Shoreline Management Model version 5.1

Handbook






This project was funded in part by the NOAA RESTORE Science Program through Grant # NA17NOS4510100 of the U.S. Department of Commerce, Gulf Coast Ecosystem Restoration Science, Observation, Monitoring, and Technology Program.

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The Shoreline Management Model (SMM) version 5.1 is a geospatial data model run in ArcGIS that provides a recommended approach for tidal shoreline erosion control. Recommended erosion control strategies are based on scientific knowledge of how shorelines respond to natural conditions and anthropogenic measures used to stabilize shorelines. The SMM uses input variables representing current conditions and recommends a strategy that falls into one of three general categories; living shorelines, traditional approaches, and special considerations (Appendix A). Data required to run the model include presence of tidal marsh, beach, submerged aquatic vegetation (SAV), riparian land cover, bank height, nearshore bathymetry, fetch, and shoreline erosion control structures (Appendix B contains the full list of data required). A link to the zip package containing the SMM v5.1 Handbook and model can be found on the Center for Coastal Resources Management's Shoreline Best Management Practices webpage (https://www.vims.edu/ccrm/ccrmp/bmp/index.php), the Adapt Virginia Tools page (http://adaptva.com/info/tools_bmp.html), and the NOAA RESTORE page (https://restoreactscienceprogram.noaa.gov/projects/living-shoreline-tool).

Background

In 2011, the Virginia General Assembly adopted a policy into law that specifies living shorelines as the preferred management practice for erosion control in Virginia waters. In accordance with the law, the Commonwealth defines a living shoreline as ... "... a shoreline management practice that provides erosion control and water quality benefits; protects, restores or enhances natural shoreline habitat; and maintains coastal processes through the strategic placement of plants, stone, sand fill, and other structural and organic materials".

The Center for Coastal Resources Management (CCRM) at the Virginia Institute of Marine Science (VIMS) has been developing tools for several years to guide local governments in shoreline management. In particular, they have focused on the use of ecologically preferred alternatives for erosion control and have conducted research into refining the appropriate uses for a large suite of possible treatments based on existing shoreline conditions. A series of Decision Trees were developed to determine shoreline best management practices when conducting onsite inspections. These were developed to support integrated guidance at the management and regulatory level (https://www.vims.edu/ccrm/ccrmp/bmp/decision_tools/index.php).

Decision Trees supported the development of this GIS spatial model known as the SMM where users can determine appropriate shoreline best management practices from the desk-top using the model output. The analysis is conducted at parcel level scale but the output represents a reach based or cumulative approach to shoreline management. Therefore, the SMM is most appropriate for desk-top reviews, regulatory compliance and comprehensive planning. The recommendations derived from the SMM may be altered due to lot size, shoreline length along a single parcel, proximity of primary buildings to the shoreline, type of existing erosion control structures, land use practices, and local biota.

Preparing Data for the Model

This Handbook assumes the user has access to ArcGIS, can create and edit shapefiles and geodatabase features, and is familiar with ArcGIS ModelBuilder and Python. The model has been edited in ArcGIS 10.6.1 and may not work properly in older ArcGIS versions or in ArcPro.

All input data (Appendix B) need to be transferred onto a copy of a shoreline polyline shapefile or feature class. Each dataset can be represented by its own shapefile or feature class, however they all must be combined into one single file for processing through the final model (SMM v5.1). The output of the model contains shoreline best management practice recommendations and definitions for defended and undefended tidal shoreline. All processing steps occur in Esri's ArcMap, ArcGIS version 10.6 software. Models are created in ArcGIS ModelBuilder and Python. Three toolboxes are provided. They are in the toolboxes folder that is part of the zipped SMM Manual package. The four-part Fetch Model is in the FetchToolbox and the Shoreline Management Model (a main model with three submodels) is found in the SMM_v5_1_Toolbox.tbx. The third toolbox, Fetch_ArcProToolbox, contains one script tool from the FetchToolbox that has been modified to run in ArcPro.

The description of each required input, associated models, expected output, and final Shoreline Management model are found below in the Data Needs and Final Model sections. Common input requirements for the SMM v5.1 Preferred SHL BMP model and the four Fetch models are a *scratch geodatabase workspace*, a *current or working geodatabase workspace*, and a *name*. A File geodatabase is the preferred workspace. The name input and an automatically generated date are used in the output file name. The input variables "Name" or "county" is the study area name (ex: York for York County).

Throughout the manual, field names will use **Times New Roman bold 11**.

The SMM model and the Fetch model described within this manual were originally created for tidal shoreline in Virginia, however these models are easily exported and adapted to other regions. The descriptions of the data layers and models below can help others create a Shoreline Management Model or Living Shoreline Suitability Model that fits their region.

Data Needs

Shoreline:

An error free shoreline is the foundation for the Shoreline Management Model. The base shoreline can be from an available shoreline dataset such as the Environmental Sensitivity Index (ESI) or NOAA Continually Updated Shoreline Product (CUSP), or it can be created by using recent high resolution digital imagery as a background and digitizing the shoreline at a scale of 1:1000. The shoreline should reasonably match the land/water interface seen on the most recent high-resolution imagery available. If there are unacceptable deviations, edit and fix the shoreline. The final shoreline should be clean with no unnecessary dangles, overlaps, or intersections. Check the topology and fix any errors as needed.

To check Topology:

1. Open **ArcCatalog**
2. Create a new file geodatabase in your working folder
3. In the file geodatabase, create a new feature dataset (give it a name such as forTopology)
4. Import the shoreline into the new feature dataset
5. Right-click the new feature dataset, select **New**, then **Topology**
    a. The New Topology wizard pops open, click Next
    b. Enter a name for your topology, click Next
    c. Check the box next to the shoreline layer, click Next
    d. Accept the default, click Next
    e. Add topology rules: click **Add Rule**; select a rule and click OK
    f. Add more rules, one at a time. For lines, use the following rules:
        i. Must Not Overlap
        ii. Must Not Intersect
        iii. Must Not Have Dangles
        iv. Must Not Self-Overlap
        v. Must Not Self-Intersect
    g. Click Next, then Finish
6. A message will appear stating that “The new topology has been created. Would you like to validate it now?” Answer Yes.
7. Open **ArcMap**

Figure 1. An example of an area with topological errors. The line errors indicate overlapping arcs and the yellow point errors show the location of disconnected arcs or dangles.

8. Add the topology layer (the layer named in step5b). Click Yes to add the feature class associated with the topology.
9. The topology layer highlights the errors in red. (Figure 1. Shows an example of an area with topological errors. Error colors have been changed from the default color (red)).
10. Click the **Customize** button in the menu bar and choose **Toolbars**, then **Topology** (Figure 2).
11. To activate the Topology Toolbar, begin editing the feature class.
12. Click the **Error Inspector** Button to open the Error Inspector window. Click the Search Now button to see the number of errors
13. Right-click the error in the Error Inspector and choose Zoom To. Fix the error if necessary.
    a. If it is not an error, right-click the selected line in the Error Inspector table and choose Mark as Exception. This will remove the error symbol.
    b. If the error is fixed but the symbol remains, click the **Validate Topology** in Current Extent button located in the Topology Toolbar to revalidate the topology.
14. Remember to save periodically!
15. When the shoreline is clean, save edits and stop editing.
16. Copy the shoreline feature layer from the file geodatabase back into the project folder as a shapefile.

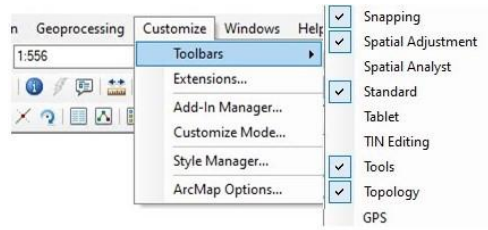


Figure 2. Display the Topology Toolbar

For more information about Topology, see the ArcGIS Desktop ArcMap website https://desktop.arcgis.com/en/arcmap/latest/manage-data/topologies/an-overview-of-topology-in-arcgis.htm

Adding the necessary information to the shoreline for use in the SMM:

All the required data (see below and Appendix B) will be transferred onto the linear base shoreline.

There are multiple methods for creating and/or transferring data onto the base shoreline. Two methods are described here. They will be referred to, along with more details, in each required dataset description below. The user does not need to follow these methods if they determine a better way to create the required linear data sets.

