Virginia Eastern Shore Coastal Resilience Mapping & Decision Support Tool

Introductory Workshop & Training Manual Version2.0

January 19 & 24, 2017
Eastern Shore Community College, Melfa, VA

A project funded by the Department of Interior Hurricane Sandy Coastal Resilience Fund

Cover Photo:
Aerial view the seaside, near Red Bank, Virginia. Photograph ©2017 Gordon Campbell/At Altitude Photography
Following Page Photo:
Fowling Point, Hog Island Bay
Photograph ©2015 Gordon Campbell/At Altitude Photography

Virginia Eastern Shore *Coastal Resilience Tool*

Introductory Workshop and Training Manual, Version 2.0

With input from the Community Leader Workshop held in November 2014, the customized Virginia Eastern Shore *Coastal Resilience* online mapping and decision support tool for visualizing and assessing regional vulnerability to storm surge, sea-level rise, and changes in coastal habitats can be found at **maps.coastalresilience.org/virginia**. Please visit the project webpage for more information at **coastalresilience.org/virginia**.

Training Team

Shannon Alexander, A-NPDC
Jill Bieri, The Nature Conservancy
Michael Bonsteel, LJT & Associates
Deborah Brosnan, Brosnan Center
Chris Bruce, The Nature Conservancy
Gwynn Crichton, The Nature Conservancy
Karen A. Duhring, Virginia Institute of Marine Science
Laura Flessner, The Nature Conservancy
Jim McGowan, The Nature Conservancy
Curtis Smith, A-NPDC
Joyce Winterton, NASA

Please contact us with your questions and input: vacoastalresilience@tnc.org

maps.coastalresilience.org/virginia

Table of Contents

maps.coastalresilience.org/virginia

Virginia Eastern Shore Coastal Resilience Tool
Exercises and Skills

Part One: Basic Navigation

Exercise A. Getting there

- Start by going to the Virginia Eastern Shore Coastal Resilience project website: http://coastalresilience.org/project/virginia-eastern-shore/
  - Scroll down the page to learn more about the Coastal Resilience work going on in the region.
  - In the upper right hand corner of the header banner, click **Mapping Portal** to launch the Coastal Resilience mapping tool *(or enter URL:* maps.coastalresilience.org).

- Either click on the **Virginia** pin on the map or scroll down and Click on **United States**, then scroll down and click on **Virginia**. Click on the **Map** button to open the mapping tool. Use the scroll bar on the right to scroll down past the project information and click on **Explore the Map** in the Getting Started window.

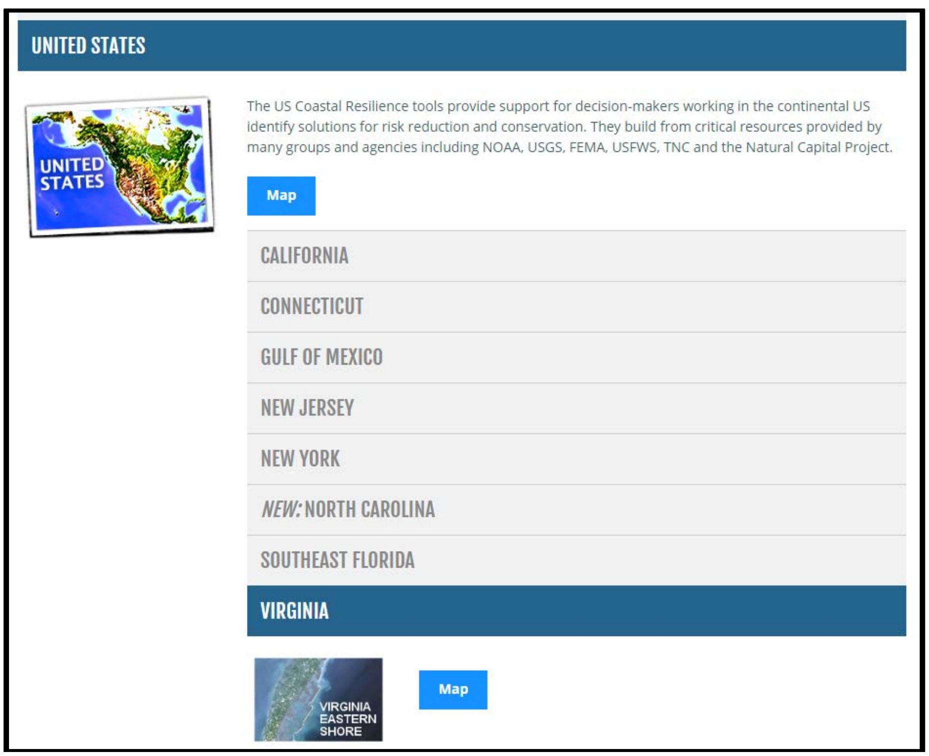


Figure 1. Accessing the Virginia map at maps.coastalresilience.org/Virginia

Exercise B. Basic orientation to framework and apps

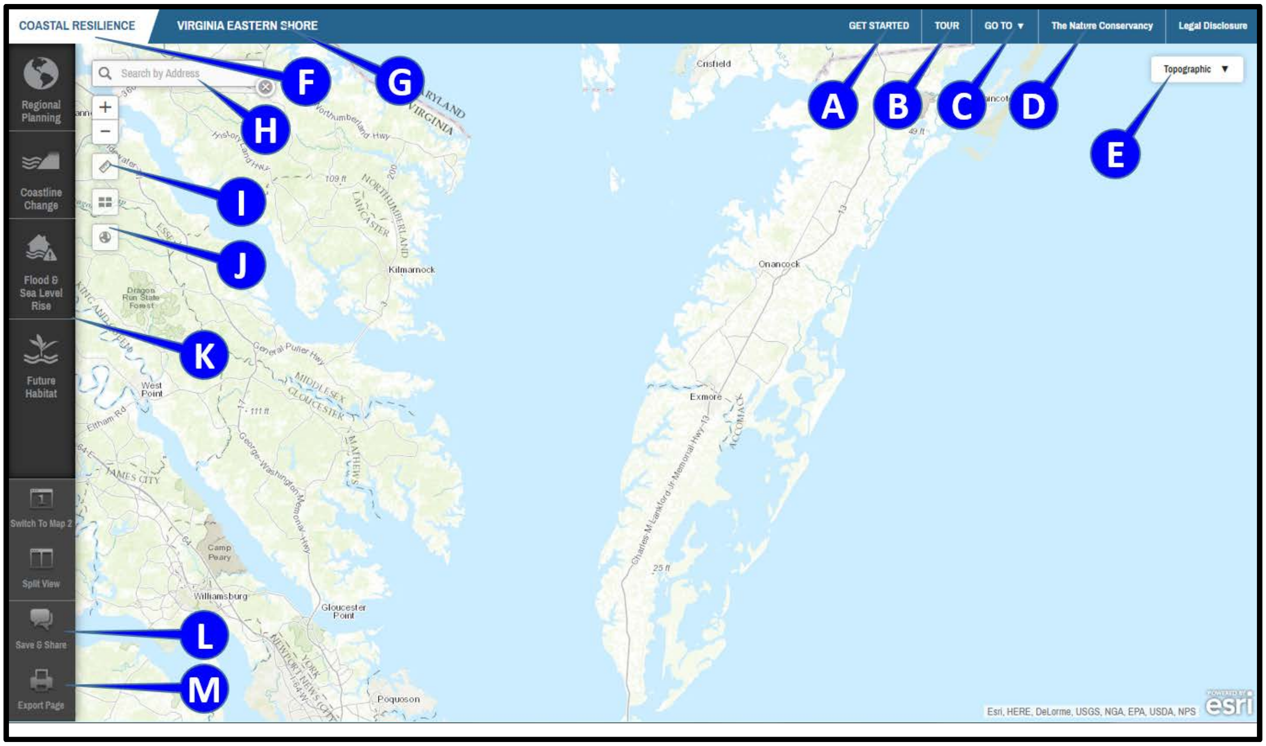


Figure 2. Orientation to the framework

- **A.** The **Get Started** window automatically appears and shows menus of bookmarked maps and information on project partners. Note that you need to scroll down to see the bookmarked maps. Close this window by clicking the **X** in the upper right hand corner.
- **B.** Click **Tour** for an introduction to the map interface. Click on each number for feature information and close this window when finished.
- **C.** Click **Go To** to access a drop down menu to toggle to different Coastal Resilience geographies.
- **D.** Click **The Nature Conservancy** to go to the www.nature.org Ocean and Coasts website.
- **E.** Click **Topographic** in upper right hand corner and select the **Imagery** basemap option. Note that other base maps are available here as well.
- **F.** Clicking on **Coastal Resilience** will go back to the main Coastal Resilience website in a new tab.
- **G.** Clicking on **Virginia Eastern Shore** at the top will open the Virginia Eastern Shore Coastal Resilience website project page in a new tab.
- **H.** Go to the **Search by Address** search window in the top left corner of the map to find and zoom to a particular area on the map:
    - a. Type in your point of interest and you will get a list of available selections from a global address database.
    - b. Choose the correct location from the dropdown menu.
    - c. Close the search window by clicking on the **X** icon twice.
- **I.** Measure an area or distance by selecting the measure tool and clicking on the map. Click the **X** to close this tool.
- **J.** Zoom to the full extent of the map by clicking the **globe** icon.

maps.coastalresilience.org/virginia

K. View Coastal Resilience apps on left hand side of screen: **Regional Planning, Coastline Change, Flood & Sea-Level Rise, and Future Habitat** (note slider bar to see all app options on smaller screens).

   a. Click on an app to activate; when active, the app icon will be blue.
   b. You can have multiple apps running at the same time; simply open other apps and they will overlap each other in the app window (the icons will stay blue), use the **Minimize button (-)** in the upper right corner to minimize or **X** to close.
   c. Click the **Learn More** link within the app interface to view a fact sheet describing the app's purpose and how it works. Note that these fact sheets open in a new tab.

L. Click on **Save & Share** at the bottom of the left pane**.** Note that the link at the top can be copied to share with colleagues.

M. Click on **Export Page** to save your map as an Adobe Portable Document Format (PDF).

Apps in the Toolbox

Regional Planning

The **Regional Planning** app includes supporting infrastructure, ecological, socioeconomic, and other data important for resilience and adaptation planning. These layers may be used in combination with the other apps to identify and assess vulnerability and potential solutions for specific locations and resources.

Flood and Sea Level Rise

The **Flood and Sea Level Rise** app allows users to view the potential future risk of inundation and flooding due to sea-level rise and storm surge on towns, homes, property, and critical built infrastructure like roads and utilities, as well as coastal habitats. This information helps support planning and decision-making related to hazard mitigation, emergency services, storm water management, land use and conservation.

Future Habitat

The **Future Habitat** app allows users to examine how coastal habitats, like salt marsh or freshwater tidal wetlands, may change and migrate inland over time under different sea-level rise scenarios. This information is useful when developing land acquisition, species management, shoreline management, or restoration plans.

Coastline Change

The **Coastline Change** app's **Historical Data** module and **Future Scenarios** module collectively serve to educate stakeholders about the dynamic nature of barrier islands over time and provide planners and managers with overall trends in shoreline changes in response to climate change. This provides planners and managers with useful context for understanding the barrier islands as they evolve in the future.

maps.coastalresilience.org/virginia

Part Two: Flood & Sea Level Rise App

Assessing Vulnerability of Property and Infrastructure to Sea-Level Rise and Storm Surge

Exercise A. Characterizing the risk of sea-level rise in Quinby, Virginia

★ **Exercise A Planning Outcome:** *Identify number of people, properties, and critical infrastructure in Quinby that are predicted to become inundated in the future under different scenarios of sea-level rise.*

- ➢ Click on the **Flood & Sea Level Rise App** on left.
- ➢ Click on **Choose Data Source** in the upper left corner of the app window and select **Basic Inundation.**
  - See **Learn More** link for information on the mapping methodology.
  - Click on the blue **" i "** icon for information on sea-level rise (SLR) scenarios; click on the **X** to close the information window.
- ➢ Move the app window down slightly by clicking and dragging on the top bar. Go to the **Search by Address** window and type **Quinby, VA** and hit **Enter**, click the search result that comes up, then click the **X** to close the search result window.
  - Zoom in or out to adjust extent by clicking on the **plus sign [+]** or the **minus sign [-]** on the upper left or by using the mouse wheel.
  - **Pan**: hold the left mouse button down and move the mouse in the direction you want to pan.
  - For **Choose SLR Scenario**, slide the bar to the **High** SLR scenario.
  - For **Choose a Scenario Year**, slide the bar to **2040** and look at results, then to **2065** and **2100**.
  - Change **SLR scenario** to **Highest.**
  - You can change the layer transparency as needed using the **Layer Properties** slider at the bottom of the app window.

- ➢ Minimize the Flood & Sea Level Rise App by clicking on the **Minimize button (-)** on the top right corner of the App window.
- ➢ Click on the **Regional Planning** app icon at the top of the left pane.
- ➢ Click **Virginia**, then **Social and Economic** and select **Persons per Square Mile**.

Question 1-A: How many people per square mile might be affected by permanent inundation under the Highest SLR Scenario in 2100 on the southeast side of the Machipongo River, immediately north of Quinby Bridge Road? Note that the Persons per square mile layer can be toggled on and off as needed.

____

maps.coastalresilience.org/virginia

➢ Uncheck **Persons per Square Mile** to turn that dataset off.
➢ Click **Base Data** and check box for **Roads**.
➢ Click **Coastal Management** and check box for **Flood Hazard Areas (2014)**.
   - Click the "**i**" button next to any layer to see brief description and link to metadata.
➢ Minimize the **Regional Planning** App by clicking on the **Minimize (_) button** on the top right corner of the App window.
➢ Click on **Flood & Sea Level Rise** app icon to reopen (note App button is blue when still active).
   - Continue to explore different SLR options by moving the **slider bars**.

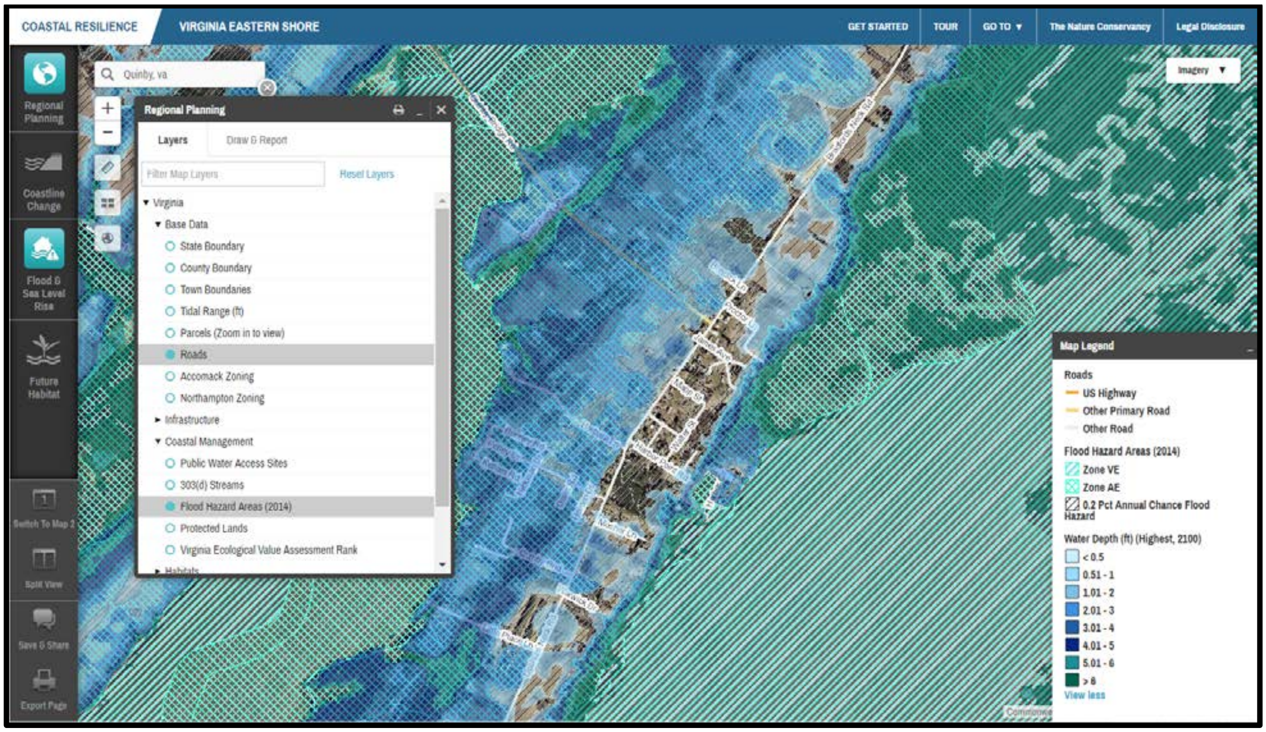


Figure 3. Example of what your screen should look like prior to Exercise A question 2-A.

