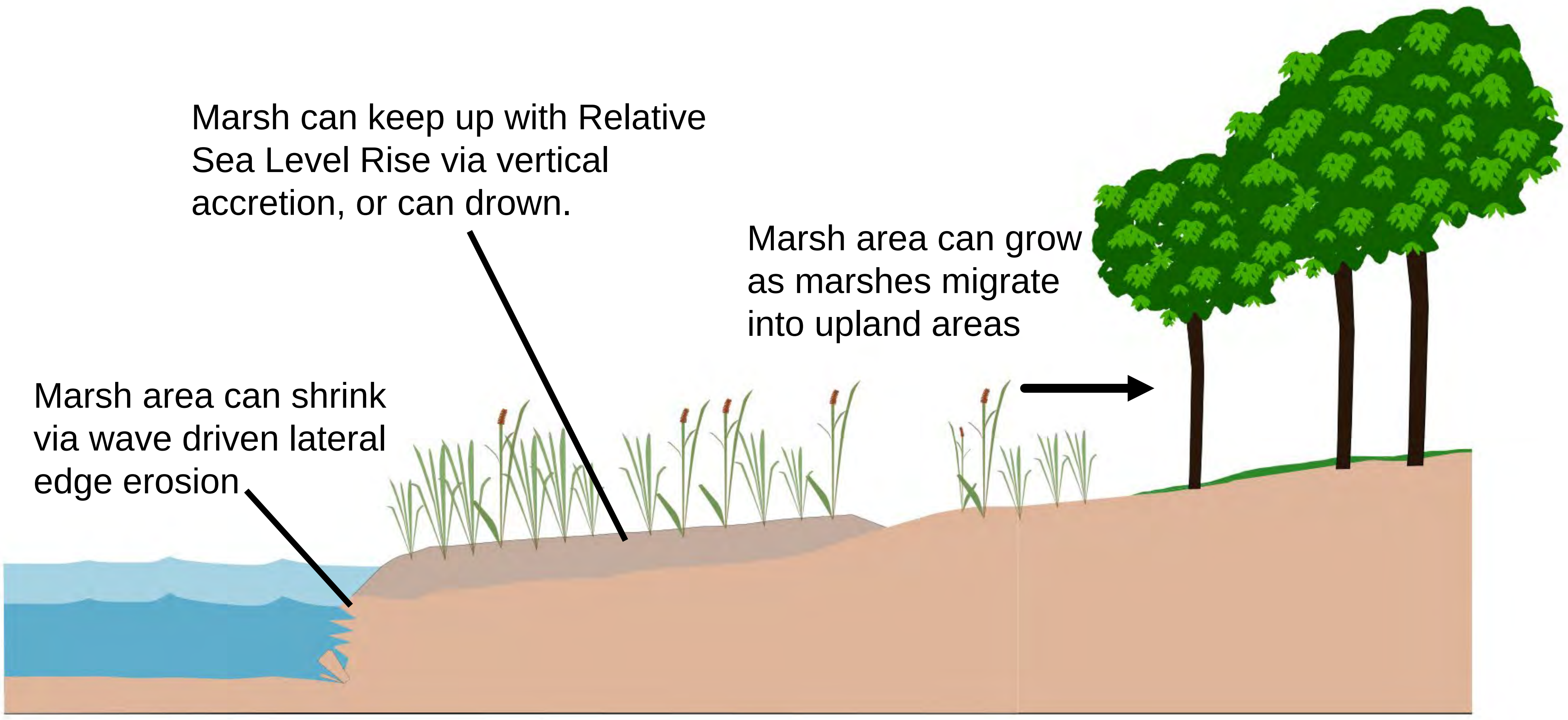




The sandy part of Wreck island likely follows Bruun Response, but the rest of the island doesn't