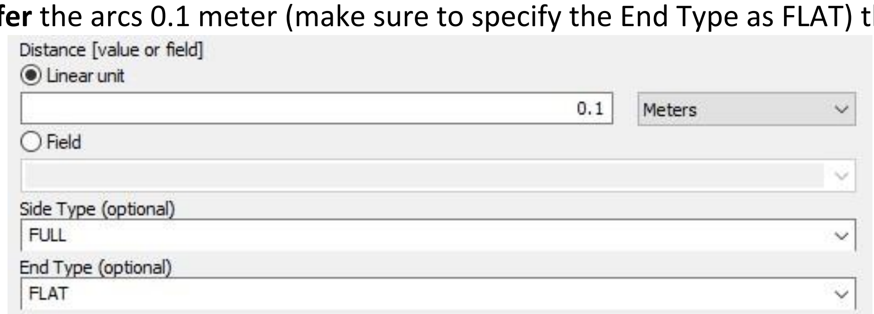
- **Split and Code Method**
    1. Make a copy of the base shoreline and give it a new descriptive name. It is easier to split and code a clean, unattributed shoreline than to select and code multiple adjacent arcs that are segmented for other attributes.
    2. Add the required field name(s) to the attribute table.
    3. In **ArcMap**, add high resolution imagery as a background (ESRI's basemap imagery will work fine if there is no other high quality recent imagery available),

the new feature class just created, and any other helpful datasets related to layer.

4. Zoom to the shoreline at a scale where details are easy to see (1:1000 to 1:2000).
5. Begin editing the new feature layer. Select the arc and use the split tool to cut the line where the feature in the imagery or external dataset changes. Select the line to be coded and calculate the field with the appropriate value.
6. Save edits frequently.

- **Trace Method**
  1. Create an empty polyline feature class and give it a descriptive name.
  2. Add the required field name(s) to the attribute table.
  3. In **ArcMap**, add high resolution imagery as a background (ESRI's basemap imagery will work fine if there is no other high quality recent imagery available), the new feature class just created, the base shoreline, and any other helpful datasets related to layer.
  4. Zoom to the shoreline at a scale where details are easy to see (1:1000 to 1:2000).
  5. Begin editing the new feature layer.
     - In the Editor toolbar, drop down the Editor button and select Editing Window -> Create Features.
     - In the Create Features window, select the template (the layer to edit), then select the Line button in Construction Tools.
     - In the Editor toolbar, select the Trace button, then click a spot on the

base shoreline to begin the trace. Double click to end the trace.
     - Code the line by calculating the field with the appropriate value.
  6. Save edits frequently.
  7. When finished, stop editing.
  8. **Buffer** the arcs 0.1 meter (make sure to specify the End Type as FLAT) then use



the **Identity** tool to put the buffer attributes onto the base shoreline. Identity creates a new feature class.

Riparian Land Use/Land Cover:

The Land Use/Land Cover layer shows the predominant land use in the riparian area within 100 feet of the shoreline. The Shoreline Management Model will query for the following land use values (Commercial, Industrial, Paved, Military, Government, Marsh Island, and Extensive Marsh) while ignoring the other land use values (Table 1). Please note that 'Military', 'Government', Marsh Island', and 'Extensive Marsh' are optional values. Marsh is dealt with in another layer described later in this document. If the SMM encounters a marsh value in the **RiparianLU** field, that section of shoreline will received a recommendation of 'No Action Needed'.

Figure 3. Example of paved land cover.

The land cover classification can include best professional judgment; particularly when there is mixed use on a large land parcel. For example, a paved parking lot that is part of a commercial establishment can be considered 'Commercial'. A residential area with a road next to the shoreline would be classified as 'Paved'. Remember, it is not necessary to create a complete land use/land cover layer since the model only requires a few land cover classes. Unclassified arcs can be can be coded as 'Not classified'. However, should there be a desire for a complete riparian land cover layer, suggested values for the **RiparianLU** field can be found in Table 1 along with definitions. Figures 3 - 5 show examples of land use and shoreline coded for land use.

Figure 4. Commercial and Forested riparian land use.

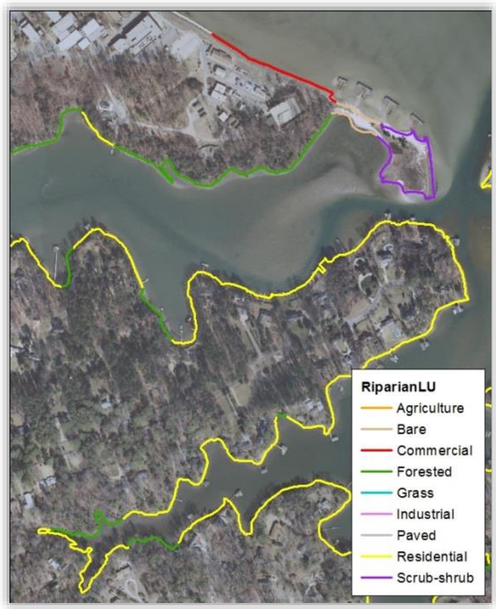


Figure 5. Riparian land use layer

To create the Land Cover layer, use the **Split and Code Method** described above.

1. Add a new text field (**RiparianLU**) to the attribute table of the newly created Land Cover layer.

2. Code for the required land cover values: Commercial, Industrial, and Paved.
3. Conditions can be verified by consulting Google Earth imagery and/or Bing Maps aerial imagery.

Table 1 Riparian land use values and definitions

RiparianLU Value	Definition (VIMS Shoreline & Tidal Marsh Inventory Glossary, Center for Coastal Resources Management)
Agriculture	Land use defined as agricultural includes farm tracts that are cultivated and crop producing. This designation is not applicable for pastureland, which is coded as Grass.
Bare	Land use defined as bare includes areas void of any vegetation or obvious land use. Bare areas include those that have been cleared for construction.
Commercial*	Commercial is a land use classification denoting small commercial operations such as shops, restaurants, as well as campgrounds. These operations are not necessarily water dependent businesses.
Extensive Marsh**	Large tidal marshes that extend into the open water, have water on two or three sides, and are often intersects by many tidal channels and creeks.
Forested	Forest cover includes deciduous, evergreen, and mixed forest stands. The land use is classified as Forest if there is a dense cover of trees and no other land use category is apparent close to the shoreline, e.g. residential, commercial, industrial, agriculture, etc.
Grass	Grasslands include large unmanaged fields, managed grasslands adjacent to large estates, agriculture tracts reserved for pasture, and grazing. While a general rule of thumb will classify a tract as "grass" if a home sits behind a large tract of grass, a designation of "residential" may be made if there are similar tracts adjacent to each other. This designation can be determined using best professional judgment.
Industrial*	Industrial operations are larger commercial businesses and can include areas where power plants, pulp mills, refineries, etc. are in operation along the coast.
Marsh Island**	A marsh island is a vegetated wetland that is completely isolated from the mainland and found in open water. A marsh that is surrounded by water due to dissection from small tidal creeks was classified as marsh, not a marsh island.
Military or Government**	A land use classification of Military marks the location of federal military reservations. This classification is generally reserved for the section of the base where active operations and infrastructure exist. Expansive military property adjacent to these areas which are unmanaged forest areas, for example, may be classified as forest land use.
Paved*	Paved areas represent roads which run along the shore and generally are located at the top of the banks. Paved also includes parking areas such as parking at boat landings, or commercial facilities
Residential	Residential land use includes single and multi-family dwellings located near the shoreline.
Scrub-shrub	Scrub-shrub is a land use class that includes small trees, shrubs, and bushy plants. This land use is easily distinguished during remote sensing compared to Forest and Grass.

* Shoreline Management Model specifically looks for these values.
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Bank Height:

Bank Height is the height of the bank measured from the base (or the toe) to the top of the bank. Height can be estimated from imagery, field inspection, videography, topographic maps, LIDAR, or from a combination of these sources. Bank height is classified into three categories: 0-5, 5-30, and > 30 feet. The User may opt to modify these categories to better suit their study region. The Bank Height categories are used to determine if a 3:1 bank slope can be achieved without impacting permanent structures (e.g. roads, houses). The shoreline buffer width is based on the bank height. The buffer is used to aid the user with the creation of the roads and permanent structures layer described further below. Additionally, this layer is used by the SMM to look for low bank height (0-5 feet) and high bank height (>30 feet) when determining recommendations.