Question 2-A: What areas within the 100-year floodplain (VE and AE Zones) in Quinby (including the Causeway) are potentially at risk of permanent inundation in 2025, 2040, or 2065 under the "High" sea level rise scenario?

____

Question 3-A: Under what SLR Scenario and Year does the 0.2 Pct Annual Chance Flood Zone in Quinby begin to experience inundation?

____

- **Where is this happening?** ____________________
- **What water depths are expected in these places?** ____________________

maps.coastalresilience.org/virginia

On Your Own:

Question 4-A: Under what SLR Scenario might portions of the Quinby Bridge and causeway (Route 182) become inundated?

____

Question 5-A: If both roads are inundated, are there alternative evacuation routes? If not, what are some options for adapting road infrastructure to accommodate the potential future areas of inundation?

____

Exercise B. Characterizing the risks due to flooding and inundation from future sea-level rise combined with storm surge in the vicinity of Quinby.

★ **Exercise B Planning Outcomes:** (1) *Identify 0.2-pct Flood Hazard Zones in Quinby and vicinity that are at risk for flooding under various scenarios of sea-level rise combined with storm surge and local conditions;* (2) *Identify potential estimated economic losses under different scenarios of sea-level rise combined storm surge.*

- In the **Flood & Sea Level Rise** app, click on **Choose Data Source** and choose **Storm Surge**.
- Click on **Learn More** hyperlink to view fact sheet and click on the blue "**i**" buttons as needed.
- See two options: **Show modeled storm surge depth** or **Show estimated economic loss**. Notice that the app defaults to modeled storm surge depth for the **Current** scenario year and **Nor'Ida** as the storm type when opened.
- Make sure you are still zoomed to **Quinby, VA**, have the **imagery basemap** turned on, and still have the **Flood Hazard Areas (2014)** layer from **Regional Planning** displayed.
- With **Show modeled storm surge depth** still selected, explore how storm surge water depths change for the three options under **Choose a Scenario Year** by sliding the bar to **2040** then **2065** while keeping **Storm Type** on **Nor'Ida**.

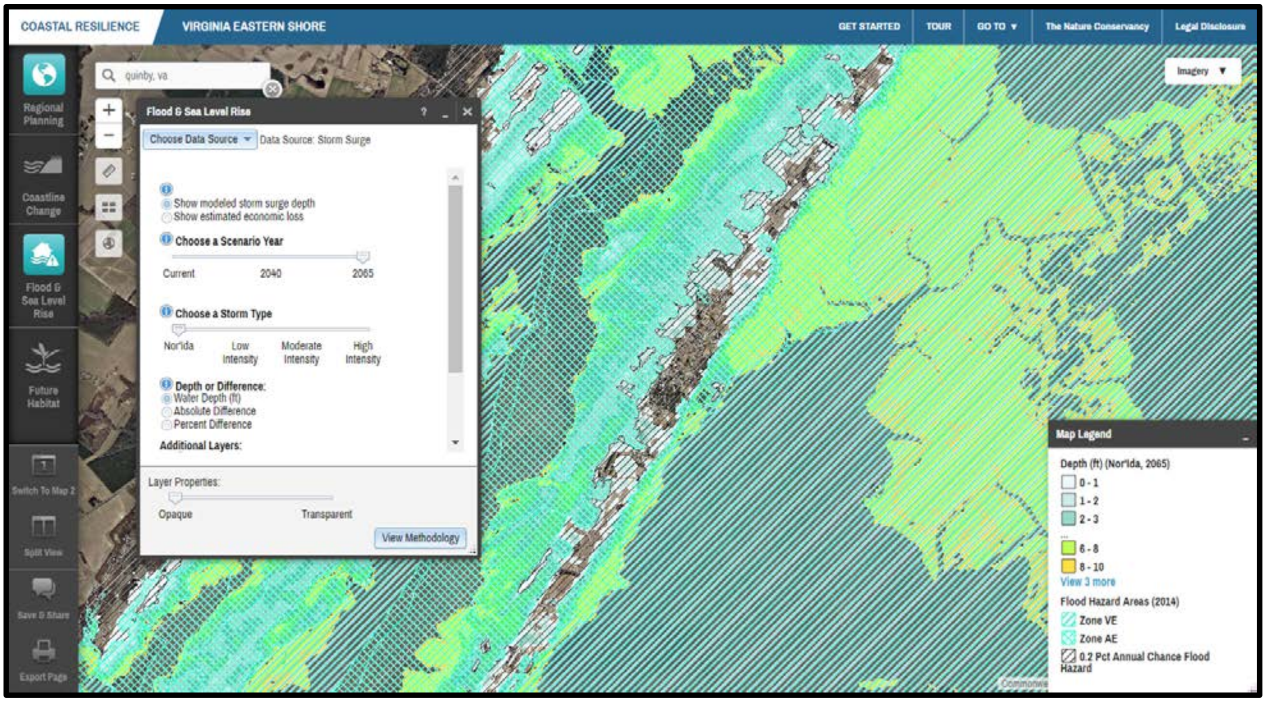


Figure 4. Example of what your screen should look like prior to Exercise B question 1-B.

Question 1-B: Roughly how many feet of surge would the 0.2 Pct Annual Chance Flood Zone near Quinby Harbor potentially experience in a 2040 and 2065 Nor'Ida event?

- Slide the top slider back to **Current.**
- Under **Choose a Storm Type**, slide the bar to **Low Intensity**, **Moderate Intensity** and **High Intensity** and compare scenarios for **Current, 2040 and 2065**.

Question 2-B: How many *more* feet of surge would the same area in Quinby potentially experience in a Moderate Intensity Storm Type in 2040 versus in 2065?

- Look at the options under **Choose Depth or Difference** (scroll down in the app window as needed) and notice that the app is automatically set to **Water Depth (ft).** Click on the blue **"i"** icon for information on **Choose Depth or Difference.**
- Click on **Regional Planning** app icon, click **Reset Layers** to turn off all ancillary data, click the **X** in the upper right corner to close the Regional Planning app.
- Click **Flood & Sea Level Rise** app icon to reopen, and zoom OUT to the area between **Wachapreague and Willis Wharf** by clicking the minus zoom extent **"-"** button three times. Pan the map as needed.

Question 3-B: What is the absolute difference and percent difference in surge due to sea-level rise in Quinby in 2065 for a Moderate Intensity storm? How does this differ from Wachapreague to the north? What is your conclusion about the risk of flooding at Quinby versus Wachapreague?

maps.coastalresilience.org/virginia

- ➢ If necessary, use the scroll bar at the right of the app window to view the **Additional Layers** section or expand the size of app window by pulling on the lower right corner with your mouse.
  - Click on **Show tidal range.** Look for tide range numbers at various locations on the map.
  - Click on hyperlink to NOAA's historic sea level trends for **Wachapreague**.

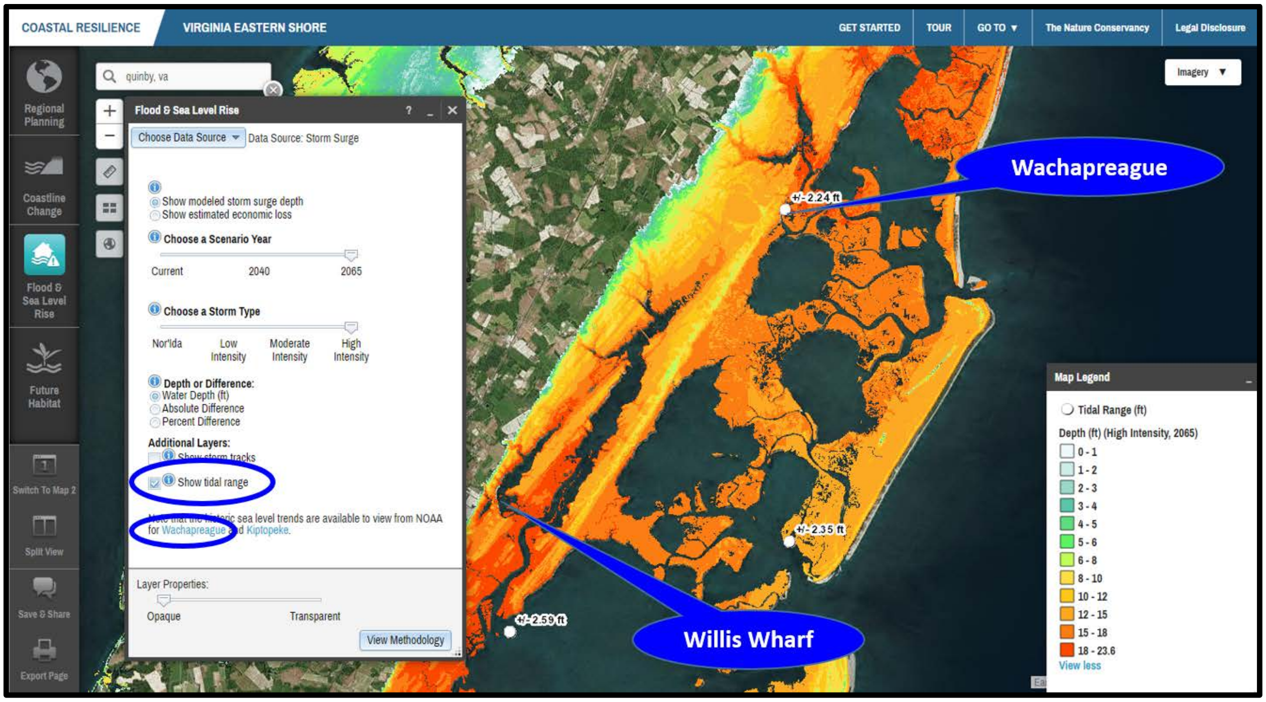


Figure 5. Example of what your screen should look like prior to Exercise B question 4-B.

- ➢ Back at the top of the app window, Select the radio button for **Show estimated economic loss**
  - Repeat exploration from above of Scenario Year and Storm Type to see potential changes in economic losses under different scenarios.

Question 4-B: Between the Towns of Wachapreague and Willis Wharf, could census blocks that did *not* experience economic losses under Nor'Ida in the Current Scenario Year potentially experience economic losses in a Nor'Ida event in 2040 or 2065?

____

On Your Own:

Question 5-B: Using the information you have visualized; how many feet might you recommend the town of Quinby increase their Base Flood Elevation by for structures located in the 0.2 Pct Annual Chance Flood Zone to minimize flood risks under a Moderate Intensity Storm in 2040?

____

maps.coastalresilience.org/virginia

TECHNICAL SKILLS COMPLETED

- ❑ Ability to assess risk and vulnerability to specific places or infrastructure due to a range of flooding scenarios based on SLR inundation only or SLR plus storm surge scenarios
- ❑ Ability to evaluate the relative impact SLR has on storm surge
- ❑ Ability to evaluate potential future economic losses due to different scenarios of SLR plus storm surge
- ❑ Ability to consider a range of hazard mitigation actions that may reduce risk of flooding to specific areas based on planning horizons.

Implementation:

- ❑ You can now use the Flood & Sea Level Rise app to help guide stakeholder workshops or conversations around community-scale socio-economic vulnerability to permanent inundation among a range of projected sea-level rise scenarios along with the potential impacts of sea-level rise on storm surge. For example, Quinby Bridge Road is vulnerable to increased inundation under future sea-level rise scenarios.
- ❑ You can now create a meaningful map that can help clearly communicate to decision-makers and stakeholders that the impacts of sea-level rise on storm surge are not uniform and vary based on place. For example, sea-level rise may have a greater impact on storm surge in areas around the Machipongo River.
- ❑ You can use the understanding of flood risk that you have gained to help make the case for adaptation recommendations like infrastructure or evacuation route relocation or future base flood elevation requirements, to help make your community more resilient.

Part Three: Future Habitat App

Identifying and Planning for Areas of Future Marsh Migration

Exercise A. Future Habitat for Marsh Retreat at a Regional Scale

★ **Exercise A Planning Outcome:** *Identify general regional trends in marsh habitat distribution and extent under different future sea-level rise scenarios for Virginia's Eastern Shore.*

- ➢ Press **F5** on your keyboard to refresh the site.
- ➢ Close the **Getting Started** window.
- ➢ Click on the **Future Habitat App** on left.
- ➢ Click on **Learn More** to open the **Future Habitat App Fact Sheet** in a new browser tab (note that Barrier Islands are not included in results).
- ➢ Begin with the **Choose Parameters** tab.

maps.coastalresilience.org/virginia

- Explore **Choose a Scenario Year** and **Choose Sea-Level Rise Scenario** by sliding the bars in varying combinations to visualize where marshes may be most vulnerable to sea-level rise (SLR) and where marshes have the most potential for migration inland.
- Click on **More Info (Click)** in the Map Legend for descriptions of future habitat types.
- Under **Filter Results by Habitat(s) of Interest**, check **Salt Marsh** and then explore different Scenario Year and SLR Scenario combinations. The filter allows the user to view only how Regularly Flooded, Irregularly Flooded, and Transitional Salt Marsh Habitat Types change over time.

Question 1-A: How do Regularly Flooded, Irregularly Flooded and Transitional Salt Marsh Habitat Types change in distribution (general locations) and extent in 2065 under the High SLR Scenario from current condition?

Exercise B: Future Habitat for Marsh Conservation in Deep Creek

★ **Exercise B Planning Outcome:** *Identify areas of potential future marsh retreat currently secured by some form of land protection that should be the focus of restoration actions in the Deep Creek area.*

- Hit **F5** to reset and click the **X** to close the Getting Started window.
- Go to the **Search by Address** box and type **Deep Creek, VA** and select **Deep Creek, Accomack County, Virginia, United States** from drop down menu. Click the **X** to close the drop down menu.
- Click on the **Future Habitat** app.
- Click on **Regional Planning** app.
- Turn on **Protected Lands** layer (under **Coastal Management**) and **Parcels** layer (**Base Data**).
- Click on **Future Habitat** app icon to bring the app window back up.
- Examine the distribution of Habitat Types and the types of habitat that are Protected Lands under current conditions (pan the map as needed).
- Slide Scenario Year to **2065** and SLR Scenario to **Highest**. Explore how the distribution of Habitat Types changes in the Parcels that are Protected Lands under different combinations of Scenario Years and SLR Scenarios.
- Slide the **Layer Properties** slider at the bottom of the app window about halfway between Opaque and Transparent.
- Zoom out and/or pan the map to view the neck of land between Deep Creek and Doe Creek (to the east of Deep Creek).
- Click on **Click to Draw an Area**. The cursor is now active and ready to draw a shape.
- Draw a polygon around a grouping of Protected Parcels in the area between Deep Creek and Doe Creek that best captures the gradient from current to potential future Transitional and Irregularly Flooded Salt Marsh under the Highest SLR Scenario in 2065. **Click once for each point** and **twice for the final point** to end. Do not hold the mouse button down as you draw.

