

# METHOD DESCRIPTION



**NOAA Coastal Services Center**  
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## Detailed Method for Mapping Sea Level Rise Marsh Migration

**May 2012**

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### Introduction

This document describes the mapping process used by the NOAA Coastal Services Center to map potential impacts to marsh environments due to sea level rise for the Sea Level Rise and Coastal Flooding Impacts Viewer. Generally, this process can be described as a modified bathtub approach that attempts to account for local and regional tidal variability.

### Goals of Mapping

- Use best publically available and accessible elevation data
- Map literature-supported levels of sea level rise (SLR)
- Account for some amount of estimated accretion
- Incorporate local and regional tidal variation of mean higher high water (MHHW) for each area

### Caveats and Assumptions

- These data are for planning, educational, and awareness purposes only and should not be used for site-specific analysis, navigation, or permitting.
- The mapping does not incorporate future changes in coastal geomorphology and assumes present conditions will persist, which will not be the case.
- The digital elevation model (DEM) used to map SLR does not incorporate a detailed pipe network analysis, or engineering grade hydrologic analysis (for example, culverts and ditches may not be incorporated resulting in incorrectly mapped areas).
- The data in the map do not consider many natural processes, such as freshwater influences to salinity, subsidence, sediment erosion dynamics, or coastal storm impacts.

## Tidal Surface Creation

To incorporate tidal variability when mapping sea level rise, a “modeled” tidal surface (or raster) is used to convert the elevation data, which is typically in the orthometric datum of NAVD88 (North American Vertical Datum of 1988). Once the elevation data have been converted to the tidal datum (i.e., MHHW), a single surface value can be used to model the sea level rise and also incorporate tidal variations.

The marsh migration procedure uses four tidal surfaces: mean high water spring (MHWS), MHHW, mean tide level (MTL), and mean lower low water (MLLW). The MHHW, MTL, and MLLW are generated from the following techniques. The MHWS surface is a modified form of the MHHW surface and is described at the end of this section.

Currently, there are two primary ways the tidal surface can be created. The first approach is to interpolate a surface using the available tide stations. This approach, while fairly simple, may have a significant amount of error, depending on station spacing and complexity of the tides. The second and more accurate approach is to use NOAA’s vertical datum conversion software, VDatum (<http://vdatum.noaa.gov>), which incorporates a hydraulic model to help determine tidal elevations between stations. Both approaches have been used by the NOAA Coastal Services Center. VDatum was used where available, and in areas lacking VDatum coverage, the tide station approach was used.

For more information on tidal conversion, each process is described in the “Topographic and Bathymetric Data Considerations” handbook ([www.csc.noaa.gov/digitalcoast/\\_/pdf/topographic-and-bathymetric-data-considerations.pdf](http://www.csc.noaa.gov/digitalcoast/_/pdf/topographic-and-bathymetric-data-considerations.pdf)).

One aspect that is not covered is the extension of tidal datums inland of the present coastline. This can be accomplished using several different techniques. Two of the more common are listed below.

### *Extension of VDatum Water Surface Inland*

- **Transect Method** – create cross-shore (perpendicular to shoreline) transects that extend inland just past the area of analysis. Transect spacing and locations are at the discretion of the user but should capture the variation in tidal surface; more complex tidal areas will require more transects than simple tidal regimes. Using the water surface elevations along the transect, extend the general tidal trends inland and assign values to the grid points nearest the transect’s path – here again, the number of points along the transect are at the discretion of the user and may depend on local variations in the tidal surface elevations. Generate a new surface from the combined VDatum (original values) and transect-generated points.
- **Interpolation Method** – in some cases an interpolated surface can be used instead of the transect method. These cases include areas where valid VDatum points exist on several sides of the area of interest (i.e., not a straight stretch of shoreline). For these areas, a natural neighbor algorithm is a good place to start. This will generate a fairly

smooth surface. To create a more generalized surface, a 1<sup>st</sup> or 2<sup>nd</sup> order trend surface can be calculated.