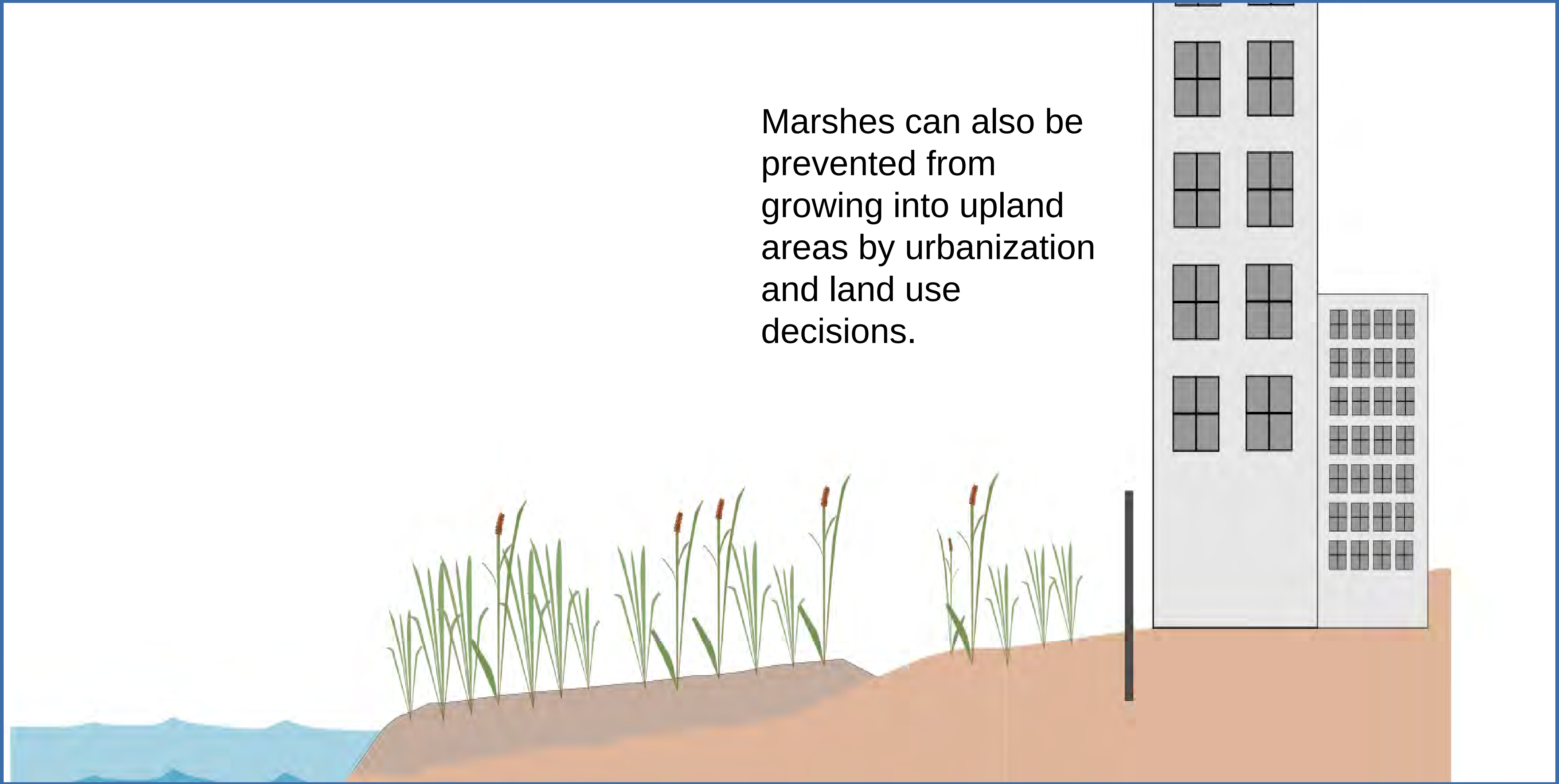
- Developed for beaches originally, and modified for barriers later, the Bruun model doesn't have universal applicability
- Most barriers do not rollover in this way (except if they are comprised of sand only)
- Their evolution is not as symmetric as depicted here
- Some modified treatment is necessary

Processes that must be modeled for items 3 and 5.



After Kirwan et al., 2016

Processes that must be modeled for items 3 and 5.