To create this layer:

1. One possible method to calculate bank height from a LIDAR raster:
    a. Convert raster cell values from meters to feet.
    b. Reclassify into the desired bank height categories (ex. 0-5, 5-30, >30). Raster values less than 0 can be ignored. Bank height pertains to the landward side of the shoreline.
    c. Convert the raster to a polygon.
    d. Add the field **bnk_height** (field type Text) to the attribute table and calculate it to equal the reclassified categories from step 1b. The **bnk_height** field is required by the SMM model.
    e. Buffer the shoreline 25 feet; convert the polygon to a polyline using the **Feature To Line** tool. The user may choose a different distance to determine the bank height depending upon the resolution of the raster data used.
    f. Intersect the buffer line with the bank height category polygons from step 1d. This step puts the bank height 25 feet from the shoreline onto a line feature. The water side buffer line will be eliminated since it should not overlap with the upland height categories.
    g. Transfer the bank height data from the upland line to the base shoreline. All required data for the SMM must be on the same final base shoreline layer.
2. Add the fields **maxHgt** (field type Short) and **bufWidth** (field type Double) to the attribute table of the layer created in step 2g.
3. Add the maximum height for the category to the **maxHgt** field.
4. To calculate **bufWidth** use the formula ((3 x maxHgt) + 20), where (3 x maxHgt) gives the preferred 3 to 1 bank slope, and 20 adds an extra 20 feet of padding. When buffering using a field value, it is assumed that the distance unit is the same as the layer's spatial reference. If it is not then, apply a conversion or create a new field and populate it with the distance and a unit (Table 2).

Table 2 Bank Buffer table example

bnk_height	maxHgt	bufWidth[1]	buf_field[2]
0-5	5	10.67	35 feet
5-30	30	33.53	110 feet
>30	40	42.67	140 feet

[1] Buffer width formula (((3 * [maxHgt]) + 20) * 0.3048) with a conversion factor to change feet to meters.

[2] Text field with distance and measurement unit

Roads and Permanent Structures:

External datasets, if available, could help with this task. Potential road datasets include TigerLine roads (downloadable from the US Census Bureau: https://www.census.gov/geo/maps-data/data/tiger.html), or the state or local Road Center Line GIS dataset. Building footprint data along with visual inspection of the imagery will aid with the coding of the permanent structure field. Please note: permanent structures are upland structures (i.e. houses or swimming pools), not shoreline structures (bulkhead, riprap, etc.).

Figure 6. Shoreline shown in red has been coded for roads. The dashed lines indicate the bank height buffer widths. The shoreline should be coded for roads if the road intersects the bank buffer.

First, create a buffer feature class for use with the Roads and Permanent Structure feature creation.

1. In **ArcMap** open the **Buffer** Tool (**ArcToolbox** -> **Analysis Tools** -> **Proximity**)
    a. Input Features = Bank Height layer
    b. Output Features = name of new buffer feature layer
    c. Distance - choose Field and specify the appropriate field containing the buffer width values
    d. End Type = FLAT
    e. Dissolve Type = LIST
    f. Dissolve Field = field containing buffer width values

Figure 7. Permanent Structures (shown in bright pink) have been traced on the shoreline. The dashed lines indicate the bank height buffer widths. Trace the shoreline parallel to the permanent structure that is within the bank buffer.

Next, to create the Roads and Permanent Structures layer, use the **Trace Method**:

1. Create an empty polyline shapefile and name it something like 'rdsPermStruc'.
2. Add two new text fields to the attribute table: **roads** and **PermStruc.**
3. In **ArcMap**, display the high resolution imagery, the base shoreline, the bank buffers, and the 'rdsPermStruc' feature layer.
4. Begin editing the 'rdsPermStruc' layer.
    a. Examine the imagery along the shoreline within the bank buffers. Look for roads and other paved surfaces (i.e. parking lots) and

permanent structures (houses, swimming pools, decks, power stanchions, dams, etc.) within the bank buffer. Use the Trace tool to digitize a line on the shoreline that parallels the permanent structure or road that falls within the buffer. (See Figures 6 and 7).

   b. Save and code the line: if it is a road or paved surface, then calculate **roads** = "roads". If it is a permanent structure, then calculate **PermStruc =** "Permanent Structure". Boat houses (any covered structure immediately adjacent and overhanging the water or alongside a dock or pier built to cover a boat), piers, shoreline protection structures, and destroyed or removed buildings with just an abandoned slab remaining are not considered for this classification. Dirt tracks and abandoned driveways should not be considered a "road".

5. Upon completion of this layer, buffer the arcs with a very narrow width (0.1 m). Make sure to set the optional End Type to FLAT.
6. Use the **Identity** Tool (**ArcToolbox** -> **Analysis Tools** -> **Overlay**) to put the **roads** and **PermStruc** fields onto the shoreline.
   a. Input Features = base shoreline
   b. Identity Features = buffered roads and permanent structure layer
   c. Output Feature Class = new feature class name (ex. 'rdsPermStruc_onShoreline')

Beach/Wide Beach:

Beaches are persistent thin or wide sandy shorelines. These features can offer bank erosion protection by reducing wave energy. To create the Beach layer, use the **Split and Code Method**.

1. Create a Beach feature class by making a copy of the base shoreline and adding two text fields to the attribute table: **Beach** and **WideBeach**.

Figure 8. Beach present but not considered a wide beach.

Figure 9. Wide beach showing a measured distance of 30 feet from dune grass to high tide line.

2. Scan the shoreline for beaches or use a pre-existing beach dataset if available. Edit the beach feature class, splitting and coding sections of the shoreline that contain beach.
3. **Beach** field values should be "Yes" if a beach is present (Figure 8) otherwise it should be "No".
4. A wide beach has sandy areas above the mean high water (MHW) elevation and is always visible (Figure 9). A wide beach should be coded **Beach** = "Yes" and **WideBeach** = "Yes". If there is no wide beach, **WideBeach** should be coded "No".

Bathymetry:

Nearshore water depth plays an important role in determining the type of erosion control structures that are feasible. Shallow nearshores can utilize on-bottom structures, where allowed, that rise above or nearly above the high water level. If the nearshore is too deep, or the gradient is too steep, strategies such as planting marshes, and constructing breakwaters or sills may not be practical. Since detailed shallow water bathymetry is almost never available, SMM calculates a distance from the shoreline to 1 meter (3.28 feet) bathymetric contour as an indicator of the shallow water morphology. The further the 1 meter (3.28 feet) bathymetric contour is from the shore, the more gradual the slope and the shallower the water (Figure 10). To determine this parameter, a bathymetry dataset is required (i.e. NOAA topobathy or bathymetric contour layer). The distance of the 1m bathymetric contour to the shoreline is used to determine if the nearshore is suitable for shallow water management strategies. When the 1m bathymetric contour is greater than 10 meters (32.8 feet) offshore, nearshore depth is considered "Shallow", otherwise it is "Deep".

To create this layer:

1. Extract the 1 meter bathymetric contour from the dataset.
2. Buffer the contour 10 meters.
3. Use the **Identity** tool to combine the buffer and the base shoreline. This will create a new feature class and not affect the base shoreline.
4. Add text field **bathymetry** to the attribute table of the new feature class. The shoreline arcs overlapped by the buffer should be coded **bathymetry** = "Deep". All other arcs should be coded "Shallow".
5. It is important to double check the results and to smooth the classification of areas with short arcs segments that alternate between shallow and deep. Check areas in and around marinas, canals, and nearshore navigation channels. Bathymetric sounding points may be scarce in these areas resulting in shallow bathymetric interpolation when the water depth is actually deep.

Figure 10. Bathymetry. The dashed yellow lines represent the 10m buffer around the -1m bathymetric contour line. Where the buffer intersects the shoreline, the bathymetry is considered deep.

Canals, Public Boat Ramps, & Sand Spits:

These datasets identify a suite of land features that require additional review outside of the model to determine a preferred erosion control option. The model steps provide a way to flag these areas and give the user some additional guidance for next steps. The three datasets can be created as one layer.