### *Considerations*

- Make the initial raster large enough to cover the area of interest.
- Use a raster resolution that will capture the tidal variability for the area but does not have an overly fine resolution (i.e., large file size).
- The DEM should be made from reputable data and also extend to MLLW if possible. If DEM values are from a data set that does not include MTL or lower values (i.e., data were collected at high tide), then the DEM can be in error in the lower marsh areas. This error can create anomalous values that affect the modeled habitats.

The one other tidal surface that is used is the MHWS. This surface is the basically the same as the MHHW surface but has been shifted upwards in relation to the highest tide levels in the spring. For example, if during the May-June period the highest predicted tides are 5.5 feet, and the MHHW datum is 5 feet, the entire MHHW surface would be adjusted upwards by 0.5 feet to generate a MHWS surface.

## **Establish a Freshwater Wetland–Upland Transition Elevation Boundary**

The last threshold value that must be derived before modeling the impacts from sea level rise is the boundary between the upper elevation of freshwater wetlands and uplands. This freshwater wetlands and uplands boundary (FWUB) is determined by comparing existing wetlands to current elevation values for the study area, and determining whether each elevation increment is primarily wetland or upland. The threshold of 66% is used to establish a conservative estimate for where this transition takes place; whatever elevation is made up of at least a 66% majority of wetlands would be considered wetland, but less than 66% wetland would be considered a primarily upland elevation value. Once established, this elevation is treated like the tidal surfaces created above.

## **Detailed Mapping Process**

This method assumes that specific wetland types exist within an established tidal elevation range, based on an accepted understanding of what types of vegetation can exist given varying frequency and time of inundation, as well as salinity impacts from such inundation.

As sea level rises, higher elevations will become more frequently inundated, allowing for marsh migration landward. At the same time, some lower-lying areas will be so often inundated that the marshes will no longer be able to thrive, becoming lost to open water.

### **Inputs**

- Sea level rise values
- Tidal surfaces (MHHW, MTL, MLLW, and MHWS) in NAVD88 values

- FWUB surface in NAVD88
- Digital elevation model
- Accretion rates
- Wetland habitat data

**Process**

1. Add desired SLR amount to each of the tidal surface grids.
  - a. For example, if you were interested in modeling for 4 feet (1.2meters) of SLR by 2100, then the total amount of SLR would be 4 feet. If you were modeling the same scenario as above (4 feet by 2100) but were interested in SLR condition at year 2050, then you would add approximately 1.75 feet. See look-up table.

		Sea Level Rise Scenario (feet)						
		YEAR	1	2	3	4	5	6
<b>No Accretion</b>	<b>25</b>	<b>0.00</b>	<b>0.50</b>	<b>0.50</b>	<b>0.75</b>	<b>1.00</b>	<b>1.25</b>	
	<b>50</b>	<b>0.50</b>	<b>0.75</b>	<b>1.25</b>	<b>1.75</b>	<b>2.00</b>	<b>2.50</b>	
	<b>75</b>	<b>0.75</b>	<b>1.50</b>	<b>2.00</b>	<b>3.00</b>	<b>3.50</b>	<b>4.50</b>	
	<b>100</b>	<b>1.00</b>	<b>2.00</b>	<b>3.00</b>	<b>4.00</b>	<b>5.00</b>	<b>6.00</b>	
<b>Low Accretion 2mm/yr</b>	<b>25</b>	0.00	0.00	0.50	0.50	0.75	1.00	
	<b>50</b>	0.00	0.50	1.00	1.50	2.00	2.50	
	<b>75</b>	0.00	1.00	1.75	2.50	3.00	4.00	
	<b>100</b>	0.50	1.50	2.50	3.50	4.50	5.50	
<b>Medium Accretion 4mm/yr</b>	<b>25</b>	0.00	0.00	0.00	0.50	0.75	1.00	
	<b>50</b>	0.00	0.00	0.75	1.25	1.50	2.00	
	<b>75</b>	0.00	0.50	1.25	2.00	2.50	3.50	
	<b>100</b>	0.00	0.75	1.75	3.00	3.50	4.50	
<b>High Accretion 6mm/yr</b>	<b>25</b>	0.00	0.00	0.00	0.50	0.50	0.75	
	<b>50</b>	0.00	0.00	0.50	0.75	1.25	1.75	
	<b>75</b>	0.00	0.00	0.75	1.50	2.00	3.00	
	<b>100</b>	0.00	0.00	1.25	2.00	3.00	4.00	

- b. The Sea Level Rise Viewer allows the user to select from six different scenario amounts of sea level rise. These include 1 foot increments between 1 and 6 feet. This process must be done to each of the tidal/threshold surfaces derived in the above steps. The result is a new surface layer for each of the following: MLW, MTL, MHW, MHWS, and FWUB.