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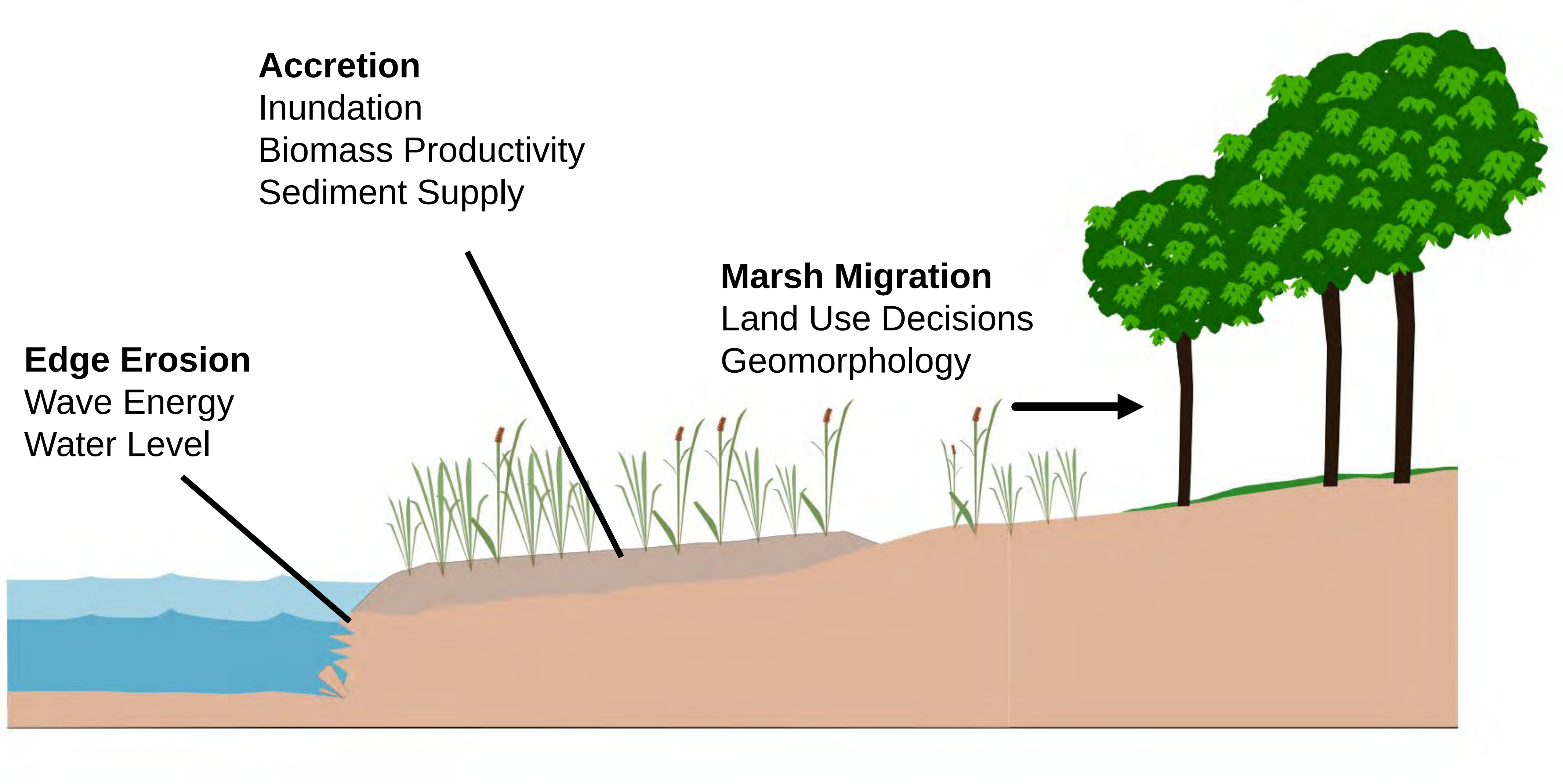
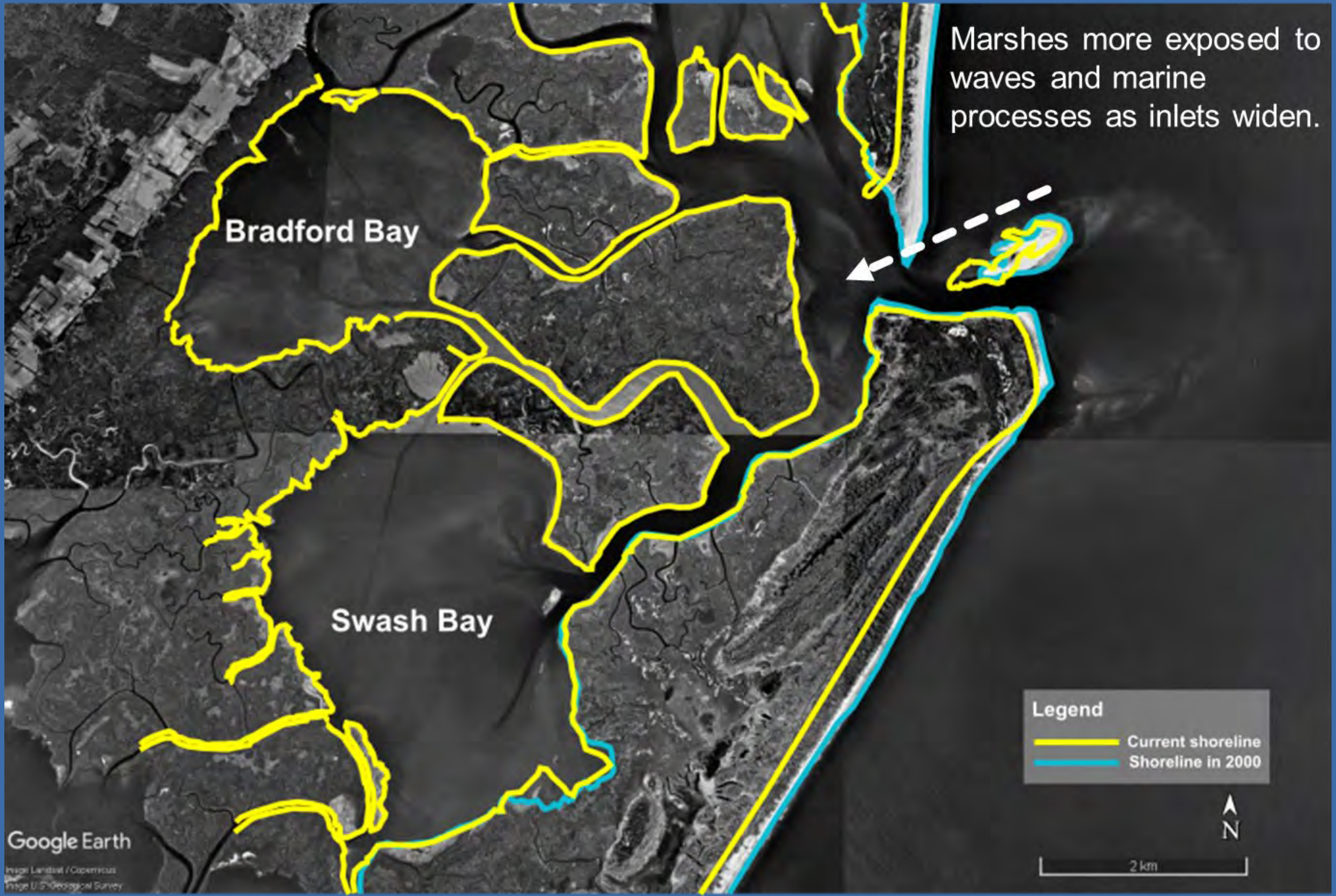