1. Copy the base shoreline and give it a descriptive name (i.e. "canals_ramps_sandspits")
2. Add the following text fields to the attribute table: **canal**, **PublicRamp**, and **SandSpit.**

Figure 11. Sand spit (shown in red) with marsh.

Figure 12. An example of canals (shown in red).

3. Scan through the shoreline, looking for finger-like projections that could indicate a sand spit (Figure 11), and straight-sided narrow waterways that could indicate navigable man-made canals (Figure 12). Zoom into the area and inspect the imagery. Code the shoreline as appropriate where **canal** = "Canal" and **SandSpit** = "Yes".
4. A public boat ramp dataset, if available, is extremely useful for locating public boat ramps. Code the shoreline **PublicRamp** = "Yes" only when there is a paved public boat ramp in working order. Only code the shoreline where the ramp is located (Figure 13).

Figure 13. Paved public boat ramp (red line).

Submerged Aquatic Vegetation (SAV) or Mangroves:

Environmental regulation and policy may prohibit the building of certain shoreline protection structures where submerged aquatic vegetation (SAV) or mangrove habitat exist. Look for SAV or mangroves within 30 feet of the shoreline (Figure 14). If available, we recommend using a composite of the most recent 5 years of SAV data (presence/absence) since SAV can be ephemeral depending on climate conditions and species. Use existing sources for geospatial SAV and Mangrove data or try developing the delineation by using imagery (preferred) or best professional judgement of sites of known occurrence.

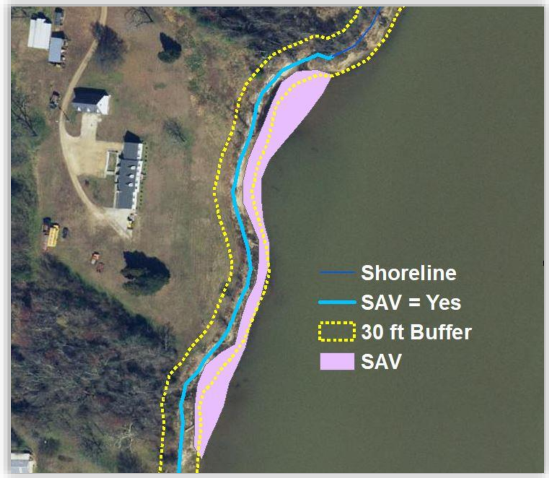


Figure 14. SAV bed present within 30 feet of shoreline.

To create this layer:

1. Buffer the base shoreline 30 feet.
2. Use the **Trace Method** to draw arcs on the shoreline to represent the SAV that is within the buffer.
3. Add the text field **SAV** to the attribute table of the new layer. Code the SAV lines **SAV** = "Yes".

The same process can be used for mangroves.

Shoreline Protection Structures:

Create a new layer for shoreline protection structures if there isn't a pre-existing GIS dataset available. The shoreline should be coded for erosion control structures that are located on or off the shoreline.

1. Add the following text fields to the attribute table: **Structure**, **offshorest**, and **defended**.
    a. The **Structure** field represents erosion control structures built on the shoreline or bank and include Bulkhead, Riprap (revetment), Marina, and Wharf (see definitions in Appendix C). Marina is included here because they often have hardened shoreline.
    b. Breakwater, Groin, and Marsh Toe (marsh sill) are coded in the **offshorest** (off-shore structures) field.
    c. Code the field **defended** = "Yes' when one or both structure fields have a value.

The user may add other shoreline erosion control structure types (referred to as structure type "X" in this document) if they don't fit into the above categories. Marinas may be recorded in a separate field if the user prefers to inventory the erosion control structures in the marina. Any changes will need to be updated in the SMM model code (discussed below).

Tidal Marsh:

Marsh datasets are generally polygons. For areas without a local wetlands dataset, the National Wetlands Inventory (https://www.fws.gov/wetlands/data/Data-Download.html) could be helpful.

1. To code for tidal marshes, use either the Split and Code Method or the Trace Method.
2. Add a text field named **marsh_all** to the new feature class attribute table.
3. Examine the high resolution imagery with or without a wetlands layer present, and code the shoreline adjacent to a tidal marsh.
4. The SMM expects a value of “Marsh present” “Marsh Island”, or “No”.

Marsh islands are isolated vegetated wetlands surrounded by water (see the definition in Appendix C), and are generally not part of the base shoreline. Inclusion of marsh islands is optional.

Fetch:

Fetch is determined as the maximum averaged distance over water to the nearest shoreline based on 16 directions (divided into 4 quadrants) radiating from a point on the shoreline. These data can be created by following the steps outlined in Appendix D for the Fetch Model.

The final Fetch Model output will have a field named **MxQExpCode (alias: MaxQuadFetchCode)** (for the maximum average quadrant fetch classification) with values of “Low”, “Moderate”, or “High”, where:

- Low = 0 - 0.5 mile (0 – 804.672 m)
- Moderate = 0.5 - 2 miles (804.672 – 3218.69 m)
- High = >2 miles (>3218.69 m).

Tributary Designation:

Small tidal creeks and tributaries with very little wave exposure occasionally may have a fetch vector that can run a considerable distance depending on sinuosity. This could lead to an erroneous output in the Fetch model which indicates the shoreline segment is “High” energy. A designation of High energy would likely yield a recommended strategy which would be over engineered for the actual site (revetment or a breakwater).

Classifying the shoreline as a “Tidal Creek” helps the model recognize that despite the presence of one or two isolated vectors that are longer than 2 miles, the tributary is a low energy setting. This classification is used in the SMM to help determine the recommendations for undefended shorelines.

To categorize the waterways:

1. Copy the base shoreline and add the text field **tribs** to the attribute table.
2. Buffer the base shoreline with a wide buffer (500 meters, dissolving on the empty **tribs** field) (Figure 15).
3. Edit the buffer:
    a. Select the polygon(s) to be divided.
    b. Use the Cut Polygons Tool  on the Editor Tool bar to split the polygon(s) at the confluence of the tidal creek or minor tributary (waterways with predominately low to moderate fetch) and high energy waters.
    c. Save edits and calculate **tribs** = "Tidal creek". Classification of other parts of the shoreline does not matter for the model but other potential values could be "Major Tributary", "Bay", or " ".
4. Use the **Identity** tool to transfer the **tribs** attribute and values from the coded buffer onto the base shoreline. The Input Features is the base shoreline and the Identity Features is the coded buffer.

Figure 15. Example of a tidal creek shown in white. The dashed lines represent the shoreline buffer polygons.

Final Steps Before Running Model

Now that all the data layers have been developed you are nearly ready to run the model. Since each layer has been created on a copy of the base shoreline, they need to be aggregated into one polyline shapefile or feature class. To do this simply:

1. Choose one layer to be the initial receiving layer. The Riparian Land Cover layer is probably the best layer as it could have the most variability. Make a copy of this layer. It does not need to be buffered.
2. Buffer all the other layers using a narrow (0.1m) buffer distance. Make sure to set the optional values of End Type = FLAT and Dissolve Type = LIST. Check the appropriate Dissolve Fields in the list (these will be the required fields that were added to each layer).

3. Use the Identity tool (Figure 16) to put a buffered layer's attributes onto the layer chosen in step 1.

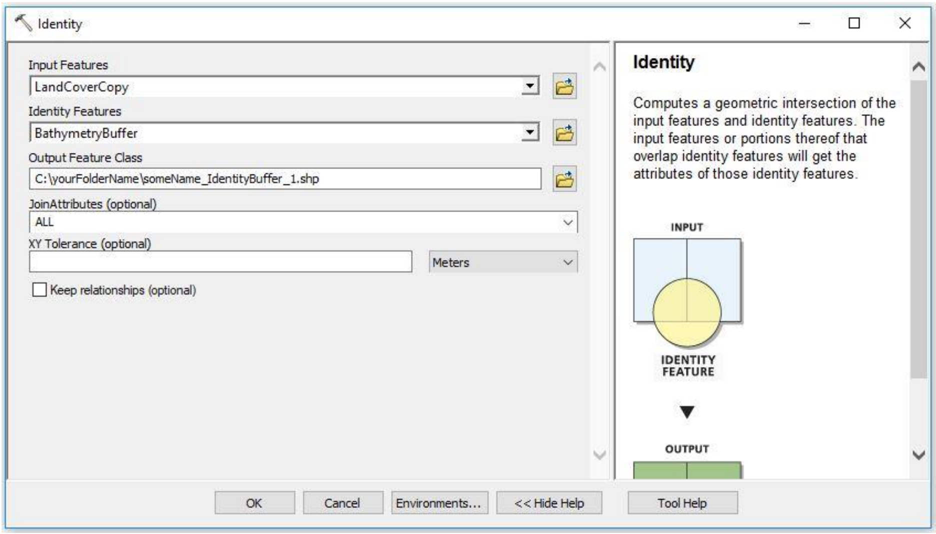


Figure 16. Identity Tool found in the Analysis Tools toolbox in the Overlay folder.