*Considerations:*

The curve used within the Sea Level Rise Viewer is based on the curve from the A1B IPCC (International Panel on Climate Change) scenario (not the actual amount, just the curve). For more information about the IPCC scenarios visit the United Nation’s Environmental Programme (UNEP) website: [www.grida.no/publications/other/ipcc\\_tar/?src=/climate/ipcc\\_tar/wg1/029.htm](http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg1/029.htm)

See the NOAA Tides and Currents website for information related to current and historical sea level trends for your area. This information can serve as a useful comparison between accelerated scenarios and current rates of sea level rise: <http://tidesandcurrents.noaa.gov/sltrends/>

Uncertainty associated with the exact amount of sea level rise, or the timing associated with each scenario, is not considered in this tool. It is up to the user to select the scenario with which they feel most comfortable, and evaluate how they will treat the predicted impacts and timing associated with each.

It is important to not focus on the exact timing or location of class transitions, but rather to use the timeframe and areas highlighted as a guide to when and where such impacts have the potential to occur, and a gauge as to how severe they may be.

2. Add the desired amount of accretion to the digital elevation model (DEM) surface.
  - a. Accretion is the vertical rise of the marsh's surface due to buildup of organic and inorganic matter. The amount of accretion is a result of sediment delivery and deposition dynamics that occur at an individual site.
  - b. The net amount of accretion for a given year is determined by the accretion rate multiplied by the number of years being modeled. For example, if modeling an accretion rate of 2 millimeters per year, the amount of accretion after 50 years would be 100 millimeters (or 1 centimeter), and total amount of accretion after 100 years would be double this amount.
  - c. In the Sea Level Rise and Coastal Flooding Impacts Viewer, the user is allowed to select from four predetermined rates of accretion. These rates are presented as high (6 mm per year), medium (4 mm per year), low (2 mm per year), and no accretion (0 mm per year). These rates were determined based upon rates generally used in previous studies.

*Considerations:*

Accretion rates can be highly variable within an individual habitat type, and within an individual geography (no matter the size). Variability is often associated with location in tidal elevation, the proximity to streams, or other sediment sources.

For the purposes of this study, accretion is handled as a simple "flat" value across the study site, regardless of any of these factors. This means that the same value is applied to all areas regardless of what type of marsh, the actual location of the pixels, or even whether the area is an actual marsh, or an upland area.

While the natural variation that should be present is largely not accounted for, it should be noted that this information does not exist for large areas of the country or in files that highlight the high degree of variability present. By instituting one flat value across the study site, we are keeping this a constant factor, which the user may need to understand and evaluate in comparison to his or her own local knowledge of sediment dynamics, etc.