Marshes and Barrier Islands are Closely Connected



- Wave impacts and water levels in the marshes are determined by the barrier island evolution, and the storage of sand in shoals.
- A modeling framework that predicts marsh evolution must also include tools for barrier islands.

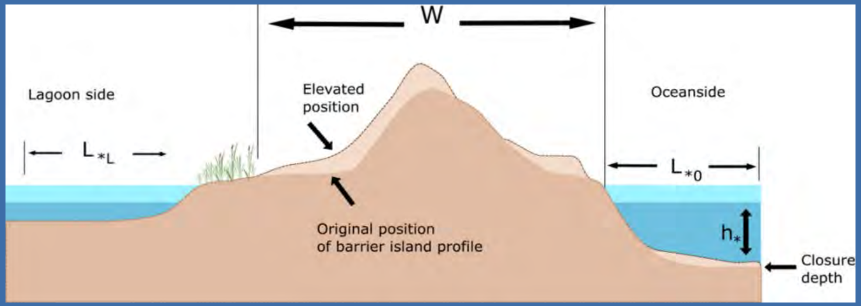
Goals:

1. A hydrodynamic model that will be used to simulate water levels, currents, and waves on a regional grid throughout the study area (both for the bay, and for Coastal Virginia Eastern Shore)

2. Simple models of marsh evolution or barrier island evolution and attendant processes that take input from the hydro model and are used to simulate complex processes based on empirical observations.