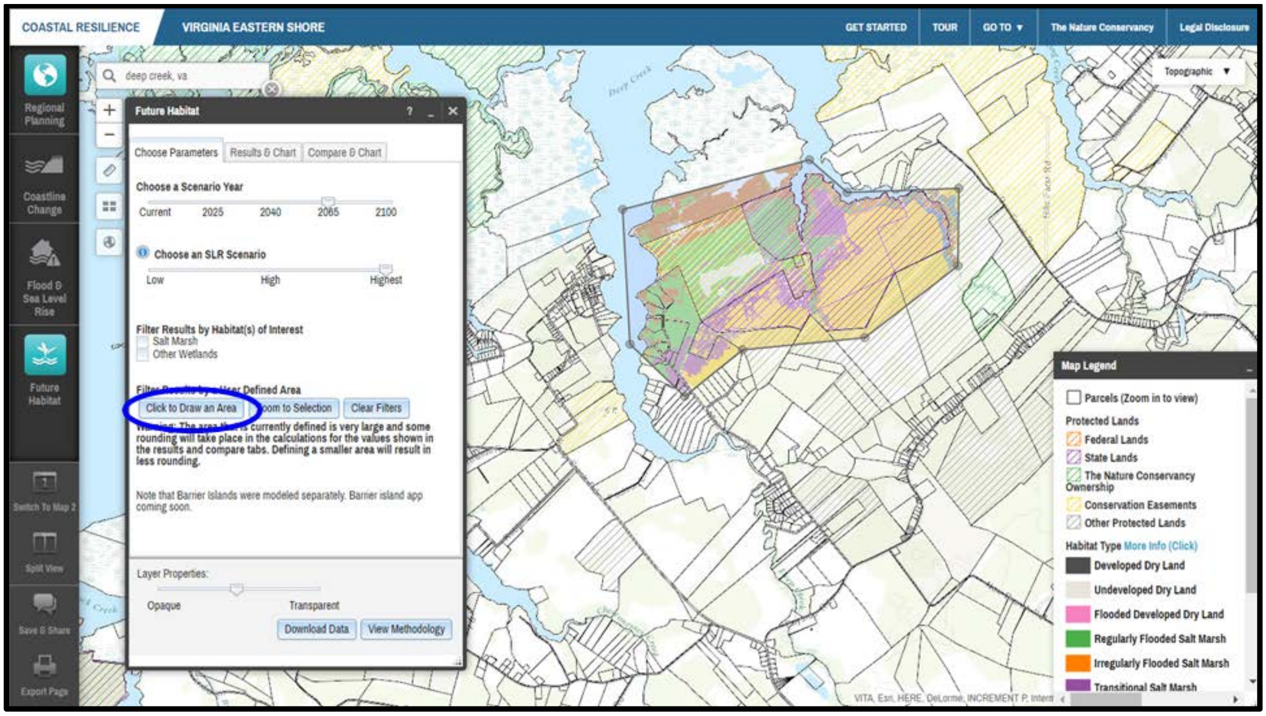


Figure 6. Example of what your screen should look like prior to Exercise B question 1-B.

➢ Select the **Results & Chart** tab at the top of the app window. View and mouse-over the **pie chart** for acreage of each Habitat Type within your custom polygon extent.

o **Scroll down** to view table format for same information.

Question 1-B: What is the total acreage and percent area for Regularly Flooded vs. Irregularly Flooded vs. Transitional Salt Marsh in your polygon?

____

➢ Click the **Compare & Chart** tab.

- View and mouse-over **chart** to see change in acreage by Habitat Type from current condition within your custom polygon extent.
- **Scroll down** to see table that shows Total Acres, Change in Acres vs. Percent for each Habitat Type found in your custom polygon extent.

Question 2-B: What is the change in acres and percent change from current condition for Undeveloped Dry Land?

____

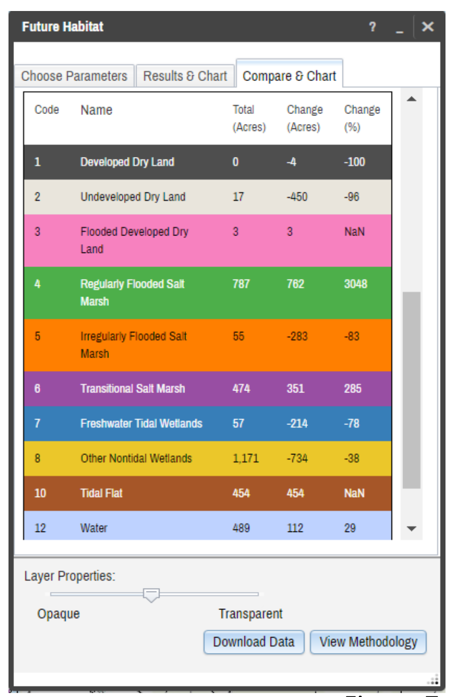


Figure 7.

➢ Select **Choose Parameters** tab and move the **Scenario Year** slider bar from **2065** to **2100**, check the box to filter results by **Salt Marsh**, and then explore filtered results for polygon using **Results & Chart** and **Compare & Chart** options, shown in figure 7.

maps.coastalresilience.org/virginia

Question 3-B: What is the change in acres and percent change from current condition for Regularly Flooded vs. Irregularly Flooded vs. Transitional Salt Marsh in your polygon?

____

- Click on **Clear Filters** to remove Draw Area.
- Let's say you want to share this analysis with a colleague to get their input. Click the **Save and Share** icon in the bottom left of the screen which creates an active bookmark of your map and any data or apps that are open. You would then copy the **Permalink** and paste it into an email.
    - To simulate what your colleague would see when they opened the link, paste the **Permalink** into a new tab in your browser. The link opens at the exact place you left off, and your colleague can continue to make changes and send back to you.

On Your Own:

Question 4-B: What are some long-term shoreline management, land use, or restoration strategies that the Protected Parcels stakeholders might consider to ensure the successful migration of marsh in this area over the next 85 years?

____

Exercise C. Future Habitat for Marsh Retreat at Henry's Point

★ **Exercise C Planning Outcome:** *Identify areas currently zoned for residential development that are currently classified as undeveloped dry land where salt marsh could potentially migrate in the future at Henry's Point (near Folly Creek).*

- Press **F5** on your keyboard to refresh the site.
- Scroll down in the Getting Started window and select **Henry's Point Future Habitat** in the One-Click Interactive Maps section.
- Move the Layer Properties slider at the bottom of the app window about halfway between Opaque and Transparent.
- Switch to **Imagery** as map background.
- Click on **Regional Planning** app and under **Virginia**...**Base Data** turn on **Parcels** to view the high density of undeveloped and developed residential lots fronting existing Regularly Flooded Salt Marsh. (Note: if you are too zoomed in, the parcels disappear so play with the zoom level by rolling the mouse wheel gently until you find the closest zoom level possible.)
- Click back to **Future Habitat** app.
- Examine the current distribution of Habitat Types in proximity to the residential parcels on Henry's Point.
- Set slider bars on Scenario Year **2065** and SLR Scenario **High**.
- Zoom into the area shown in Figure 8.

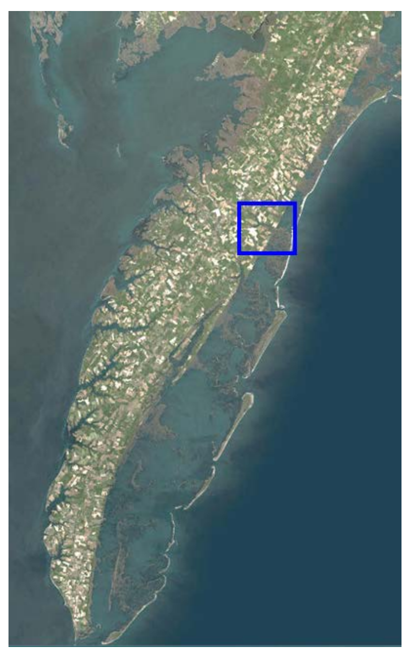


Figure 8. Henry's Point Lane Area.

maps.coastalresilience.org/virginia

➢ Click on **Click to Draw an Area** and draw a polygon that captures the residential development area between Custis Neck Road, Seaview Street, and the creek fronting Henry's Point Lane. **Click once for each point** and **twice for the final point** to end and don't hold the mouse button down as you draw.

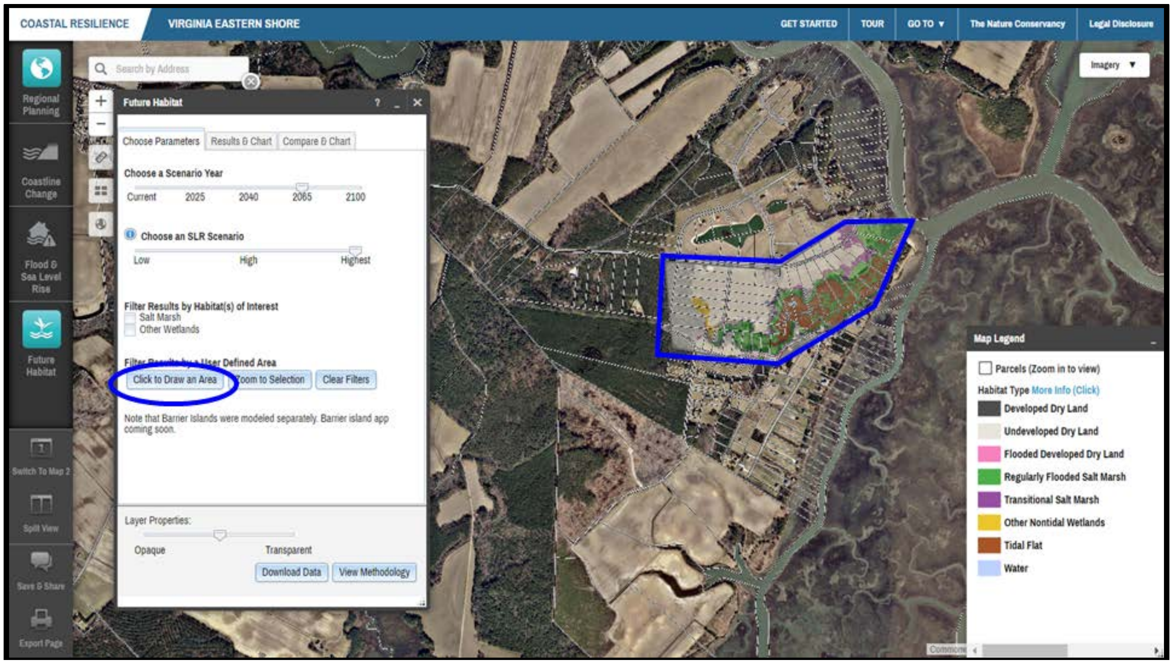


Figure 9. Example of what your screen should look like prior to Exercise C question 1-C.

On Your Own:

Question 1-C: In your polygon, how much Undeveloped Dry Land could be converted to different Marsh Habitat Types?

____

Question 2-C: Roughly how many undeveloped parcels (empty lots) are most vulnerable to marsh migration without intervention?

____

Question 3-C: Based on visible development, which groups of parcels and shoreline segments would you recommend for natural marsh migration versus living shoreline treatments versus conventional bulkheads?

____

TECHNICAL SKILLS COMPLETED

- ❏ Ability to identify places where habitats, particularly salt marsh, may change in the future due to sea-level rise
- ❏ Ability to identify areas that are currently undeveloped dry land but that could become salt marsh under future sea-level rise scenarios
- ❏ Ability to consider a range of planning options that would allow marshes to migrate naturally

Implementation:

- ❏ You can use the Future Habitat app to more effectively communicate to decision-makers and stakeholders that coastal habitats will respond dynamically to sea-level rise.
- ❏ You have a better understanding that although potential exists to lose much of the existing tidal marshes due to sea-level rise in the future, the landscape has high capacity for marsh migration on the mainland at the regional scale. The ability for marsh migration to occur unimpeded on the mainland will ultimately depend on shoreline management and land use decisions. Armed with this information, you can begin to work with private landowners, resource management entities, and localities to identify open spaces or parcels where accommodating inland marsh migration is a viable management approach.
- ❏ You can use the "Save and Share" feature to work collaboratively with colleagues to get input on an analysis or create a map to help make the case for a project proposal.

Part Four: Coastline Change App

Understanding Past and Future Changes to the Seaside Barrier Islands

Exercise A: Historical Shoreline Change Data for Virginia's Barrier Islands

★ **Exercise A Planning Outcome:** *Gain understanding of historic long- and shorter-term rates of shoreline change at the scale of individual barrier islands and for the regional Virginia Barrier Island chain.*

- ➢ Press **F5** on your keyboard to refresh the site, then close the Getting Started window.
- ➢ Click on the **Coastline Change App** on left.
- ➢ Review opening infographic and hyperlinks to fact sheets for each module.
- ➢ Click **Next** to launch app.
    - Note: You can check the box **Don't show this on start** to skip the opening infographic in the future.
- ➢ The app automatically loads historical data.
    - Once app is open if you click **?** at the top, it will take you back to opening infographic.
    - Click **Explain Each Choice** for additional information on the various options below.

maps.coastalresilience.org/virginia

- Click **Hide Explanations** to hide this information.

- Click on **Learn More** to view the Historical Data Fact Sheet and Supplemental Information in a new browser tab. This document can be downloaded or printed out and shared with colleagues or decision makers.
- Select **Hog Island** from the island dropdown menu
- Click **Play** underneath the Select Shoreline Year slider to see how the Hog Island shoreline has evolved since the 1850s.
- Click **Stop** and move the slider to **1910s**.
- In option 3 (Display Historic Shorelines) select **Multiple** then check the boxes for **1940s** and **2014.**

Question 1-A: Does the Hog Island shoreline appear to be rotating or is it moving progressively in one direction across its entire length?

____

- Zoom in to the northern part of Hog Island then select **Change Rate** in option 2. Notice that the imagery basemap changes to a more recent image.
- Click on a few transects on the map to view change rate information about each transect in the bottom of the app window, as shown in Figure 10. Note that the length of each transect is proportional to the change rate.

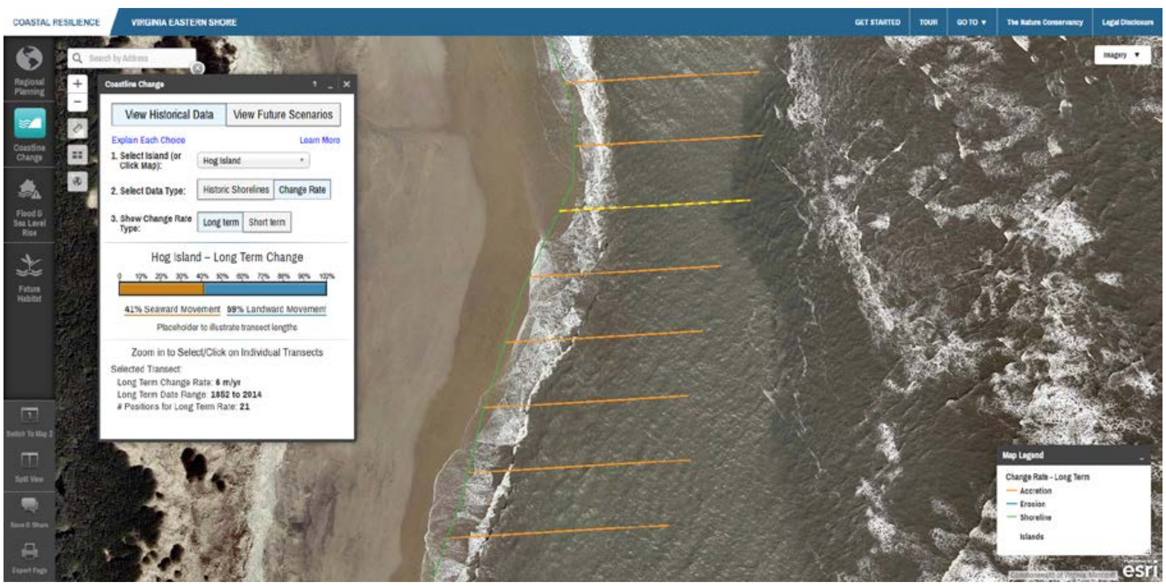


Figure 10. Zoomed to transects in northern part of Hog Island.

- Zoom out until the full extent of Hog Island is visible.
- In option 3 select **Short term**. Now select **Long term** for comparison.
- Toggle back and forth between these two options for comparison.

Question 2-A: Where has Hog Island experienced a change in the long-term coastline change trend?

____

maps.coastalresilience.org/virginia

➢ Select **Virginia Eastern Shore** from the **Select Island** dropdown menu.
➢ Select **Change Rate** and **Short term**.

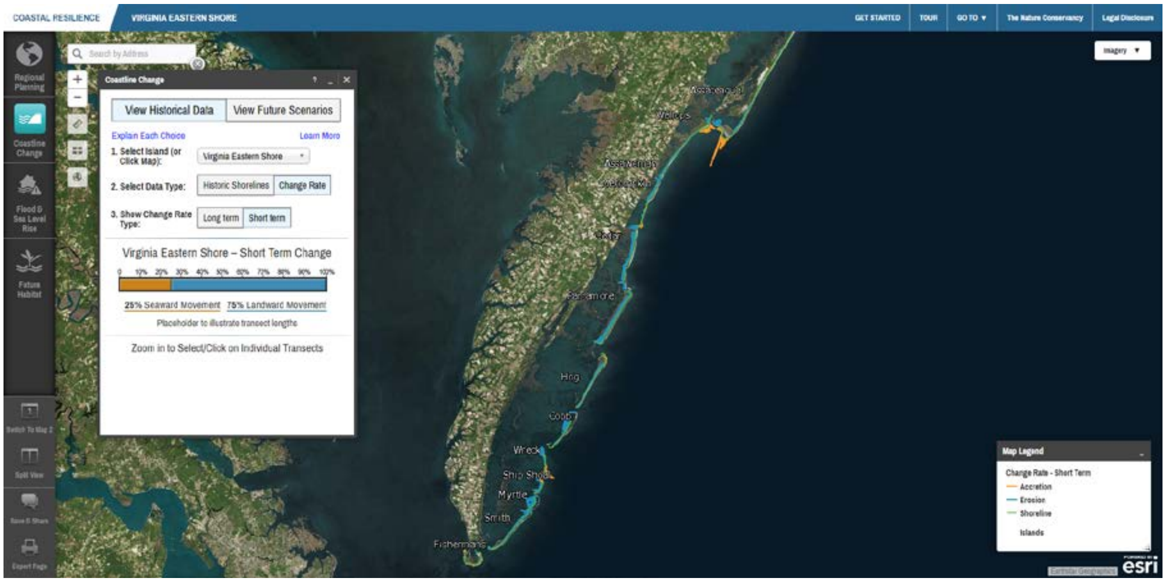


Figure 11. Example of what your screen should look like prior to Exercise A question 3-A.