4. Using the output from the preceding Identity as the input to the next Identity, cycle through all the buffered layers.
5. The output file from the final Identity will have all the required fields in its attribute table.
6. Use the Dissolve tool to remove unnecessary fields (Figure 17, red box - A) and to potentially reduce the number of arc segments. Make sure to uncheck the Create

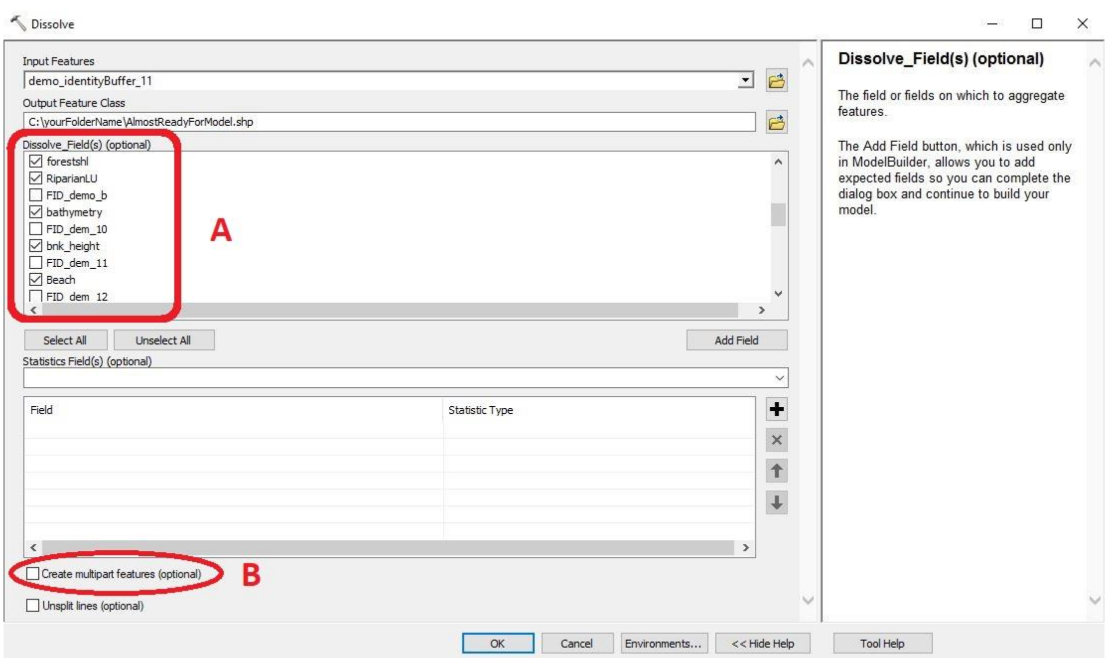


Figure 17. The Dissolve Tool is located in the Data Management Tools toolbox in the Generalization folder.

multipart features box (Figure 17, red oval - B). It is important that each arc be a singlepart feature, not linked to another arc with the same variable combination in a different geographic location within the dataset. For a list of all fields required for the SMM, see Appendix B.

7. Empty or NULL values in fields (**canal**, **offshorest**, **PermStruc**, **PublicRamp**, **roads**, **SandSpit**, **SAV**, **Structure**, **tribs**, **WideBeach**) can be replaced with 'Not Observed' or 'No'.
8. If the final dissolved layer is a shapefile, copy it into a file geodatabase. A geodatabase will automatically create a **Shape_Length** field and maintain the layer's geometry.
9. Check for arcs ≤ 1 m in length and merge them into an adjacent arc. Recheck topology for overlapping arcs and unnecessary dangles (refer to "Topology" under the Shoreline section). This can be a time consuming step but is essential for a clean product. Using buffers to transfer attributes onto another polyline can result in overlapping arcs and tiny arc segments. The small buffer width and flat buffer ends suggested in this manual attempts to mitigate some of the overlap errors but it is not perfect.

Shoreline Management Model (v5.1)

What it is

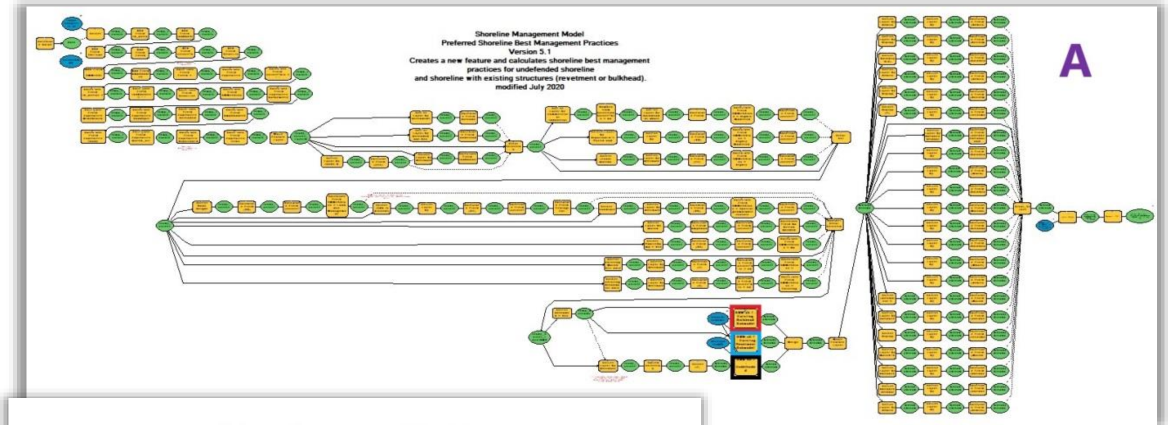
The Shoreline Management Model (version 5.1) model is comprised of four models (one main model and 3 submodels) found in the SMM_v5_1_Toolbox. The models were built in ArcMap version 10.6.1 using ModelBuilder. The main model, ***SMM v5.1 Preferred SHL BMP - Main*** (**A**), calls on the three submodels (***SMM v5.1 – Existing Bulkhead Submodel*** (**B**), ***SMM v5.1 – Existing Revetment Submodel*** (**C**), and ***SMM v5.1 – Undefended Submodel*** (**D**)) (see Figure 18). Initially the four models were part of one large, complex model. Editing the single model was time consuming and difficult to maintain. Therefore, the processes pertaining to existing bulkhead, existing revetment, and undefended shoreline were broken out into separate submodels and reconnected as tools in the main model. By reducing the original model's complexity, it is easier to edit the models for updates and variable changes. Do not run the submodels, only run the Main model.

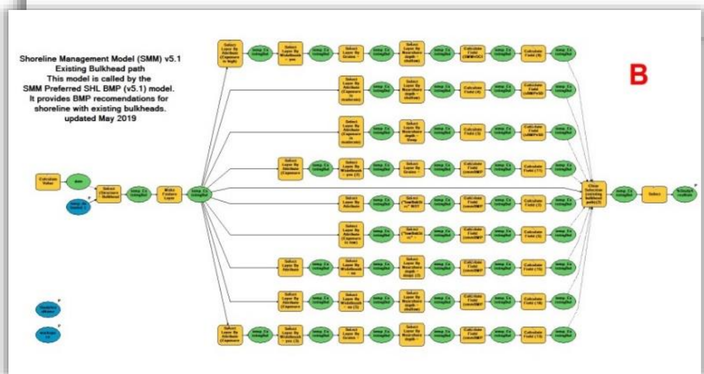
Before running the model, set up the workspace with two file geodatabases: a scratchGDB and a workspaceGDB.