3. A probabilistic analysis framework.

Activities



- Subtask 1: Hydro Model Selection
  - Inventory, review model options
  - Coordinate with model develops to assess potential application to CRMP
  - Identify additional model links
- Subtask 2: Catalog and compile input and calibration data
  - Catalog DEMs and accuracy in context of application
  - Compile accretion and edge erosion data
  - Compile barrier island morphology data
  - Gap analysis
- Subtask 3: Develop model linkages and workflows between model components
- Subtask 4: Develop a probabilistic analysis framework to provide a foundation for the 2026 desired outcomes

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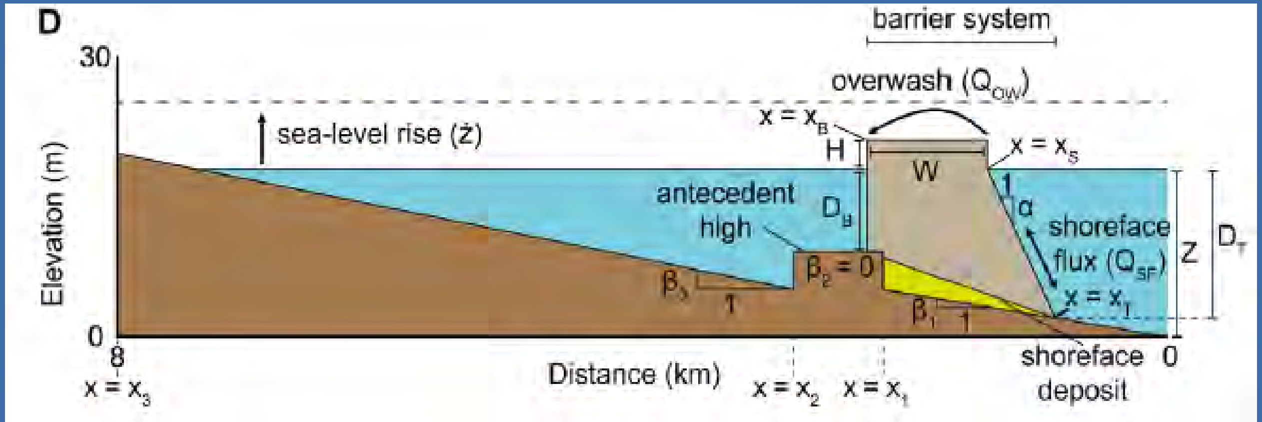
Outputs

- Decision document on Hydro model selection, model component integration, and probabilistic analysis framework to use for 2026.
- Documented and tested model linkages and workflows.
- Description of how model output in the 2026 plan will be assessed against available data
- How the 2026 model process will incorporate uncertainty



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Limitations

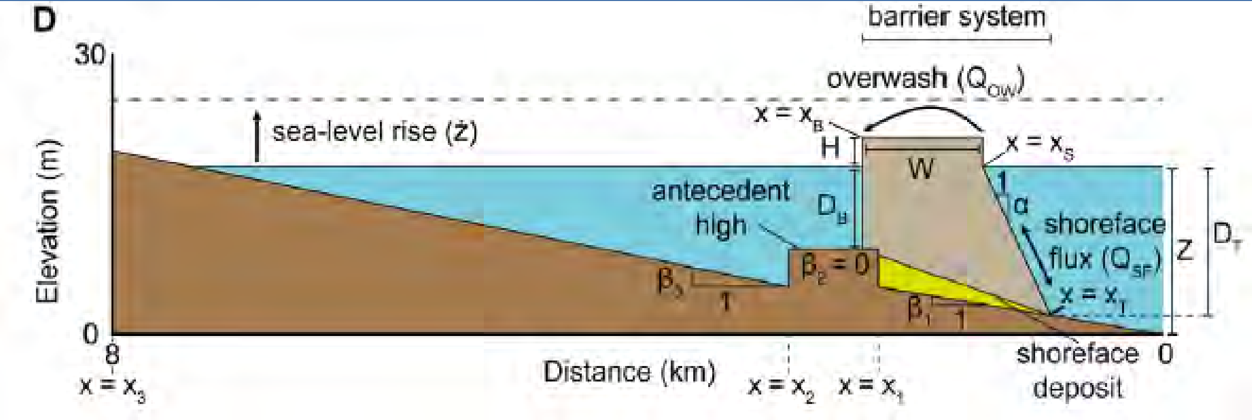
- Historical data availability for each model component. Identifying and resolving this limitation to the extent possible is a goal of the 2022 iteration.

Benefits

- Treating each system component separately within a model framework that is driven by a shared hydro model allows for integration of scenario choices as well as a decoupled uncertainty across scales. This facilitates the probabilistic analysis framework.
- For many areas coastal change is a more important hazard than flooding.
- This tool provides a basic resource to aid resilience planning in the coastal zone.

Potential Long-term Enhancements

- Activities:
  - Hydro Model Development
  - Wetland Model Development
  - Barrier Island Model
  - Model Production Runs
  - Analysis and Reporting



- Outputs:
  - Model development and production run data will be documented in a report.