Question 3-A: What percentage of the entire Seaside barrier island chain has experienced seaward movement (accretion) according to the short-term trend?

➢ Hover the cursor over **Metompkin Island** on the map (Note that the outline appears blue) and click. This is another method for zooming to a specific island.
➢ Select **Long term** change rate. Now select **Short term** for comparison.

Question 4-A: What is the direction of movement and approximate range in rate of change for Metompkin Island according to the long-term trend? (Note that you may need to zoom in to select individual transects.) Are there parts of the island that are stable or experiencing seaward movement (accretion) according to the short-term trend? How does this pattern of coastline change compare to that of Hog Island?

➢ Select **your favorite island** from the **Select Island** dropdown menu or select it by clicking on the map.
➢ Explore historic shorelines and rates of change for this and other islands of your choosing.

maps.coastalresilience.org/virginia

On Your Own:

Question 5-A: Where is the short-term rate of change the greatest for both erosion and accretion? Hint: Look for very long transect lines.

____

Question 6-A: Can you find places where the short-term rate of change is relatively stable?

____

Exercise B: Future Scenarios of Barrier Island Evolution

★ **Exercise B Planning Outcome:** *Understand the extent to which relative sea-level rise, changes in wave climate, and beach nourishment activities may change and influence the evolution of the Virginia Barrier Island chain.*

- Click on **View Future Scenarios** at the top of the app window.
- Click on **Learn More** to view the Future Scenarios Fact Sheet and Supplemental Information.
- Click on **Explain Each Choice** to see more information about each option then click **Hide Explanations**.
- Note that zooming is disabled in Future Scenarios due to the approximate nature of the model used to generate the data.
- Note that the data presented represent a modeled, hypothetical shoreline and do not represent the actual individual islands illustrated on the base map.
- Select **Highest** and **High** sea-level rise scenarios and note differences in **Change Rate Difference** on the map and in the chart at the bottom of the app window, shown in figure 12. Note that the numbers in the legend and on the chart refer to the difference in rate of change from a baseline. The baseline is future change under current climate conditions where relative sea level rises at the rate of 3 mm per year, the wave climate is consistent with the best-known present wave climate, and no nourishment occurs at any location.

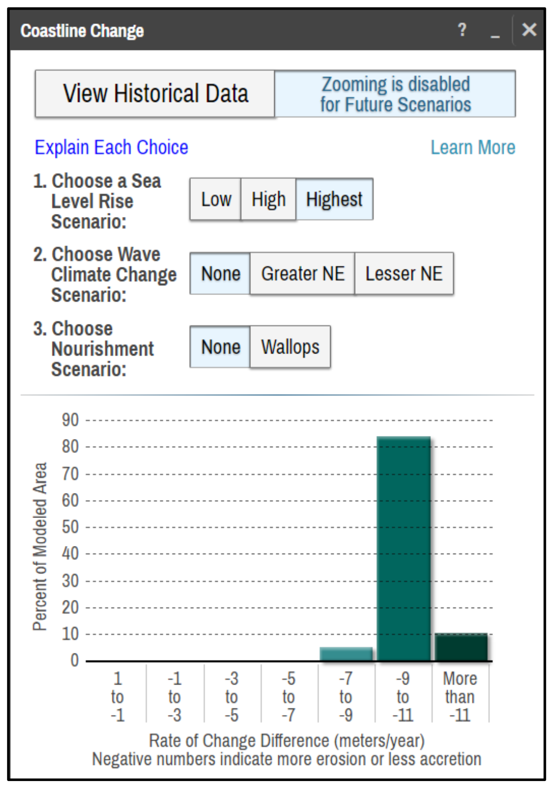


Figure 12. Coastline Change app Future module Scenario Dialogue Box

maps.coastalresilience.org/virginia

Question 1-B: Which areas are suggested to experience the greatest Rate of Change Difference in the High and Highest sea-level rise scenarios along the Seaside?

- With the **High** sea-level rise scenario selected, choose **Greater NE** wave climate scenario and **Wallops** nourishment scenario. Now choose **Lesser NE** wave climate scenario.
    - **NOTE:** *Wallops Island was modeled as a zone where beach nourishment may occur in the future since it has been implemented in the recent past. The modeled projections should in no way indicate an endorsement of beach nourishment as a management option, on Wallops or elsewhere in the region.*
- With any combination of wave climate and nourishment scenarios selected, select the **Highest** sea-level rise scenario.

Question 2-B: Do changes to wave climate and nourishment scenarios have a potentially greater or lesser influence on the Seaside shorelines as compared to sea-level rise?

- Select **Highest** sea-level rise scenario and **None** for both wave climate and nourishment scenarios. Notice the area in the vicinity of Wallops Island.
- Select **Greater NE** wave climate scenario. Compare this with the **Lesser NE** and **None** options.

Question 3-B: What are the suggested changes to the Wallops Island area according to the various wave climate changes?

On Your Own:

Question 4-B: Does the Future Scenarios module suggest that nourishment may result in widespread or more localized changes along the Seaside?

maps.coastalresilience.org/virginia

TECHNICAL SKILLS COMPLETED

- ❏ Ability to view various historic shoreline positions along with rates and direction of barrier island movement for all of the Eastern Shore barrier islands
- ❏ Understanding of how sea-level rise, potential wave climate shifts, and nourishment scenarios may affect future changes to barrier island shorelines

Implementation:

- ❏ Organizations and agencies who manage barrier islands, research scientists, and local governments may use the Future Scenarios module in the Coastline Change app to explore different regional climate and nourishment scenarios in order to better anticipate and manage shoreline changes in the future.
- ❏ Suggested conclusions of the Future Scenarios modules outputs:
    - ❏ The Coastline Change app demonstrates that the Virginia Barrier Island chain is highly dynamic and dependent on the interaction of local and regional processes.
    - ❏ On a regional scale, the results suggest that relative sea-level rise is the dominant factor in causing more erosion or less accretion along the barrier island chain.
    - ❏ Nourishment activities are suggested to have a more limited and local effect on the barrier island chain than expected.
- ❏ The information from Future Scenarios as a springboard for additional inquiry and modeling efforts regarding potential local coastline change in the future.

COASTAL RESILIENCE

COASTALRESILIENCE.ORG

Coastal Resilience is a program led by The Nature Conservancy to examine nature's role in reducing coastal flood risk. The program consists of an approach, a web mapping tool, and a network of practitioners around the world supporting hazard mitigation and climate adaptation planning.

APPROACH

The approach consists of four critical steps:

1. Assess Risk and Vulnerability to coastal flood hazards including current and future storms and sea level rise

2. Identify Solutions for reducing flood-related risk across social, economic and ecological systems

3. Take Action at priority conservation and restoration sites to help communities identify and implement nature-based risk reduction solutions

4. Measure Effectiveness to ensure that efforts to reduce flood risk while increasing community and ecosystem resilience are successful

Coastal Resilience projects around the U.S., encompassing 17 coastal states, in the Caribbean, across Mexico and Central America, and a global effort enable planners, government officials, and communities to develop risk reduction, restoration and resilience strategies.

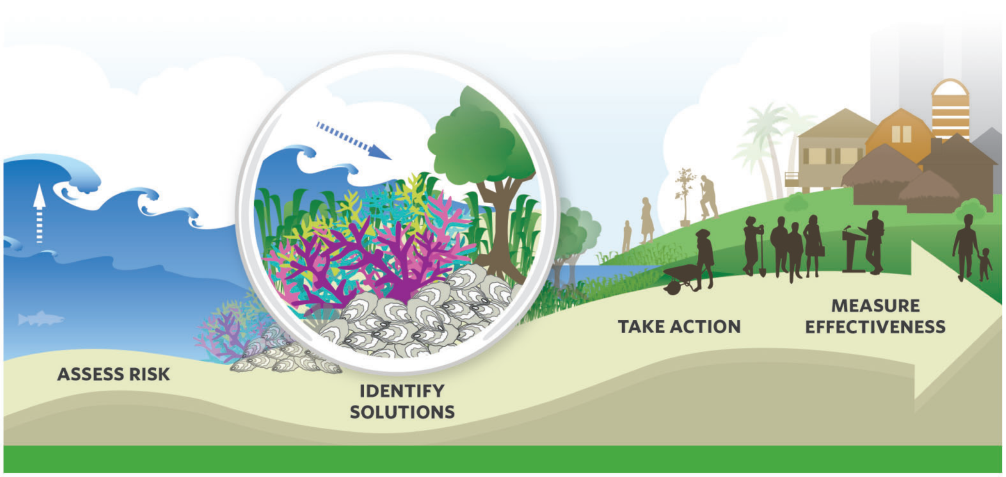
The program has trained and supported over 100 communities around the world on the uses and applications of Coastal Resilience, focusing on the identification of nature-based adaptation and risk mitigation solutions.

SOLUTIONS & ACTIONS

The best solutions may depend less on modern infrastructure, and more on rethinking how we value existing natural resources. By providing information on coastal hazards, socio-economics, habitats and ecosystems, Coastal Resilience explores nature-based solutions in:

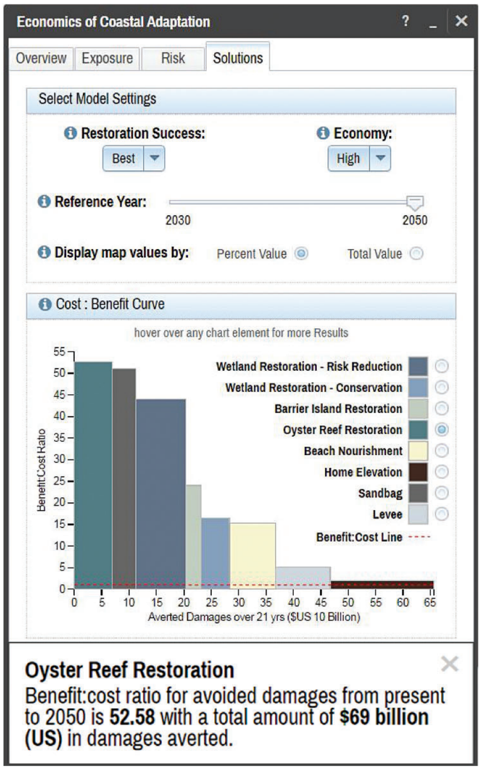
- protecting or restoring habitats as buffers to flooding in front of coastal communities
- developing hybrid approaches that link natural and built defense structures
- accommodating the landward movement of tidal marshes and mangroves as sea levels rise
- designing restored oyster and coral reefs as breakwaters that reduce wave height and power
- removing incentives to build in high-risk areas

The science of nature-based solutions in reducing coastal flood risk is growing rapidly; a Coastal Resilience communication and decision support tool examines when and where they are most effective.



MAPS & APPS

An innovative web-mapping tool consists of a data-viewing platform and web apps designed to engage key stakeholders and provide decision support.



The Coastal Resilience tool allows users to:

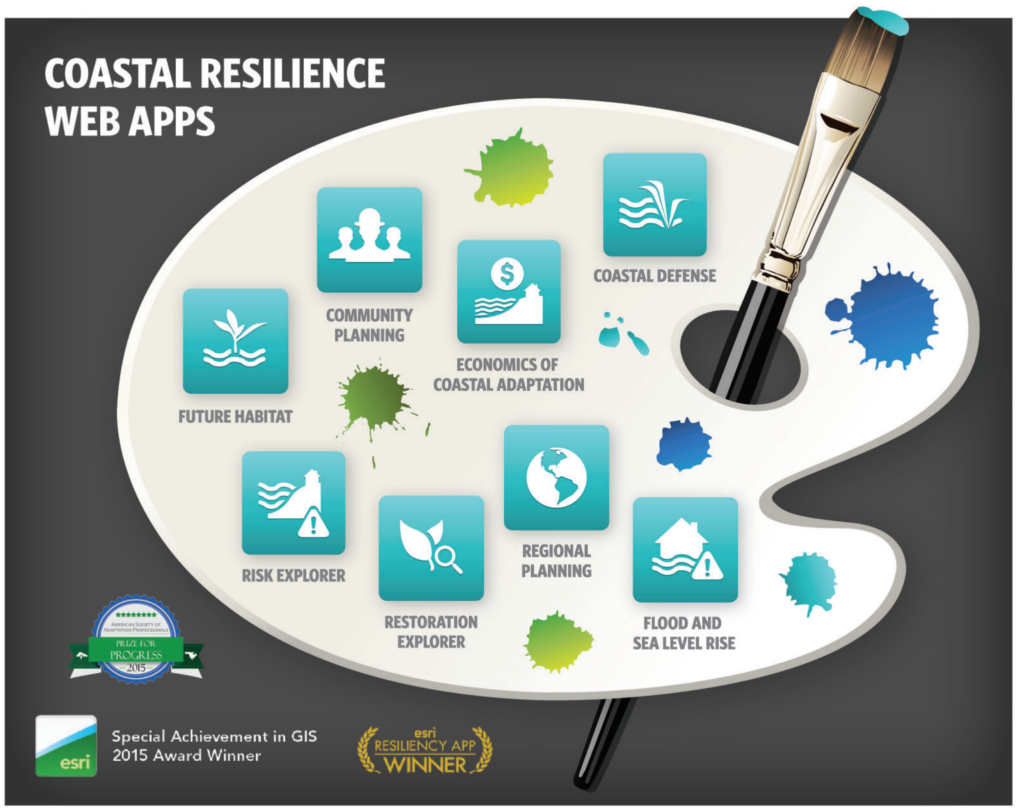
- view potential impacts of sea level rise, surge from storms and hurricanes, and inland flooding
- combine coastal habitat and exposure with socio-economic data to identify where habitat management may most reduce risks
- examine natural and built coastal defense strategies
- compare risk and vulnerabiltiy indicators across countries

Web apps are customized to meet a specific need, whether a coastal management policy, post-storm disaster decision-making, community assessment, hazard mitigation plan or cost effectiveness evaluation.