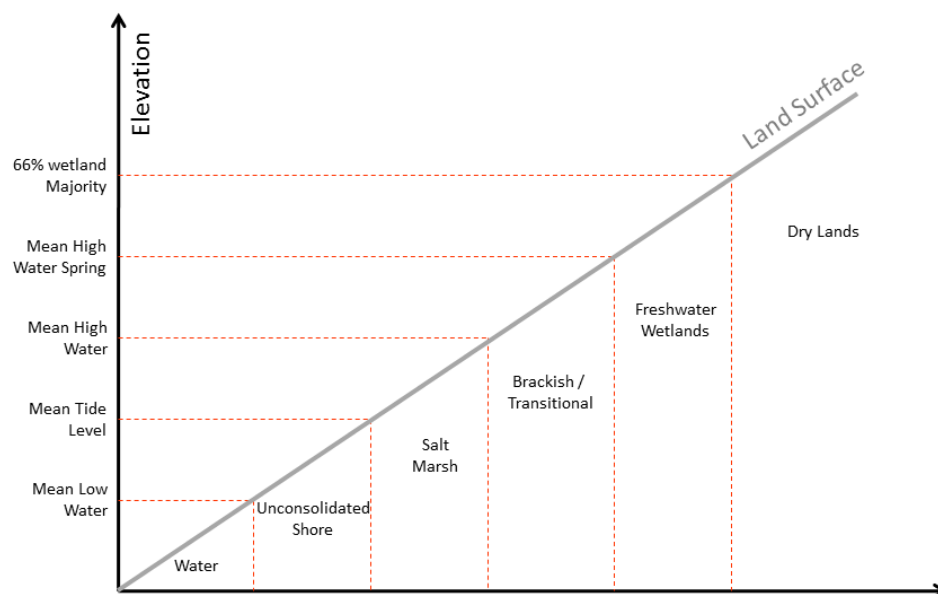
See the U.S. Geological Survey website on Surface Elevation Tables for more information about how to obtain detailed, accurate accretion information: [www.pwrc.usgs.gov/set](http://www.pwrc.usgs.gov/set)

3. Subtract the resulting tidal surface layers from the resulting DEM.
  - a. This process must be done to each of the surfaces derived in step 1 above. The result is a new surface layer for each of the following: MLW, MTL, MHW, MHWS, and FWUB.

*Considerations:*

Be sure that units used in each of the above sets are equal (i.e., feet or meters).

4. Model the class transition rule set.
  - a. With the new tidally adjusted elevation surfaces created in step 3 above, a simple rule set can be instituted to model wetland habitat class transitions.
  - b. Within the Sea Level Rise and Coastal Flooding Impacts Viewer, wetland categories are assumed to exist within the boundaries between the tidal thresholds as defined in the figure below.



- c. As the amount of sea level rise causes an area to move down within the tidal spectrum (based upon the modeled surfaces derived above), wetland categories will change from one type to the next according to their new location.
- d. For example, as sea level rises, and the tidal threshold locations move up in elevation relative to the land, upland categories may transition into fresh marsh, and freshwater marsh areas may transition into brackish, salt marsh, or unconsolidated shore habitats.
- e. In the Sea Level Rise and Coastal Flooding Impacts Viewer, classes are not allowed to transition in the opposite direction (i.e. saltwater marshes are not allowed to become freshwater marshes). This would only be the case if the amount of accretion would exceed the amount of sea level rise being modeled, and it is assumed that this would not be likely, given that the accretion rate on the upper end of the tidal spectrum would be less than optimal, and that areas not flooded regularly would have no accretion at all.

*Considerations:*

These thresholds are based on average or theoretical habitat ranges, but natural systems are inherently unpredictable and there are often areas of overlap between these habitat types (especially on the edges of these zones).

The location of class transitions highlighted should be used as a guide to where such impacts have the potential to occur. Users should evaluate these areas in light of local knowledge of geography, tides, and individual species that may be present.

## Wetland Habitat Data

Wetland data portrayed as the initial condition within the viewer is derived from NOAA's Coastal Change Analysis Program (C-CAP). C-CAP produces a nationally standardized database of land cover and land change information for the coastal regions of the U.S. These products provide inventories of coastal intertidal areas, wetlands, and adjacent uplands with the goal of monitoring these habitats by updating the land cover maps every five years. Data used in this analysis reflect conditions as they existed when mapped in the 2005 to 2006 timeframe.

For the purposes of this analysis, the full C-CAP classification scheme has been simplified, removing detail in upland features to place emphasis on wetland areas. This simplified classification system, and associated color scheme can be seen to the right.



Note that brackish, or transitional, marsh is not a C-CAP class and is therefore not mapped within the current condition. This class is included to highlight areas of transition between salt and freshwater marsh, as identified based upon the elevation-based rule set described above. This provides additional information to the user about the degree of impact in certain areas.

The minimum mapping unit of the initial condition products has also been modified in order to remove smaller features from consideration. These products have been resampled to remove features that were smaller than 1 1/3 acres in size.