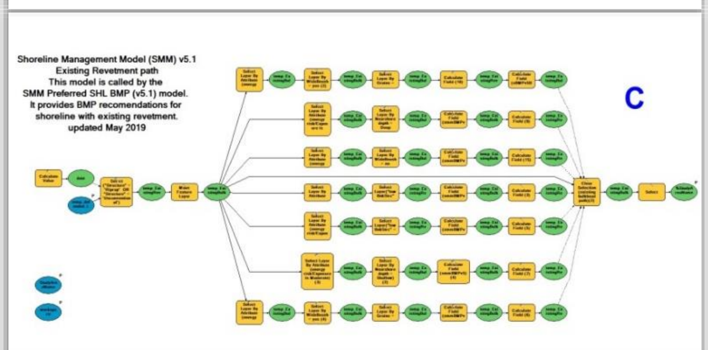
There are four input parameters: *Input Feature* (the polyline feature class created above in the Data Needs section), *workspaceGDB* (the name and location of an existing geodatabase workspace), *scratchGDB* (the name and location of an existing scratch geodatabase workspace), and *StudyAreaName* (this name becomes part of the output feature class name). Running the model creates a new feature class with recommended preferred shoreline best management practices for defended and undefended shoreline.

The model is based on flow diagrams (Appendix E) developed by the Center for Coastal Resources Management (CCRM) at VIMS for determining the appropriate management of tidal shoreline erosion in Virginia. It produces thirteen possible recommendations: three living shoreline options, three traditional management approaches, two maintain existing treatment suggestions, and five cases of special consideration (Appendix A). The recommendations and definitions may be customized to reflect regional terminology and guidance for shoreline erosion control strategies.

The model is designed to examine specific attribute fields and values found in the input feature class. Any deviations in field names or values will need to be changed in all sections of the model and submodels. This will be discussed below along with a description of each model section.







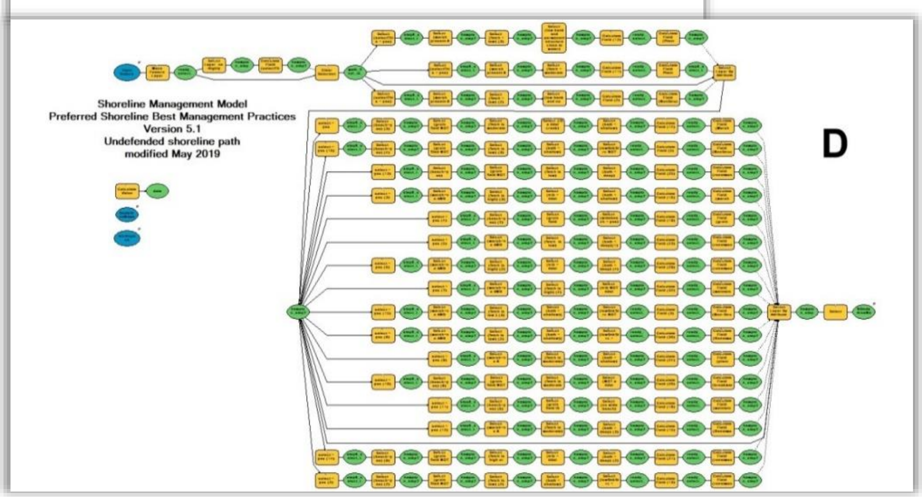


Figure 18. Shoreline Management Model (SMM) version 5.1. Model A is the main model. The three tools outlined in red, blue, and black are the three submodels: Existing Bulkheads Submodel (B - red box in A), Existing Revetment Submodel (C - blue box in A), and Undefended Submodel (D - black box in A).

SMM Preferred SHL BMP (v5.1) Model – Main Model

There are seven sections in the main model referred to here as the SMM Preferred SHL BMP.

Section 1. The first section (Figure 19) copies the input shapefile or feature class (the shoreline with all the added data) and adds eight new fields (**rd_pstruc**, **lowBnkStrc**, **ShlType**, **Fetch**, **selectThis**, **StrucList**, **SMMv5Class**, and **bmpCountv5**) that will be populated and used by the model. The sixteen "Calculate Field" processes ensure that the values in the fields from the input dataset are capitalized and the newly added fields have an empty value. The field **SMMv5Class** (SMM v5.1 classification) will hold the preferred shoreline best management practice recommendations determined by the model. The field **bmpCountv5** (best management practice count v5.1) tracks the number of recommendations given for a shoreline segment. A value that is 0 will not have a recommendation in the **SMMv5Class** field. This could indicate an error and the attributes for the line segment should be reviewed. A value greater than 1 will indicate a recommendation has been overwritten. This could occur for shoreline that is classified as an area of special consideration. For example: a commercial property with a bulkhead could also have SAV present.

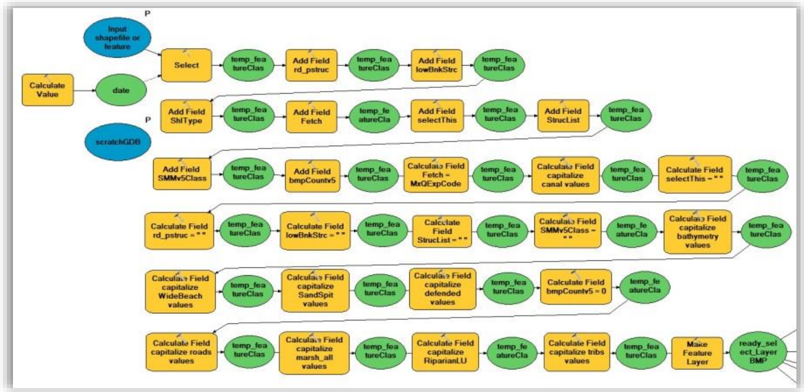


Figure 19. Shoreline Management Model: section 1 – addition of new fields and setting values.

Section 2. Section 2 (Figure 20) adds values to three of the fields created in section 1.

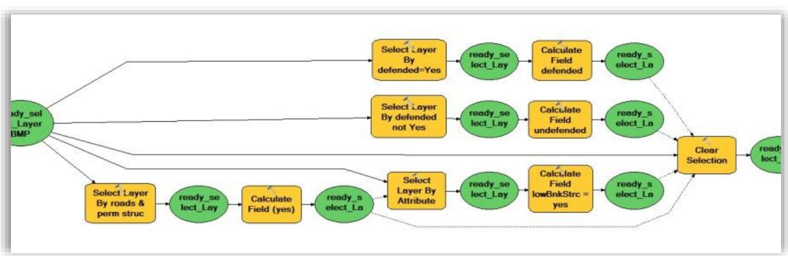


Figure 20. Shoreline Management Model: section 2 – calculates three fields.

- **rd_pstruc** (roads and permanent structures) – the model selects records where the value in the **roads** field equals "Roads" OR the value in the **PermStruc** field equals "Permanent Structure", then calculates the **rd_pstruc** field to be "Yes".
- **lowBnkStrc** (low bank and structure) – This field receives a "Yes" value for records that have a low bank (bank height 0-5 feet) and a permanent structure or road within 35 feet of the shoreline. Also included are areas were bank height is 5-30 feet and **rd_pstruc** is "Yes".
- **shlType** (shoreline type) – The value for this field is "Defended" for records where **defended** = "Yes" and "Undefended" for records where **defended** is not equal to "Yes".

Section 3. Section 3 (Figure 21) is the first of two sections that identifies Areas of Special Consideration. These are areas where the model may not be able to provide an appropriate recommendation due to ecological, geological, or highly developed conditions. Areas of Special

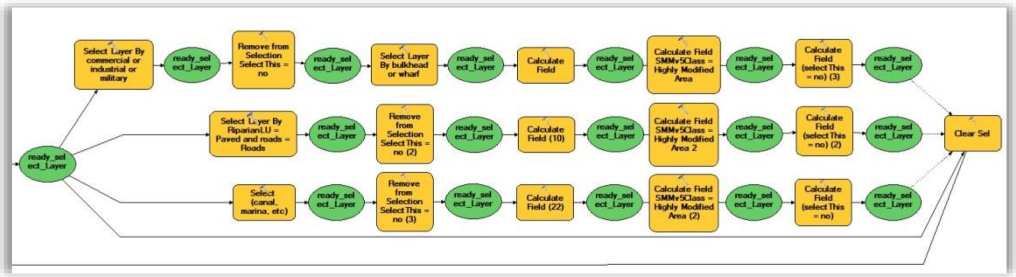


Figure 21. Shoreline Management Model: section 3 – identifying highly modified areas.