NETWORK

Coastal Resilience practitioners are collaborating with engineering firms, the reinsurance sector, aid groups and multi-national institutions to find viable nature-based solutions to climate change, for instance:

- guiding Connecticut's sea level rise policy
- developing a cooperative agreement with the U.S. Navy to actively manage strategic retreat of a naval base in Southern California
- assessing social-ecological vulnerability and prioritizing mangrove and coral reef restoration with the Red Cross in Grenada
- determining the costs and benefits of natural and built infrastructure with SwissRe in the Gulf of Mexico



Contact us at **coastalresilience@tnc.org**, discover the tool at **maps.coastalresilience.org**, and follow us **@CoastResilience**

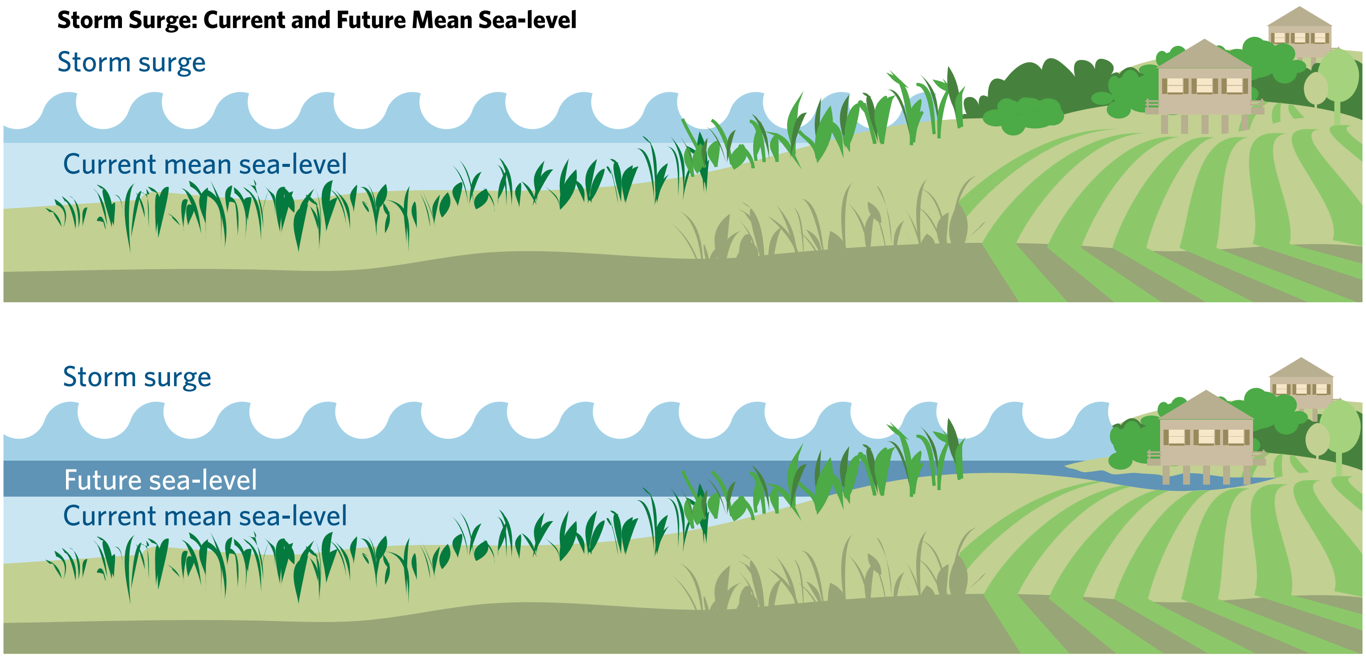
PARTNERS INCLUDE:

International Federation of Red Cross and Red Crescent Societies
The Nature Conservancy — Protecting nature. Preserving life.
USGS — science for a changing world
Alliance Development Works
United Nations University UNU-EHS Institute for Environment and Human Security
natural capital PROJECT
Global Disaster Preparedness Center
The University of Southern Mississippi
esri

Flood & Sea-Level Rise App: Storm Surge Fact Sheet

VIRGINIA EASTERN SHORE *COASTAL RESILIENCE* TOOL

Storm Surge: Current and Future Mean Sea-level



What is the Storm Surge part of the Flood & Sea Level Rise App?

The Storm Surge module in the Flood & Sea Level Rise app in the *Coastal Resilience* tool shows the potential effects of sea-level rise on wind- and wave-driven storm surge along Virginia's Eastern Shore. Both potential modeled depths and estimated economic losses due projected storm surge are available in the app module.

Multiple theoretical hurricanes and one historic nor'easter were modeled in the app module. The theoretical storms were selected from the Federal Emergency Management Agency's (FEMA) Flood Insurance Study database. The selected storm scenarios include a variety of storm parameters and tracks to capture a range of potential surge conditions in areas of interest identified by community stakeholders. In addition, FEMA's Hazus model, a nationally standardized methodology that estimates potential economic losses due to flood hazards, was run with the storm surge model results.

Who should use it?

Planners and managers can use this app to visualize the potential future risk of storm surge in response to sea-level rise on towns, homes, property, and critical built infrastructure like roads and utilities, as well as coastal habitats. This information helps support planning and decision-making related to hazard mitigation, emergency services, storm water management, land use and conservation.

How does it work?

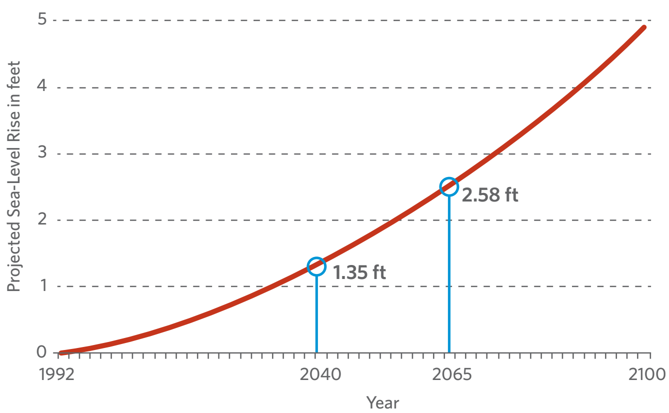
The app shows the potential maximum storm surge water depth and estimated economic losses for multiple modeled storms for three intensity categories and one historic storm defined, as follows:

- **Low Intensity** includes three Category 1 hurricanes with maximum winds of 80 mph.
- **Moderate Intensity** includes a combined total of six Category 1 and 2 hurricanes with maximum winds between 85 and 110 mph.

- **High Intensity** includes a combined total of seven Category 2 and 3 hurricanes with maximum winds between 95 and 115 mph.
- **Nor'Ida** shows the modeled storm surge generated by that particular storm, which occurred in 2009.

All storms were modeled for current (2015), 25-year (2040) and 50-year (2065) sea-level rise scenarios using the projected "high" sea-level rise curve based on the 2012 National Climate Assessment and corrected for local land subsidence by the Virginia Institute of Marine Science.

The sea-level rise scenarios selected to model with storm surge, (feet above baseline)



What are strengths and limitations?

The app demonstrates that surge does not respond uniformly in response to sea-level rise as commonly portrayed by simplistic "bath tub models", but rather, is influenced by topography, bathymetry, and land cover in addition to sea-level rise. Simply stated, a given sea level rise will not affect all places equally. Users can see these differences in the app by clicking on the absolute difference (in feet) or percent difference options.

All the storm surge modeling was done based on mean tide level. Since the purpose of the app is to convey how wind- and wave-driven surge will be affected by rising sea levels, tides are not needed to evaluate the sensitivity of surge to sea level. The app allows users to visualize surge-only results and to view the local tidal amplitude for locations throughout the study area. Importantly, actual water levels may be higher or lower based on tidal conditions at the time of the surge. The modeled storms in the app do not have a probability of occurrence associated with them. However, subjectively speaking, a low-intensity storm has a higher probability of occurring in any given year than a high intensity storm. Also, the storms were randomly generated and, therefore, do not share the same track, which results in varying flooding potential for seaside versus bayside. Finally, uncertainties inherent in the economic loss estimates may result in significant differences between the modeled results and the actual economic losses following a specific flood event.

How is the app being used?

The Storm Surge module of the Flood & Sea Level Rise app is currently being used by Accomack-Northampton Planning District Commission to update the Eastern Shore Hazard Mitigation Plan.

Who developed it?

The Storm Surge module of the Flood & Sea Level Rise app was developed through a partnership between The Nature Conservancy, Arcadis and the Virginia Coast Reserve Long-Term Ecological Research Program with-input from local community stakeholders on Virginia's Eastern Shore. Economic loss data were developed with guidance from the FEMA Hazus team.

For general info about the Virginia Eastern Shore *Coastal Resilience* project: **coastalresilience.org/virginia**

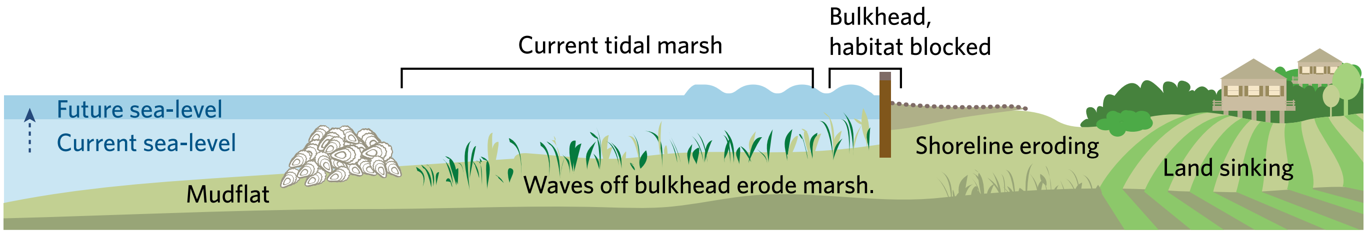
To access the Virginia Eastern Shore *Coastal Resilience* mapping portal: **maps.coastalresilience.org/virginia/**

For questions, contact info, etc: Chris Bruce, GIS Manager | vacoastalresilience@tnc.org | (434) 951-0565

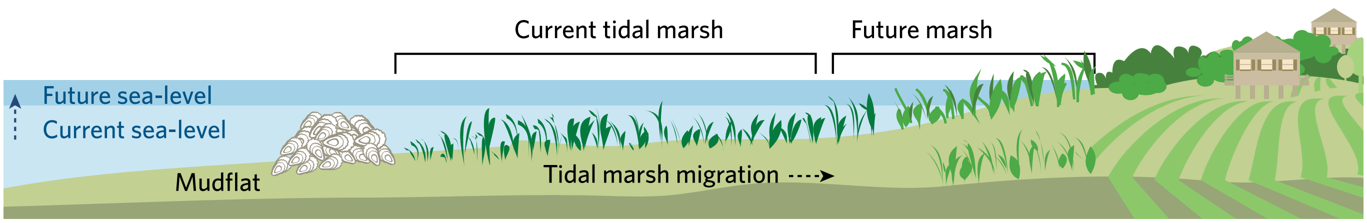
Future Habitat App Fact Sheet

VIRGINIA EASTERN SHORE *COASTAL RESILIENCE* TOOL

Future Habitat Changes: Landward Marsh Migration Scenarios



Tidal marsh migration blocked as sea-level rises.



Tidal marsh able to migrate landward as sea-level rises.

What is the Future Habitat App?

The Future Habitat app in the *Coastal Resilience* tool shows how the size and distribution of tidal marshes and other coastal habitats on the Virginia Eastern Shore may change in response to future projected sea-level rise scenarios. Tidal salt marshes connected to the mainland have the ability to migrate landward as sea-level rises. This depends on several factors including the elevation of the marsh, the rate of sediment accretion, the rate of sea-level rise, and existing barriers to migration in the landscape (e.g., bulkheads, roads).

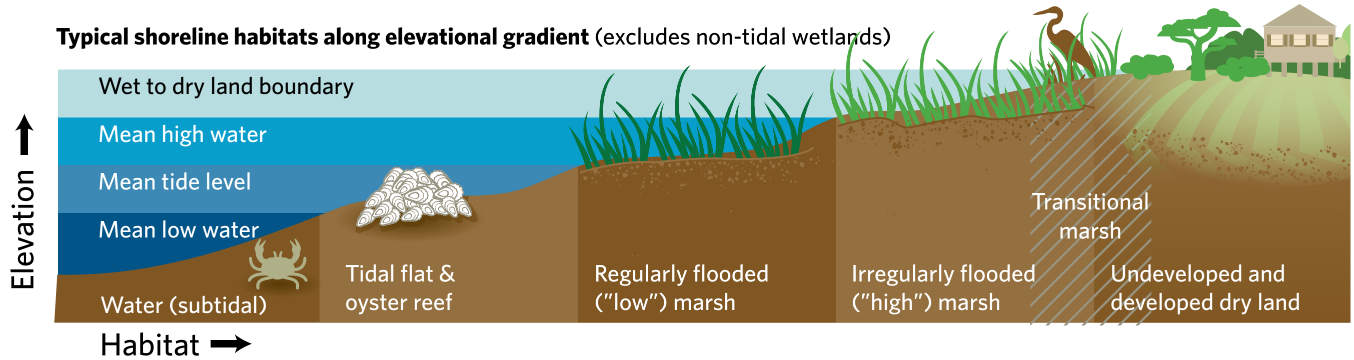
Who should use it?

Planners, managers and property owners can use this app to visualize general trends in the distribution and location of marsh habitat in response to sea-level rise. This information helps support shoreline management, hazard mitigation planning, land use planning and restoration plans. However, this app is not appropriate for local siting or permitting decisions without gathering more site-specific information.

How does it work?

The app displays results generated from the Sea Level Affecting Marshes Model (SLAMM) that incorporates elevation, land cover, and wetland extent with locally-derived empirical data on tides, accretion and erosion rates to predict where tidal marshes may migrate upland in response to changes in sea-level over time. Relative sea-level rise scenarios are based on the low, high and highest projections from the 2012 National Climate Assessment that have been adjusted for local land subsidence rates by the Virginia Institute of Marine Science. For each of the three sea-level rise curves, the model was run for the following years: 2025, 2040, 2065, and 2100.

In addition to visualizing various scenarios on a map, results can be filtered for a user-defined area using the "Click to Draw an Area" tool or by habitat types of interest. Charts and tables are generated to show both the percent and absolute change (acreage) in habitat types for selected relative sea-level rise scenarios compared to current condition.



What are the strengths and limitations?

Multiple sources of unquantified uncertainty exist in SLAMM results concerning the future rates of sea-level rise, as well as local rates of accretion. The Future Habitat app should be considered as a general representation of how tidal marshes may respond to sea-level rise, with the understanding that actual changes in coastal wetlands are complex and difficult to predict.

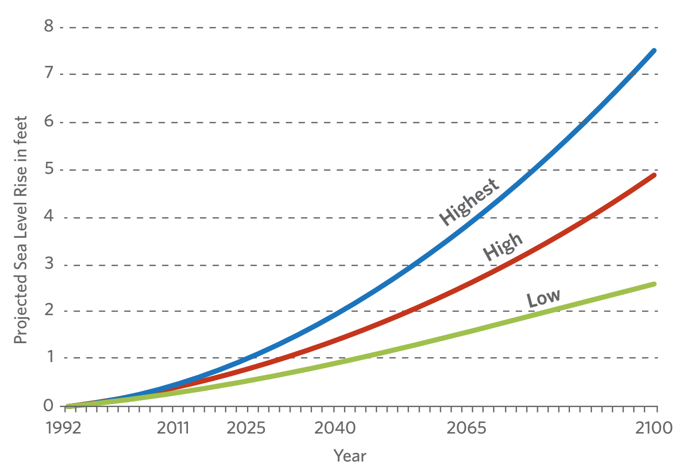
Further, SLAMM is designed to model mainland marsh migration that is driven largely by accretion of sediment, whereas barrier islands and back barrier marshes migrate in response to a more complex suite of geophysical processes. Therefore, SLAMM cannot reliably predict the future extent and location of barrier islands and back-barrier marshes. Consequently, Atlantic barrier islands and inlets are modeled separately and the results are presented in the future scenarios portion of the Coastline Change app.

How is the app being used?

The Future Habitat app is being used by natural resource managers on the Eastern Shore to target areas for conservation and restoration activities. In addition, the Accomack-Northampton Planning District Commission is providing information from the Future Habitat app to local planning commissions for updates to county comprehensive plans.

Relative Sea-Level Rise Projections Modeled in Future Habitat app (in feet) from 2011 baseline.

	2025	2040	2065	2100
Low	0.23	0.59	1.22	2.29
High	0.34	0.97	2.20	4.51
Highest	0.48	1.41	3.32	7.07



Who helped develop it?

The Future Habitat app was developed through a partnership between Warren-Pinnacle Consulting, Inc., the Virginia Coast Reserve Long-Term Ecological Research Program, the University of Southern Mississippi, and The Nature Conservancy.

For general info about the Virginia Eastern Shore *Coastal Resilience* project: **coastalresilience.org/virginia**

To access the Virginia Eastern Shore *Coastal Resilience* mapping portal: **maps.coastalresilience.org/virginia/**

For questions, contact info, etc: Chris Bruce, GIS Manager | vacoastalresilience@tnc.org | (434) 951-0565

The Nature Conservancy | warren pinnacle consulting, inc. | VCR LTER | The University of Southern Mississippi

Coastline Change App: Historical Data Fact Sheet

VIRGINIA EASTERN SHORE *COASTAL RESILIENCE* TOOL

Historical shoreline change along a Virginia Barrier Island

Illustration: © Vin Reed/Vin Design

What is the Historical Data module in the Coastline Change app?

Beaches and barrier islands are dynamic systems that move constantly in response to processes that erode, transport, and deposit sand. The Historical Data module of the Coastline Change app in the *Coastal Resilience* tool uses a robust dataset that covers 165 years of observed shoreline changes along the Virginia barrier islands (including Assateague Island), allowing users to explore how much and in which direction these shorelines have changed over this time period.

Who should use it?

Organizations and agencies who manage barrier islands, research scientists, local governments, and citizens who want to learn about the dynamic nature of Virginia's barrier islands may benefit from viewing the historical data that provides useful context for understanding the barrier islands as they continue to evolve in the future.

How does it work?

The Historical Data module in the Coastline Change app allows users to view two kinds of data: (1) the geographic location of past shorelines, and (2) the calculated change rates (in meters per year) for shorelines over short- and longer-term time ranges. Users can explore the historical shorelines by playing an animation that illustrates sequential shoreline locations over the years for which data exist or by manually selecting multiple shorelines to display side by side.

Users can also view shoreline change rates at multiple spatial and temporal scales. Shoreline change was measured at transects spaced 50 meters apart and approximately perpendicular to the shoreline. **Long-term rates of change** are based on an analysis of all historic shorelines from the earliest to most recent dates. Sometimes, a change in the long-term trend is observed. Where this is the case, a **short-term rate of change** has been calculated from the time the change occurred to the most recent date available.

When viewing change rate data in the app, the percent seaward and landward movement is summarized at the scale of the entire Virginia Eastern Shore or of individual islands. Negative rates of change indicate **landward movement** of the shoreline (erosion) and positive rates of change indicate **seaward movement** (accretion). Shorelines can switch from landward to seaward movement, or vice versa, over time, leading to a short-term rate of change that may differ from the long-term rate.

Additional data about shoreline trends are available for individual transects on the islands, including the rate of change in meters per year, the time span of the earliest and latest date, and the number of shoreline positions measured to calculate the change rate.

What are strengths and limitations?

The historic shoreline data presented in the Coastline Change app are among the most comprehensive and long-term datasets describing shoreline change anywhere in the world, including 38 unique years of data spanning 1850-2014. However, it is important to recognize that quantifying shoreline positions is only a proxy for how coastal processes such as sea-level rise, storms and sediment dynamics impact barrier islands and cause them to move in space and time. While a good proxy for island movement—and a proxy used by many federal and state coastal management agencies— shoreline change rates do not provide correlations with, or information about, the coastal processes that produce the shape changes to islands over time.

In addition, there are sources of error in these data. Digitizing shorelines from paper maps may introduce more error into shoreline rate of change calculations than digitizing shorelines from aerial photos because the on-ground survey techniques did not always use the same techniques or the same sea-level datum. Aerial photographs (or orthophotographs) provide actual imagery of a beach, but contain potential distortion error. Fortunately, the amount of error introduced into shoreline rate of change calculations by comparing different shorelines decreases as the amount of time between the earliest (oldest) recorded shoreline and latest (most recent) recorded shoreline increases.

Who developed it?

The database for the Historical Data module of the Coastline Change app was funded by National Science Foundation Research Opportunity Awards through the University of Virginia's Long-term Ecological Research Program and developed by a partnership between Randolph-Macon College and the University of Mary Washington. The app design and functionality was developed by a partnership among Randolph-Macon College, University of Mary Washington, The Nature Conservancy, NASA-Wallops Flight Facility, National Park Service Assateague Island National Seashore, U.S. Fish and Wildlife Service Chincoteague National Wildlife Refuge, the Accomack-Northampton Planning District Commission, and the Virginia Coast Reserve Long-Term Ecological Project.

For general info about the Virginia Eastern Shore *Coastal Resilience* project: **coastalresilience.org/virginia**

To access the Virginia Eastern Shore *Coastal Resilience* mapping portal: **maps.coastalresilience.org/virginia/**

For questions, contact info, etc: Chris Bruce, GIS Manager | vacoastalresilience@tnc.org | (434) 951-0565

Coastline Change App: Historical Data Supplemental Information

VIRGINIA EASTERN SHORE *COASTAL RESILIENCE* TOOL

Coastline Change App: Historical Data Supplemental Information

VIRGINIA EASTERN SHORE *COASTAL RESILIENCE* TOOL

DR. MICHAEL FENSTER, RANDOLPH-MACON COLLEGE
Contact: mfenster@rmc.edu

Introduction

Shorelines are the intersection of land and sea and move constantly over sandy coastal environments such as beaches and barrier islands. Shorelines move (or migrate) in response to oceanographic and geologic processes that operate over a variety of time scales. On one end of the time spectrum, daily waves and the currents resulting from the change in tides move sediment (sand) that can make shorelines move. On the other end of the time spectrum, changes in sea level (rise or fall) and/or to the supply of sand (increases or decreases) influence the direction and rate that shorelines move.

The current state of scientific knowledge does not enable a cause-and-effect analysis of shoreline movement (or migration). In other words, we can measure the rate at which shorelines move, but cannot conclusively explain "why?" they move. Consequently, coastal scientists, land managers and planners use the rates of shoreline movement (in meters or feet per year) as a proxy for (or representation of) the processes that erode, transport and deposit sand and to assess the mobility of beaches and barrier islands. In other words, measurements of the rate and direction of shoreline movement (i.e., migration) provide insight into the mobility of beaches and barrier islands and into the processes that are responsible for causing shorelines to move.

Description of Shoreline Change Database

The data used to calculate the rate and direction of shoreline movement over a particular time period come from a variety of sources. These sources include aerial photographs taken perpendicular to the land surface (orthophotographs), beach surveys on the ground using Global Positioning System (GPS) technology or other survey technology (e.g., beach profiles), historical maps and T-sheets (nautical charts), and, more recently, airborne Light Detection and Ranging (LiDAR) technology. Most scientists agree that the high water line (HWL), i.e., the boundary between the wet and dry parts of a beach, is the best representation of a shoreline. However, maps, T-sheets, and LiDAR can use other reference lines as the shoreline (e.g., mean high water [MHW]; mean low low water [MLLW], etc.). Fortunately, the amount of error introduced into shoreline rate of change calculations by comparing "different" reference shorelines decreases as the amount of time between the earliest (oldest) recorded shoreline and latest (most recent) recorded shoreline increases.

For the Virginia barrier islands south of Assateague Island, a subset of 38 individual (unique) years of partial or complete shorelines spanning the time period 1850-2014 was used for analyzing the rate of shoreline change. For Assateague Island, 34 shorelines spanning 1849-2014 were used. These shoreline data were developed "in-house" or came from well-known repositories of shoreline data, including the University of Virginia, the United States Geological Survey, and the National Park Service.

Shoreline Change Analysis

Shorelines from all sources were entered into sophisticated software programs such as Geographic Information Systems (GIS) software which position them accurately in space (on a map). An additional software program (Digital Shoreline Analysis System, [DSAS]) determined each shoreline's distance away from a baseline (in meters) at shore-perpendicular transects spaced 50 meters apart along the coast (Figure 1).

The transects are "cast" every 50 meters at right angles from the baseline which is situated offshore and approximately parallel to the shoreline. At each transect, the distance from the baseline to the intersection of each shoreline provides the data necessary to calculate a shoreline rate of change statistic and direction of movement (i.e., seaward or landward) using a linear regression (or best fit line) analysis (Figure 2).

Figure 1:

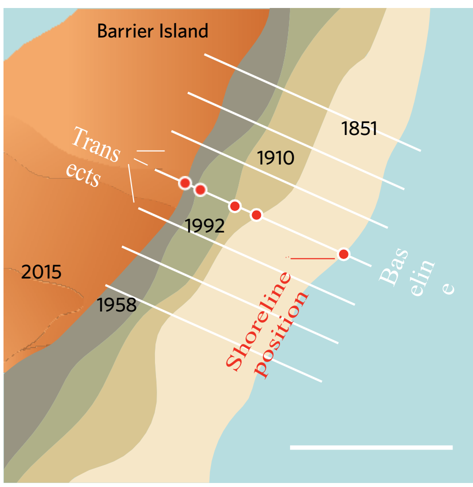
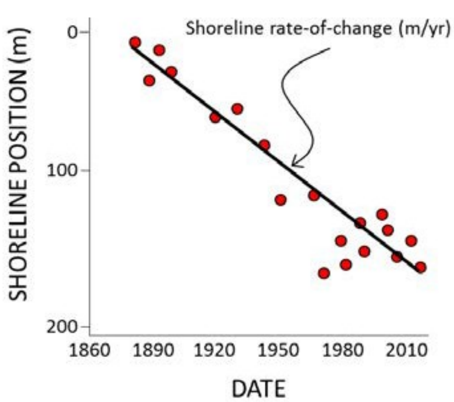


Figure 2:



While DSAS calculates shoreline rates of change, an additional program was used to calculate both rates of change, any short-term changes to long-term rates of change, and the direction of shoreline movement (and possible changes in direction).

This method, known as the Minimum Description Length (MDL), assesses the complexity of successively increasing functions that best fit the data against the accuracy of each function to determine if either one, two, or no changes in the long-term trend occurred:

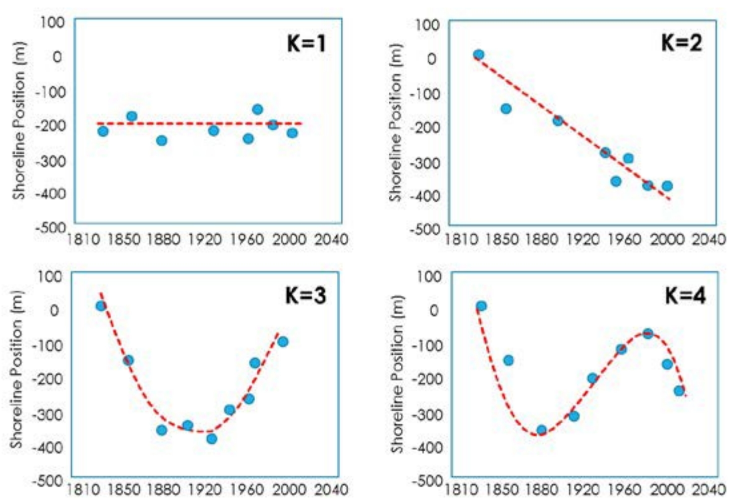
$$MDL_k = MSE_k + \frac{\ln(N)\ x\ K\ x\sigma_p^2}{N}$$

Accuracy ←———→ Copmplexity

WHERE...
MSE_k is mean squared error
N is the number of positions
K is the number of parameters in the model
σ_p^2 is the given prior noise variance

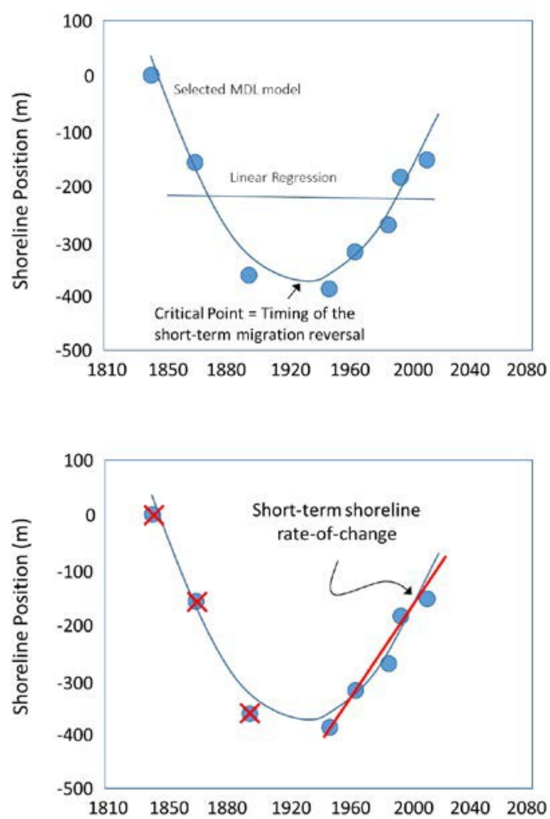
The minimum value of that analysis determines whether a constant (i.e., stable shoreline with no landward or seaward migration), linear (i.e., trend that does not change), quadratic (i.e., one short-term change in the long-term trend occurred) or cubic (i.e., two short-term changes in the long-term trend occurred) function best represents the historical shoreline migration history (Figure 3).

Figure 3:



If one short-term change occurred to the long-term trend, the MDL method uses a mathematical method to determine when the historical trend change occurred (called the critical point, which occurs when the first derivative of a function is equal to zero) and the rate-of-shoreline change after the shoreline migration reversal occurred (Figure 4). If two short-term changes have occurred to the long-term trend, only the shoreline position data of the most recent reversal were used to calculate a short-term linear regression rate of change.

Figure 4:



Using this approach, both long-term and shorter term change rates (when K=3 or 4) using linear regression are represented in the Coastline Change app for each individual transect along the Virginia barrier islands and Assateague Island. Additionally, the Coastline Change app provides info on the number of shoreline positions used in both the long- and short-term calculations as well as the earliest and latest date (time span) used to calculate the long-term trend.

Overall Conclusions from Historic Shoreline Database

The Virginia barrier islands constantly change in area (two dimensions) and volume (three dimensions) in response to sediment erosion, transportation and deposition resulting from coastal processes that affect the beach synergistically and operate over various temporal and spatial scales. These processes include sea-level changes, storm surges, storm waves, tidal inlet migration, tidal currents, and non-storm ("everyday") waves.

Shoreline movement along the Virginia barrier islands has had a complex history during the past 165 years. Individual islands have rotated clockwise and counter-clockwise, moved entirely landward or moved simultaneously both landward and seaward along their lengths. Furthermore, these patterns have changed over time. For example, most of the shorelines have had one or two short-term reversals in their longer-term trends. Preliminary analyses of these data show that nearly 91% of the Virginia barrier islands have experienced two changes in their long-term shoreline migration trend history, a little more than 6% of the shorelines have migrated linearly (monotonically or without a reversal) and only 1.5% have been stable. Of those shorelines that experienced a short-term trend reversal, the most recent change apparently occurred in the late 1880s toward landward migration. These data also show that an "arc of (perpetual) erosion" along the northern 35 km of the Virginia barrier islands (Wallops Island to Cedar Island) has apparently extended southward to Parramore Island during the past decade.

References

Fenster, M.S., Dolan, R., and Elder, J. 1993. A new method for predicting shoreline positions from historical data, *Journal of Coastal Research*. Volume 9 (1):147-171.

Dolan, R., Fenster, M.S., and Holme, S. 1991. Temporal analysis of shoreline recession and accretion, *Journal of Coastal Research*. Volume 7 (3): 723-744.

Crowell M., Leatherman S.P., Buckley M.K. (1991). Historical shoreline change: Error analysis and mapping accuracy. *Journal of Coastal Research. Volume 7 (3): 839-852.*

Coastline Change App: Future Scenarios Fact Sheet

VIRGINIA EASTERN SHORE *COASTAL RESILIENCE* TOOL

What is the Future Scenarios module of the Coastline Change App?

The Future Scenarios module of the Coastline Change app in the *Coastal Resilience* tool provides results from a modeling effort that allows users to explore how climate change combined with management actions over a 50-year time frame may affect the rates of shoreline change along a simulated Virginia barrier island system. In exploring the Future Scenarios module of the app, you can compare a variety of possible climate change and management scenarios and learn about potential long-term, large-scale coastline and barrier island evolution resulting from these changes.

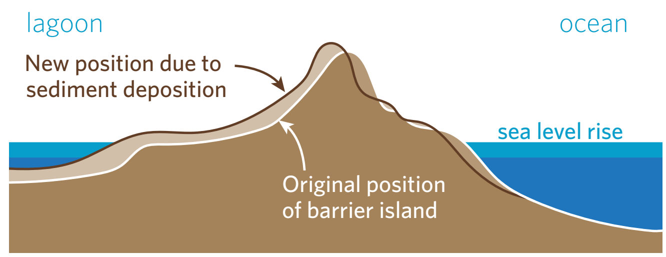
Who should use it?

Organizations and agencies who manage barrier islands, research scientists, and local governments may use the Future Scenarios module in the Coastline Change app to explore different regional climate and nourishment scenarios in order to better anticipate and manage shoreline changes in the future. This information should not be used to identify future shoreline changes for specific locations along the Virginia barrier islands, but rather should be a springboard for additional inquiry and modeling efforts regarding potential local coastline change in the future.

How does it work?

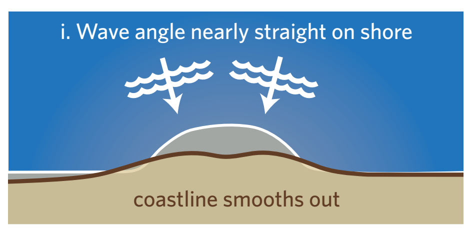
This app enables users to explore 36 different future scenarios of coastline change along a generalized Virginia barrier island system. The scenarios are based on three coastal processes that act alone or in combination to create a shift to the coastline via erosion or accretion of sediment:

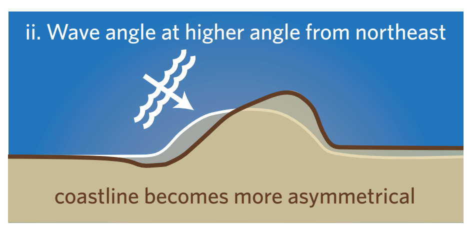
- Relative sea-level rise
- Shifts in wave climate
- Beach nourishment



Landward migration of barrier island as sea level rises

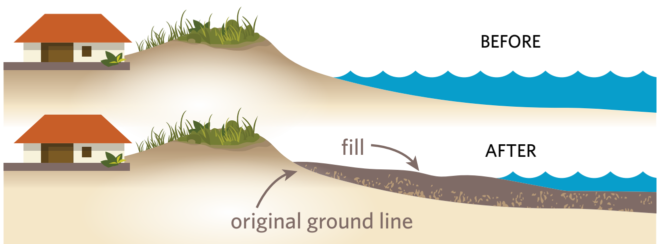
Relative sea-level rise occurs because of the expansion of oceans due to warming temperatures, the melting of land-based ice, and local rates of subsidence. Accelerated rates of sea-level rise can cause barrier islands to migrate toward the mainland, allowing them to maintain elevation as long as they can get enough sediment.