Consideration are not processed through the defended and undefended submodels but are given recommendations that include the instruction to seek expert advice. Section 3 picks out Highly Modified Areas. These areas are canals, marinas, areas where land use is paved (e.g. large parking lots) and roads have been identified as being close to the shoreline, and commercial or industrial areas with hardened shoreline (Bulkhead, Riprap, Wharf). If the user has added or changed any values in the **Structure** field, the changes will need to be added in this section, specifically in the top row where land use is selected, followed by a subset selection of structures. The model begins to populate the following fields:

- **bmpCountv5** – the value is increased by 1 each time the record is selected and given a recommendation.
- **SMMv5Class** – the shoreline recommendation for arcs selected in this section is “Highly Modified Area. Seek expert advice.”
- **selectThis** – this field is used to determine which records are available for further analysis. All records that are classified as Highly Modified will be removed from further consideration later in the model. The field **selectThis** is coded as “No”.

Section 4. Section 4 (Figure 22) finds additional Areas of Special Consideration and areas with existing hybrid living shoreline (see flow chart in Appendix E Chart E1). These areas are given special recommendations and are also removed from further analysis by giving the field **selectThis** a value of “No”. These include:

- Bank heights greater than 30 feet receive the recommendation "Land Use Management. Seek expert advice." If the user has altered the bank height categories, the ‘Select Bank Height >30 feet’ tool will need to be opened and edited to fix the selection expression with the new highest category.
- SAV or other ecological conflicts such as Mangroves are often protected by state government rules and regulations that prevent placing structures near them. The user can modify the ‘Select (SAV is present)’ tool to include ecological conflicts present in their area, provided it has been coded in the input dataset. The recommendation for these areas is “Ecological Conflicts. Seek regulatory advice.”

- Sand spits are natural features that should be allowed to move over time. The recommendation is “Special Geomorphic Feature. Seek expert advice.”
- Public ramps, and Marsh islands or Extensive marsh generally do not need any management. The recommendation is “No Action Needed”.
- Existing Breakwaters and existing Marsh Sills are considered structural or hybrid living shorelines. The recommendation for these areas is to maintain the structure.

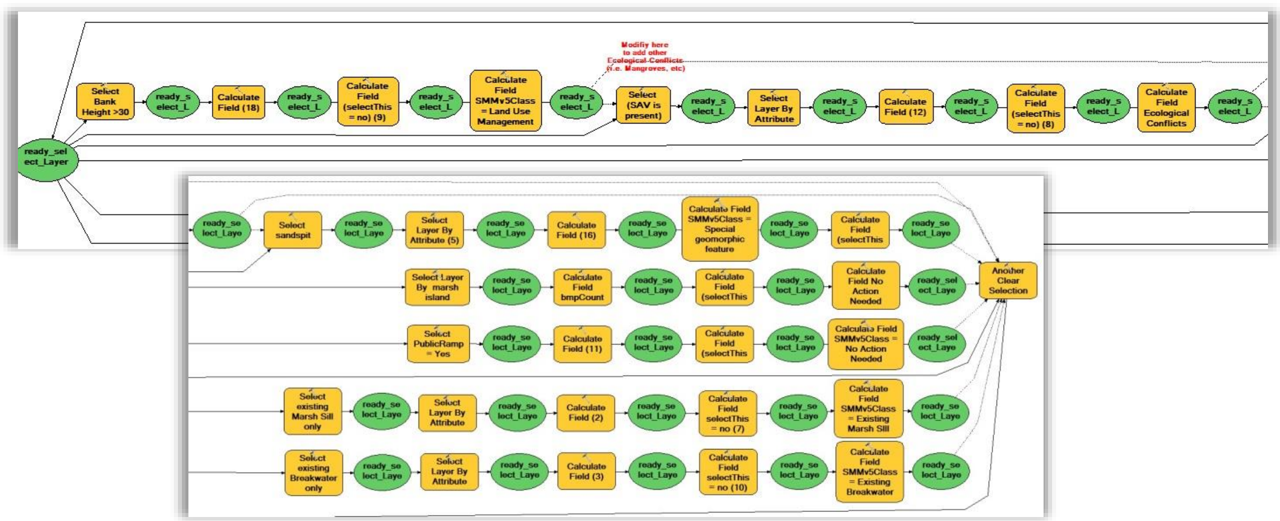


Figure 22. Shoreline Management Model: section 4 - areas of special consideration and maintain existing treatment.

Section 5. Section 5 (Figure 23) selects the defended shoreline and sends it as input into the **SMM v5.1 – Existing Bulkhead Submodel** and **SMM v5.1 – Existing Revetment Submodel** tools. All shoreline that has ***not*** been coded for **Structure** equal to “X” (where X could be a Bulkhead, Riprap, Unconventional, or Seawall as examples) is passed to the **SMM v5 Undefended Submodel** tool (see description of these submodels below). Note that any changes or additions to the **Structure** field will need to be addressed in this section and in the two existing structure submodels. The results from the three external submodels are merged back into one dataset

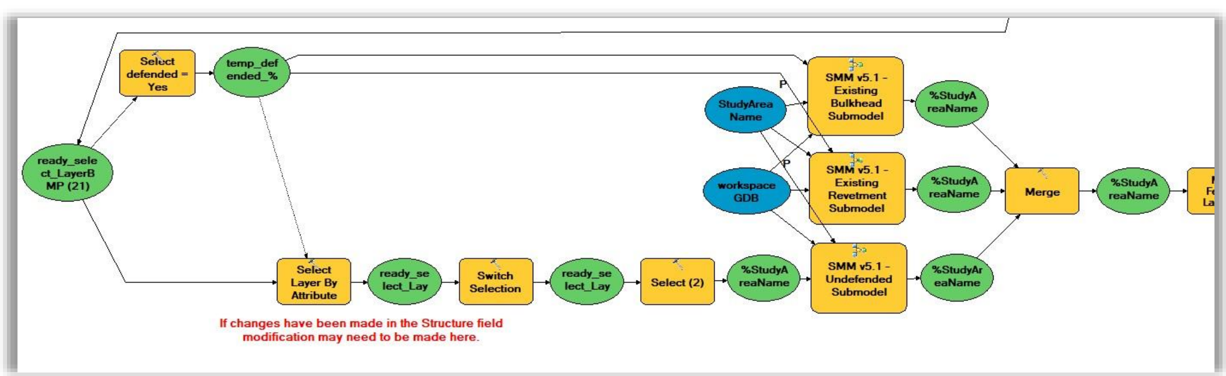


Figure 23. Shoreline Management Model: section 5 – calls three embedded external models to process defended and undefended shoreline.

(%StudyAreaName%_SMM_v5_1_%date%_merged). The submodels do not need to be edited if no changes are made to field names, variables, or recommendations.

Section 6. Section 6 (Figure 24) sorts through the erosion control structures from the **Structure** and **offshorest** (offshore structures) fields and populates the **StrucList** (Structure List) field. This section is not integral to the model. It simply creates a complete list of all the structures in one field. If the user has changed or added new values to the structure fields, then this section of the model should be reviewed and modified as necessary.