Shifting wave climate under (i) existing condition and (ii) changing climate scenario

Shifts in wave climate, or the average distribution of wave characteristics over many years, affects patterns of coastline change rates. Wave climate includes a number of factors relevant to sediment transport including the angle waves are approaching from and the height of the waves. If storm frequency or intensity changes because of climate change, the influence of waves approaching from different directions may also change, affecting how sediments shift and therefore how coastlines evolve.



Barrier island beach profile before and after nourishment

Beach nourishment is a management strategy implemented by people to prevent erosion and beach loss in an effort to stabilize or protect shorelines. Beach nourishment was modeled only for those areas where it has been undertaken in the past (Wallops only) or may be considered in the future (Assateague) based on stakeholder input, **but the selected nourishment scenarios should in no way indicate an endorsement of any management option, either in those areas or elsewhere in the region**.

In this app, you'll be able to explore the modeled effect—alone or combined—of three relative sea-level rise projections, three potential wave climate scenarios, and four beach nourishment scenarios, on the rate of coastline change. The results will show you, along a generalized coastline, whether these scenarios will lead to more erosion and less accretion or less erosion and more accretion along the modeled future shoreline than would be expected to occur in the future under current conditions.

What are the strengths and limitations?

Because of the uncertainty in the environmental variables affecting coastline change, coastal geomorphologists cannot make detailed predictions of where barrier islands will be or what shape they will have in the future. However, numerical modeling allows scientists to take an important step toward determining how certain physical processes may affect the future evolution of barrier islands and the coastline. Modeled future scenarios in the app of a simulated Virginia barrier island coastline are a leap forward in the field of coastal science. However, at this early stage, the results are not yet intended to support decisions but to serve as a springboard for new and additional research and modeling efforts. Lessons learned from this breakthrough model will provide opportunities for next steps in modeling possible coastline and island evolution and advancing the science of coastal geomorphology.

Who developed it?

The Coastline Change app was developed through a partnership between a team of coastal geologists and geomorphologists from University of North Carolina at Chapel Hill, University of North Carolina Wilmington, Duke University, and Randolph-Macon College (team that performed the modeling work) and staff from The Nature Conservancy, NASA-Wallops Flight Facility, the U.S. Fish and Wildlife Service Chincoteague National Wildlife Refuge and the Accomack-Northampton Planning District Commission.

For general info about the Virginia Eastern Shore *Coastal Resilience* project: **coastalresilience.org/virginia**

To access the Virginia Eastern Shore *Coastal Resilience* mapping portal: **maps.coastalresilience.org/virginia/**

For questions, contact info, etc: Chris Bruce, GIS Manager | vacoastalresilience@tnc.org | (434) 951-0565

Coastline Change App: Future Scenarios Supplemental Information

VIRGINIA EASTERN SHORE *COASTAL RESILIENCE* TOOL

Coastline Change App: Future Scenarios Supplemental Information

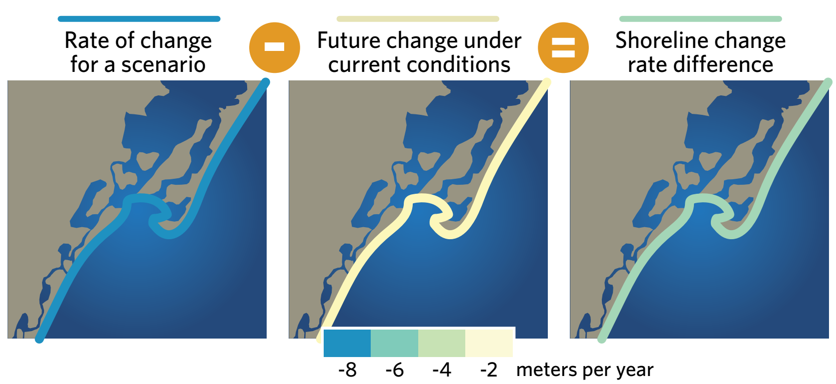
VIRGINIA EASTERN SHORE *COASTAL RESILIENCE* TOOL

Margaret B. Jones, University of North Carolina at Chapel Hill, Geological Sciences
Laura J. Moore, University of North Carolina at Chapel Hill, Geological Sciences
A. Brad Murray, Duke University, Nicholas School of the Environment; Center for Nonlinear and Complex Systems
Dylan E. McNamara, University of North Carolina Wilmington, Department of Physics and Physical Oceanography/Center for Marine Science
Kenneth Ells, University of North Carolina Wilmington, Department of Physics and Physical Oceanography/Center for Marine Science
Jonathan Whitley, University of North Carolina Wilmington, Department of Earth and Ocean Science/Center for Marine Science

Overview

A first-of-its-kind model was used to make reasonable estimates of how shorelines might move in the future, along a model coastline that shares some key characteristics with the Virginia coast. To do this, the model extrapolates from the best scientific understanding about processes that contribute to shoreline movement; such as the effect of waves on erosion, transportation and deposition of sand. With more frequent and intense storms expected in the future, waves and currents—in combination with relative sea-level rise (RSLR)—are expected to strongly influence the way that shorelines move. One management strategy employed in response to these changes is the engineered rebuilding of shorelines using a process known as beach nourishment. Wallops Island is one example of a location with a history of using beach nourishment to counter the effects of coastal erosion.

By comparing the difference between the base case of shoreline movement and experimental future scenarios, this app helps identify climate and nourishment scenarios that are likely to cause shifts in the rates of shoreline change. The base case is defined as future change under current climate conditions where relative sea level rises at the rate of 3 mm per year, the wave climate is consistent with the best-known present wave climate, and no nourishment occurs at any location. The results are presented as the *shoreline change rate difference* (SCRD). The shoreline change rate difference is the 50-year average difference in the rate of shoreline change between the base case and the experimental scenario (which includes a higher rate of RSLR and may include a shift in wave climate or beach nourishment).



Shoreline change rate difference calculation used in model

A negative SCRD indicates that the experimental scenario causes more erosion or less accretion relative to the base case, whereas a positive SCRD indicates that the scenario causes more accretion or less erosion relative to the base case. Although this information cannot be used to identify specific shoreline positions at future points in time, it does support the exploration of different regional climate and nourishment scenarios in order to better estimate and plan for the management of future shoreline changes.

The Selection of Scenarios

A scenario is a specific combination of potential climate and/or human management changes that might affect shoreline change rates. A total of 36 future scenarios were modeled for the app. These include different combinations of three sea-level rise scenarios, four wave climate scenarios, and three beach nourishment scenarios. The specifics of each scenario are described below.

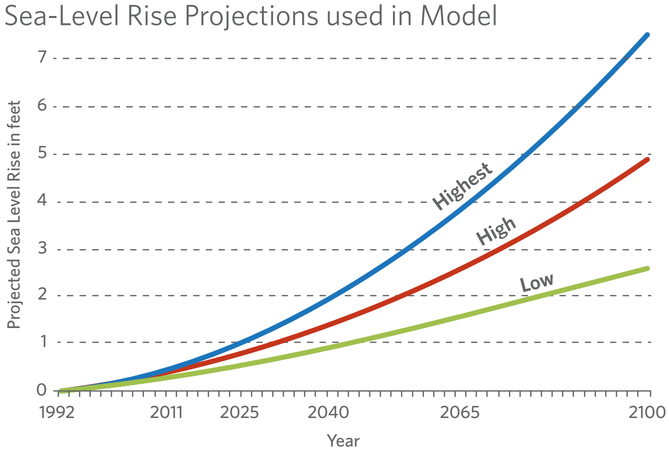
Description	No. of Scenarios
Sea-Level Rise Only	3
Sea-Level Rise + Wave Climate Change	6
Nourishment + Sea-Level Rise	9
Nourishment + Sea-Level Rise + Wave Climate Change	18
Total	**36**

A. Relative sea-level rise: Relative sea-level rise scenarios are based on the customization for Virginia, developed by the Virginia Institute of Marine Science, of the 2012 National Climate Assessment. The three sea-level rise scenarios that were modeled were selected by stakeholders and are as follows:

1. The "low" scenario is based on the Intergovernmental Panel on Climate Change 4th Assessment model using conservative assumptions about future greenhouse gas emission (the B1 scenario).

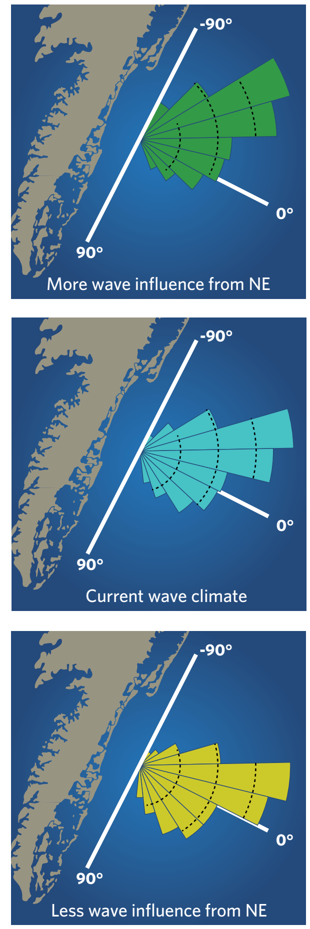
2. The "high" scenario is based on the upper end of projections from semi-empirical models using statistical relationships in global observations of sea level and air temperature. Generally, scientists currently see this as the most likely scenario.

Sea-Level Rise Projections used in Model



3. The "highest" scenario is based on estimated consequences from global warming combined with the maximum possible contribution from ice-sheet loss and glacial melting (a practical worst-case scenario based on current understanding).

B. Wave Climate: Climate change is likely to lead to increases in the frequency of the most intense hurricanes. In addition, the frequency and magnitude of winter storms is likely to shift in a changing climate. This will affect future patterns of coastal erosion and accretion by altering the prevailing wave climate (specifically wave heights and angles of approach). Although it is not clear how wave climate may change in the future, two potential future wave climates were considered to provide an understanding of how changes in storm intensity may alter patterns of shoreline change along the Virginia Eastern Shore. The modeled wave climates represent changes to the present wave climate that involve either a greater or lesser proportion of wave influence approaching from the northeast. The three wave climate scenarios modeled in the app are:



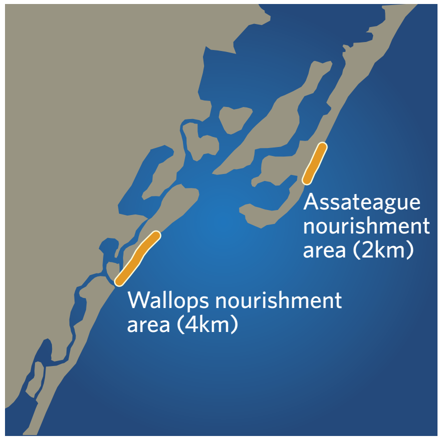
Wave climate angles of approach for three scenarios used in model

1. No change; present wave climate stays the same in future.

2. Shift to northeast by 15 degrees from present wave climate.

3. Shift to southeast by 15 degrees from present wave climate.

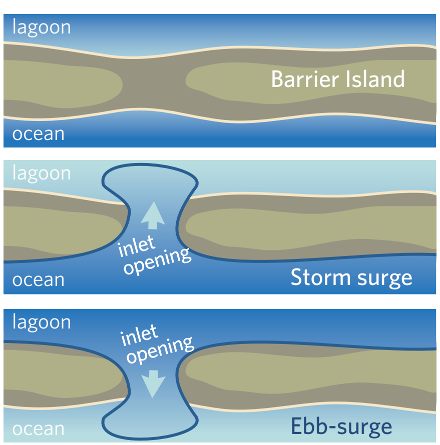
C. Beach Nourishment: Based on stakeholder input, two zones corresponding roughly to sites on Assateague Island and Wallops Island were identified as areas where beach nourishment may take place in the future. To estimate the effects of nourishment, the model considered a 2 km stretch of beach as the nourishment zone for Assateague Island and a 4 km stretch for Wallops Island. The model assumes that (1) nourishment is done at just the right long-term rate to maintain the shoreline position, (2) the sand used for nourishment comes from far enough away that removing it doesn't affect the coastal response, and (3) nourishment will continue for the entire model run regardless of cost. These projections represent hypothetical future scenarios which are intended to enhance the stakeholders' understanding of the potential evolution of the coastline in response to climate change and management interventions. Beach nourishment was modeled only for those areas where it has been undertaken in the past (Wallops only) or may be considered in the future (Assateague). ***However, the modeled projections should in no way indicate an endorsement of any management option, either in those areas or elsewhere in the region.***



Suggested zones of existing or potential future beach nourishment used in model

Potential Inlet Openings

Tidal inlets are openings in the shoreline connecting the ocean to bays, lagoons, or marshes. On low-lying barrier islands, inlets may form during storms when storm surge overtops island dunes and erodes sediment from the top of the barrier island, effectively cutting a channel, or when water levels on the bay side of barrier islands become higher than water levels on the ocean-side causing a channel to be cut in the seaward direction. Whether an inlet remains open depends on the volume of water flowing into and out of the inlet during the tidal flood and ebb cycles. This process is represented in the model, yet the temporal and spatial resolution of the model experiments do not allow for explicit predictions of where and when inlet openings could occur. At the beginning of each model experiment, the model starts with enough inlets so that the processes that keep inlets open are working at about the same magnitude as they currently do on the Virginia coast (note: the specific locations of initial inlets are generalized and don't correspond to the present-day inlet locations). At the end of each 50-year experiment, island height is measured at each shoreline location. Areas with critically low elevations at the end of the 50-year experiment, and which are in excess of the number of original open inlets, are deemed as coastal areas with enhanced potential for inlet opening.



Barrier island inlet formation process

Major conclusions for each group of scenarios

The specific locations mentioned in the summaries below are referenced only for the purpose of discussion. The scenarios presented in the module were considered for the model coastline that shares some key characteristics with the Virginia coast, not for the actual Virginia coastline. Additional research will be necessary to confirm the summary statements for the specific locations mentioned below.

Relative Sea-level Rise only

- In all scenarios, accelerated sea-level rise results in more erosion or less accretion compared to the base case scenario (which includes only 3 mm/yr relative sea-level rise). Some areas respond to sea-level rise more dramatically than other areas. For example, in the model, the south end of Assateague Island is more responsive to increased sea-level rise compared to its surroundings, while the Wallops Island area is less responsive to increased sea-level rise. These results indicate that future rates of shoreline change are likely to be sensitive to the rate of relative sea-level rise.
- The model does not indicate enhanced potential for inlets to open along the simulated coastline under the sea-level rise only scenarios.

Relative Sea-Level Rise + Wave Climate Change

- During both wave climate change scenarios, the southern end of Assateague Island is still affected more strongly by accelerated rates of sea-level rise compared to its surroundings.
- In contrast, the southern end of Assateague just north of Fishing Point may be affected less strongly by accelerated rates of sea-level rise compared to its surroundings. This effect is diminished when a lesser proportion of wave influence is from the northeast.
- The Wallops Island area is also affected less strongly affected by accelerated rates of sea-level rise compared to its surroundings. This effect is diminished when a greater proportion of wave influence is from the northeast.
- The model indicates the enhanced potential for inlets to open in the vicinity of southern Wallops Island when a greater proportion of wave influence is from the northeast at the highest sea-level rise rates.

Nourishment + Relative Sea-Level Rise

- Differences in shoreline change rates resulting from nourishment appear to be limited to within only a couple of kilometers of the nourishment area. This finding is surprising given that previous work suggests that effects of nourishment are often non-local.
- At higher sea-level rise rates, nourishment affects shoreline change rates more dramatically and farther away from the nourishment site than in low sea-level rise scenarios.
- The model does not indicate the enhanced potential for inlets to open along the simulated coastline under the nourishment plus sea-level rise scenarios.

Nourishment + Relative Sea-Level Rise + Wave Climate Change Conclusions

- **Relative sea-level rise is the dominant factor in causing more erosion or less accretion along the coastline**. Although sea-level rise may affect some parts of the coast more strongly than others, these results suggest that, with accelerated rates of sea-level rise, the whole coast will experience more erosion or less accretion, regardless of wave climate shifts.
- **Wave climate shifts affect patterns of erosion and accretion.** Generally speaking, a greater proportion of waves approaching from the northeast is predicted to result in lower rates of erosion near the southern part of Assateague Island and higher rates of erosion in the Wallops Island area. The converse is true for lesser proportions of waves approaching from the northeast. These findings have implications for rates of nourishment needed at each site to maintain a constant shoreline position.
- **Nourishment has a more limited alongshore effect than previously anticipated.** For this area, the nature of the wave climate relative to the shoreline limits alongshore effects of nourishment.
- **The model suggests that there is enhanced potential for inlets to open in the vicinity of southern Wallops and Assateague Islands** under various combinations of wave climate and beach nourishment scenarios at the high and highest sea-level rise rates.

Further Information

Ashton, A. D., and a. B. Murray (2006a), High-angle wave instability and emergent shoreline shapes: 1. Modeling of sand waves, flying spits, and capes, *J. Geophys. Res.*, *111*(F4), F04011, doi:10.1029/2005JF000422.

Ashton, A. D., and a. B. Murray (2006b), High-angle wave instability and emergent shoreline shapes: 2. Wave climate analysis and comparisons to nature, *J. Geophys. Res. F Earth Surf.*, *111*(4), F04012, doi:10.1029/2005JF000423.

Ashton, A. D., J. Nienhuis, and K. Ells (2016), On a neck, on a spit: Controls on the shape of free spits, *Earth Surf. Dyn.*, *4*(1), 193–210, doi:10.5194/esurf-4-193-2016.

Ells, K., and A. B. Murray (2012), Long-term, non-local coastline responses to local shoreline stabilization, *Geophys. Res. Lett.*, *39*, doi:10.1029/2012GL052627.

Johnson, J. M., L. J. Moore, K. Ells, A. B. Murray, P. N. Adams, R. A. M. Iii, and J. M. Jaeger (2014), Recent shifts in coastline change and shoreline stabilization linked to storm climate change, doi:10.1002/esp.3650.

Jones, M. J., 2016. Considering holistic coastal response to climate-change induced shifts in natural processes and anthropogenic modifications. M.S. Thesis, Univeristy of North Carolina- Chapel Hill.

McNamara, D. E., and B. T. Werner (2008a), Coupled barrier island-resort model: 1. Emergent instabilities induced by strong human-landscape interactions, *J. Geophys. Res. F Earth Surf.*, *113*(1), F01016, doi:10.1029/2007JF000840.

McNamara, D. E., and B. T. Werner (2008b), Coupled barrier island-resort model: 2. Tests and predictions along Ocean City and Assateague Island National Seashore, Maryland, *J. Geophys. Res. Earth Surf.*, *113*(1), doi:10.1029/2007JF000841.

Mitchell, M., et al. 2013. Recurrent Flooding Study for Tidewater Virginia, Virginia Institute of Marine Science (VIMS), William & Mary, Williamsburg, VA. http://ccrm.vims.edu/recurrent_flooding/Recurrent_Flooding_Study_web.pdf

Parris, A., P. Bromirski, V. Burkett, D. Cayan, M. Culver, J. Hall, R. Horton, K. Knuuti, R. Moss, J. Obeysekera, A. Sallenger, and J. Weiss. 2012. Global Sea Level Rise Scenarios for the US National Climate Assessment. NOAA Tech Memo OAR CPO-1. 37 pp.

Glossary of Terms (alphabetical)

Locations where these terms occur are noted in [brackets]:
Flood & Sea Level Rise = [F&SLR]   Future Habitat = [FH]   Regional Planning = [RP]   Coastline Change = [CC]
Map Viewer = [Map Viewer]

Absolute Difference: A measure in feet of the difference between current water levels and those during modeled storm events. [F&SLR]

Base Data: A map layer which shows boundaries, parcels, and roads. [RP]

Basic Dark Gray: A gray background map layer. [Map Viewer]

Basic Inundation: A data source within the Flood & Sea Level Rise App which displays predicted sea-level rise for several sea-level rise scenarios and scenario years. [F&SLR]

Choose Parameters: A tab in the Future Habitat App window which allows the user to select the Scenario Year and SLR Scenario, affecting the data displayed in the map viewer. [F&SLR]

Clear Filters: Clicking this button (Clear Filters) resets the visible data to its original state, removing drawn areas and other filters that narrow results. [FH]

Click to Draw an Area: Clicking this button (Click to Draw an Area) allows the user to draw an area of interest which will exclude all other data. [FH]

Compare & Chart: A tab in the Future Habitat App window which allows the user to view changes between the current inventory of habitat area and the predicted condition. Note that data is only displayed if a future Scenario Year (e.g., 2025) is selected. [FH]

Change Rate Type: Includes both long- and short-term change rates for historical shorelines. Long-term change rates are calculated using all historic shoreline data from the earliest to the most recent dates for the selected area. Short-term change rates are calculated using historical shoreline data from the most recent change in the long-term rate to the most recent dates for the selected area. [CC]

Coastal Management: A grouping of map layers that include public access sites, boat ramps, streams, flood hazard areas, protected lands, and Virginia Ecological Value Assessment. [RP]

Coastline Change App: An app ( ) which shows historic and future changes in coastlines in response to predicted sea-level rise. [Map Viewer]

Choose Data Source: A dropdown menu in the Flood & Sea Level Rise App that allows the user to choose which data they would like to view: Basic Inundation or Storm Surge. [F&SLR]

Download data: Clicking this button (Download Data) allows the user to download the data used to populate the app in an ESRI geodatabase format. [FH]

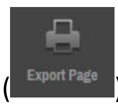
Dropdown menu: A vertical menu of options which is opened by clicking on it. [Map Viewer - Topographic ▼] [F&SLR - Choose Data Source ▼]

Economic Loss: Estimated potential monetary impacts resulting from the selected storm surge scenario. [F&SLR]

Ecosystem: A system of biological components (species) and physical components (geography and resources). [FH]

Erosion: Degradation of features such as shorelines or structures, usually by the action of water or wind. [FH]

Explain Each Choice Clicking this text (Explain Each Choice) shows additional information regarding Coastline Change App options. Additional information may be hidden by clicking on the "Hide Explanations" text (Hide Explanations). [CC]

Export Page: Clicking this button (

) allows the user to export the current view as an Adobe Acrobat document. The map may also be exported by clicking the printer icon () in the upper right of the Regional Planning App window. [Map Viewer] [RP]

Filter by Habitat(s) of Interest: A section of the Future Habitat App which allows the user to reduce the data being displayed to only salt marsh, only "other wetlands", or to an extent drawn by the user. [FH]

Flood & Sea Level Rise App: An app () which shows the predicted effects of sea-level rise and storm surge on the Eastern Shore of Virginia. Includes two datasets: Basic Inundation (focuses on the effects of sea-level rise) and Storm Surge (displays predictions for storm surge from hurricanes and tropical storms). [Map Viewer]

Full Extent: Clicking this button () returns the view to the entire Virginia Eastern Shore. [Map Viewer]

Future Habitat App: An app () which shows changes in habitat type in response to predicted sea-level rise. [Map Viewer]

Get Started: Clicking this text (GET STARTED) opens the Launchpad with bookmarked map locations and information. [Map Viewer]

Habitat: The biological and physical settings in which species exist. Also, a map layer which shows commercial shellfish aquaculture, public oyster grounds and tidal marshes. [RP]

Hide Explanations Clicking this text (Hide Explanations) hides additional information regarding Coastline Change App options. [CC]

maps.coastalresilience.org/Virginia

Imagery: Aerial imagery of the Virginia Eastern Shore. [Map Viewer]

Infographic: A simple graphic meant to quickly illustrate the purpose or main concepts of an app. The infographic for the Future Habitat App is accessible by clicking the question mark icon ( ) in the upper right corner of the app window. [FH]

Infrastructure: A grouping of map layers that include schools, fire stations, roads vulnerable to sea level rise, and evacuations routes. [RP]

Inundation: Flooding of upland areas. [FH]

Land Accretion: Increase in elevation or area of land due to sediment deposition. [FH]

Launch Pad: A collection of geographies (locations) and one-click interactive maps (pre-set data views). [Map Viewer]

Legend: A window which shows the list of active layers and their symbology. This can be toggled on and off with the legend button ( ). [Map Viewer]

Regional Planning App: An app ( ) which includes information data layers including schools, roads, tidal range, protected lands, and wetlands. [Map Viewer]

Measure: A tool used to measure distance and area. It is activated by clicking the measure button ( ). [Map Viewer]

Methodology: A description of the methods used to develop data layers. [F&SLR] [FH]

National Geographic: A background map layer developed by National Geographic. [Map Viewer]

Nor'Ida: A nor'easter that impacted the mid-Atlantic in November 2009. [F&SLR]

Nourishment: The action of replenishing or restoring a beach with sand. [CC]

Ocean: A background map layer developed by the National Oceanic and Atmospheric Administration. [Map Viewer]

Opacity: The extent to which an image is not transparent. [RP]

Opaque: The opposite of transparent. Appears in transparency slider bars (Opaque Transparent). [F&SLR] [FH]

Pan: Moving the map by clicking, holding, and dragging the mouse. [Map Viewer]

Percent Difference: A measure in percentage of the difference between current water levels and those during modeled storm events. [F&SLR]

Permalink: A permanent hyperlink to a map showing selected features. [Map Viewer]

Physical Features: A map layer which shows physical geography. [RP]

Reset Layers Clicking this text (Reset Layers) clears all selected layers in the Regional Planning App. [RP]

Rate of Change Difference: The 50-year average difference in the rate of shoreline change (in meters per year) between the base case (current conditions) and a modeled scenario. Also known as the shoreline rate of change difference. [CC]

Results & Chart A tab in the Future Habitat App window which allows the user to view a pie chart and chart explaining acreage of habitat types in the total dataset or a user-defined area for the selected Scenario Year and SLR Scenario. [FH]

Save & Share: Clicking this button (

) allows the user to save the map view and active datasets in order to return to the map or share it with others. [Map Viewer]

Scenario Year: The year for which predictions (sea level rise, storm surge, or habitat change) were calculated. [F&SLR] [FH]

Sea Level Rise (SLR): The predicted increase in the elevation of sea water over time. [F&SLR] [FH] [RP] [CC]

Shaded Relief: A background layer which shows elevation of uplands. [Map Viewer]

Social and Economic: A map layer which shows persons by age, area, and certain types of employment, as well as percent of mobile home housing units and 1% annual chance flood economic losses. [RP]

Spatial Model Outputs: Data generated by models which, in this case, estimate changes in marsh extent due to sea level rise. [FH]

Storm Surge: Increased water height due to storm dynamics. Also a data source in the Flood & Sea Level Rise App. [F&SLR]

Storm Tracks: Paths taken by hurricanes and tropical storms which were used as the basis for modeling storm surge. [F&SLR]

Storm Type: A classification format for modeled hurricane impacts in the Flood & Sea Level Rise App Storm Surge dataset. Impacts from low Intensity storms were based on three theoretical Category 1 hurricanes with maximum winds of 80 miles per hour (mph). Impacts from Moderate Intensity storms were based on six theoretical Category 1 and 2 hurricanes with maximum winds between 85 and 110 mph. Impacts from High Intensity storms were based on seven Category 2 and 3 hurricanes with maximum winds between 95 and 115 mph. Impacts from Nor'Ida are based on the storm surge generated by that particular storm. Impacts from each of these Storm Types are shown for current conditions and two future Scenario Years in which the sea level has risen. [F&SLR]

Streets: A background map layer which shows roadways. [Map Viewer]

Terrain: A background map layer which shows differences in terrain. [Map Viewer]

Tidal Range (ft): Data regarding the typical variability in water level due to tides. [F&SLR] [RP]

Topographic: A background map layer which shows roads, waterways, elevation, forested land, and wetlands. [Map Viewer]

Tour: Clicking this text (

) opens a quick reference for the parts of the *Coastal Resilience* tool map viewer. [Map Viewer]

Transect: A line along which data is collected. [CC]

Transparent: Allowing light or background images to be seen, as through glass. [F&SLR] [FH]

Water Depth (ft): A measure of the predicted depth of water in feet due to storm surge. [F&SLR]

maps.coastalresilience.org/Virginia

Wave Climate: A term which includes the predominant direction of wave influence on a system. [CC]

View Methodology: Clicking this button (View Methodology) will load a document which explains the methods used to develop data for the subject app. [F&SLR] [FH]

Zoom: To change the scale of the map viewer. Click on the zoom in button (+) for a narrower view or the zoom out button (−) for a wider view. [Map Viewer]

Zoom to Selection: Clicking this button (Zoom to Selection) will zoom to the area drawn by the user using the Click to Draw an Area option. [FH]

Hints and Tips

1. The *Coastal Resilience* tool is web-based. Make sure your internet connection is working before use.

2. The *Coastal Resilience* tool can be used in most internet browsers, including Chrome, Internet Explorer, Firefox, and Safari. However, be sure your browser is up-to-date to avoid issues.

3. It is a good practice to reboot your device before using the tool to ensure that you have sufficient memory available to use it.

4. It may be helpful to periodically refresh the browser window (refresh button or F5 key) in which you are viewing the *Coastal Resilience* tool in order to prevent errors from occurring. Keep in mind that refreshing will return the *Coastal Resilience* tool to its beginning state.

5. Refresh your browser window if the *Coastal Resilience* tool seems laggy, if layers are stuck or not showing, or if features seem to be acting strangely. Again, this will return the *Coastal Resilience* tool to its beginning state. The F5 key is your friend!

6. If the *Coastal Resilience* tool really seems to be stuck, try clearing the local cache in your browser by pressing Control + F5 (you may want to press this several times to fully clear the system). On an Apple machine the command is Command + R. You can also close the browsing window or tab and open it again to fully refresh the site.

7. Another option to avoid issues caused by web browser history is to open the *Coastal Resilience* tool in a window which does not retain cookies or other browsing data. This is known by different names in different web browsers. For example:
    - Chrome: incognito window
    - Internet Explorer: InPrivate Browsing
    - Firefox and Safari: private browsing window

8. The *Coastal Resilience* tool is optimized to work on desktops and laptops, and may experience issues when open in a tablet or hand-held devices. Additionally, the *Coastal Resilience* tool map viewer may seem crowded when viewed on a laptop.

9. If a background map layer does not load (grey screen displayed), try choosing another layer or changing the zoom level. Some layers do not appear when zoomed in extensively.

10. For a quick run-down on the functions of the tool click on Tour – this will point to the different elements of the tool and give a short explanation of them.

11. When you open an app the icon changes color and appears like an app on your phone. When done using the app you can either use the close ('x') button in the upper right hand corner to remove it from being active, and remove its data from the map, or the minimize ('_') button to have it remain active and, therefore, keep data on the map. You can have multiple apps

open – minimizing the apps helps maximize how much of the map is shown. Keep in mind that opening the Regional Planning app will minimize other open apps.

12. Likewise, the Map Legend can be minimized ('_'). To show the legend again, click on the plus button ('+') on the right side of the Map Legend header.

13. Most of the windows that appear on the map (i.e. app windows, map legend) can be dragged around by clicking and holding on your mouse left key when the cursor is hovering over the top black bar. They can also be resized and may need to be, depending on your browser, platform (computer, tablet, etc.), and the amount of data being shown (Map Legend, for example). Click and drag the bottom right corner of the window to resize it, or simply scroll up or down in the window to view additional data.

14. App data displays in the order in which you access it. For example, if you open the Flood & Sea Level Rise app first, then the Future Habitat app, future habitat data will be layered on top. For this reason, we recommend opening the Regional Planning app last if you wish to use it.

15. Clicking on data that appears on the map will open an Identify window showing the attributes of the data layer at that point. If the Identify box is too big and goes off the map then pan the map (click and hold mouse down, then drag) until you see the entire window. Note that the Identify window does not move.

16. You can also hold the Shift key down and click and hold the mouse to draw a box for zooming into a particular area. This may allow you to zoom to a level that is between those used by the zoom in and zoom out buttons.

17. Remember that the *Coastal Resilience* tool is a work in progress! If you find obvious errors, feel free to report them to vacoastalresilience@tnc.org.

Thank you very much for using the *Coastal Resilience* tool!

If you have any feedback, please submit it in the form of our Post-Workshop Survey, or speak with a member of our training team.