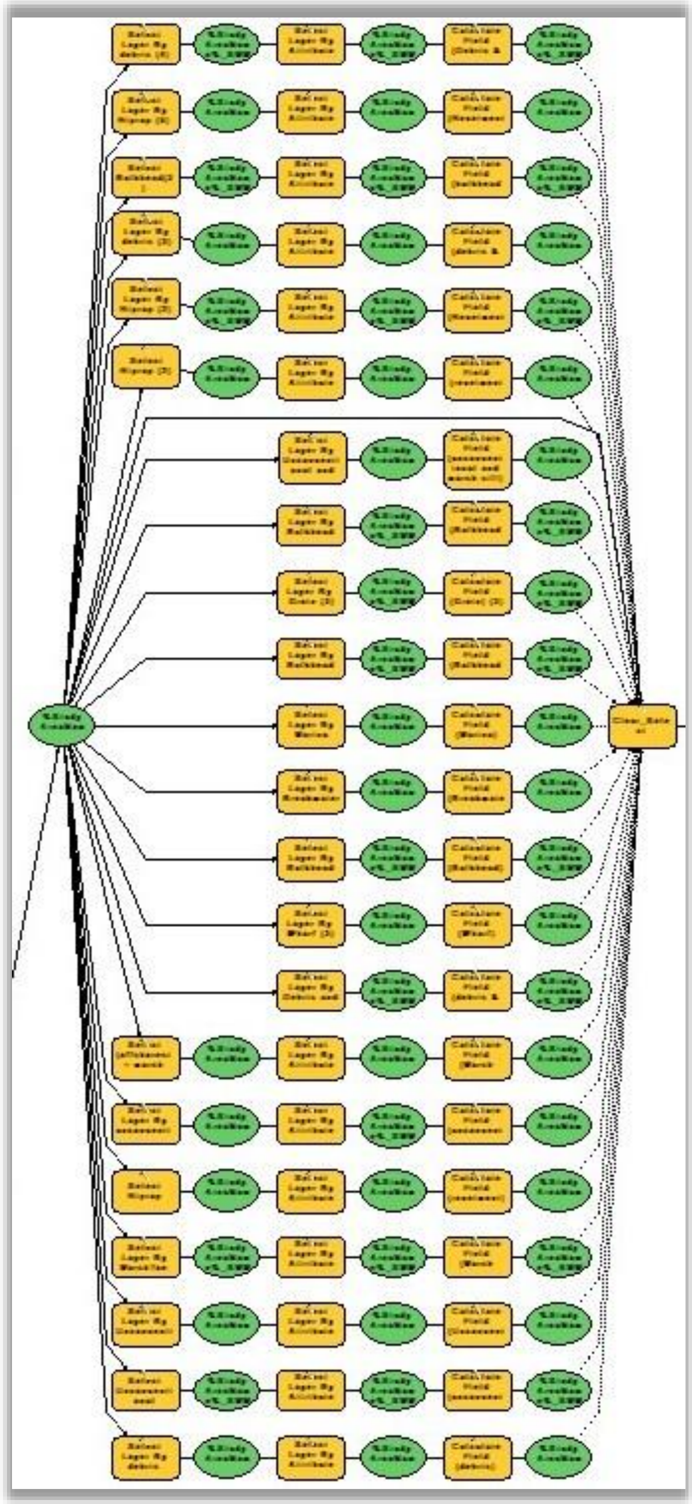


Figure 24. Shoreline Management Model: section 6 - populates the Structure List field (StrucList)

Section 7. This is the last section of the **SMM Preferred SHL BMP** model. Section 7 (Figure 25) joins the recommendation definitions to the model output. The definitions are located in a separate geodatabase table that has been zipped along with the SMM v5.1 Toolbox. If the user has made changes to the recommendations and/or definitions, the definition geodatabase table will need to be updated. The model output is a geodatabase feature class with the name structured like *StudyAreaName*_SMM_v5_1_Date.

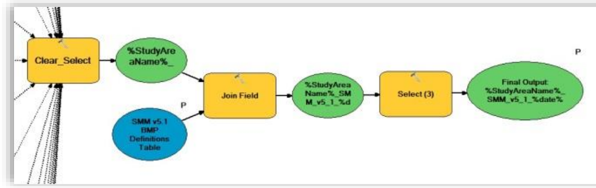


Figure 25. Shoreline Management Model: section 7 – joins the recommendation definitions to the dataset.

SMM v5.1– Existing Bulkhead Submodel

This model is referenced in section 5 of the main model (described above). The input is all shoreline that is defended (**defended** = "Yes"). The model (Figure 26) selects **Structure** = "Bulkhead" or **Structure** = "Seawall". If the user has added other shoreline structures that are similar to Bulkhead, then they should be added to the selection code (ex. or **Structure** = "X"). The selected records are processed using a series of selections and reselections to find various conditions based on fetch (**Fetch**), nearshore depth (**Bathymetry**), wide beaches (**WideBeach**), groins (**offshorest**), and roads/permanent structures next to a low bank (**lowBnkStrc**) (see flow chart in Appendix E Chart E2). If any changes have been made to the values in these fields, modify this submodel to reflect the changes. The result of this submodel is represented as the output variable from the embedded submodel tool in **SMM v5.1 Preferred SHL BMP – Main Model** (see Figure 23).

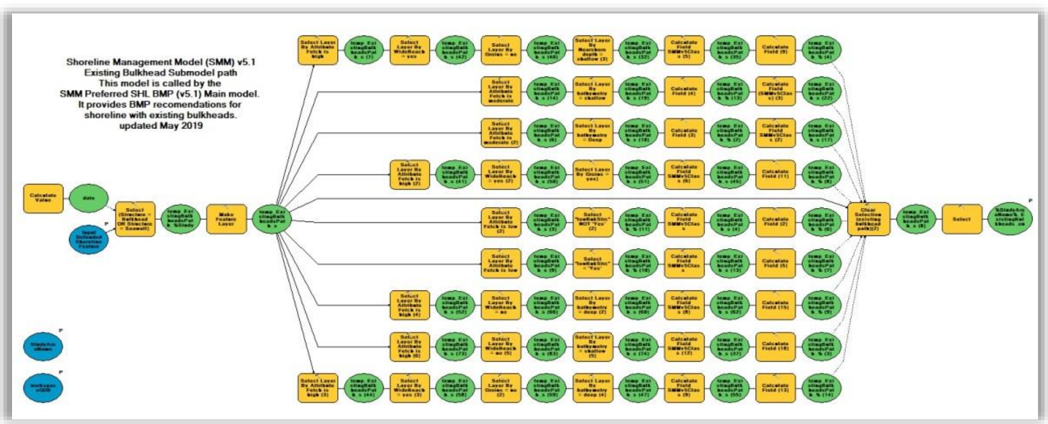


Figure 26. SMM v5.1 - Existing Bulkhead Submodel determines recommendations for shoreline with existing bulkhead or seawall.

SMM v5.1– Existing Revetment Submodel

This model is referenced in section 5 of the main model, **SMM Preferred SHL BMP** described above. The input is all shoreline that is defended (**defended** = “Yes”). The model (Figure 27)

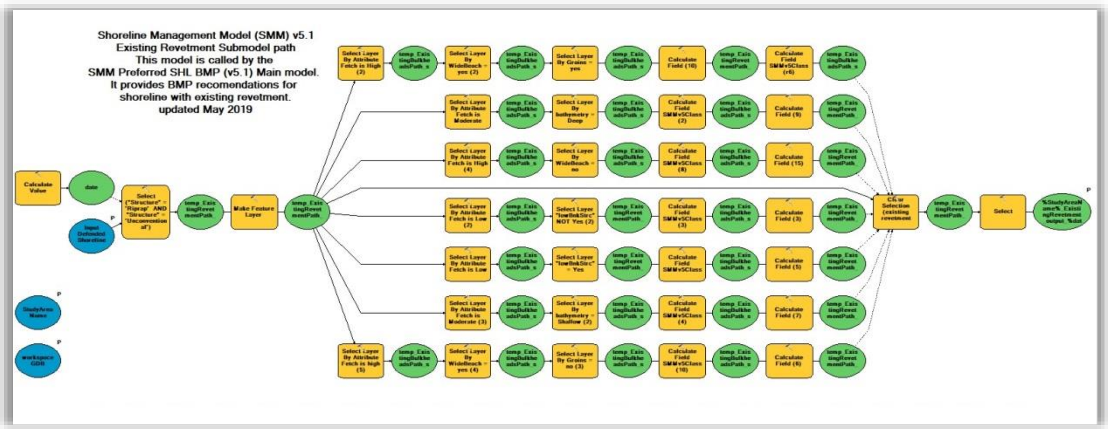


Figure 27. SMM v5.1 - Existing Revetment Submodel determines recommendations for shoreline with existing revetment or unconventional structures.

selects **Structure** = “Riprap” or **Structure** = “Unconventional”. If the user has added other shoreline structures that are similar to Revetment, then they should be added to the selection code (ex. or **Structure** = “X”). Just like the Existing Bulkhead submodel, this model continues with selections and reselections to find various conditions based on fetch (**Fetch**), nearshore depth (**Bathymetry**), wide beaches (**WideBeach**), groins (**offshorest**), and roads/permanent structures next to a low bank (**lowBnkStrc**) (see the flow chart in Appendix E Chart E3). If any changes have been made to the values in these fields, modify this submodel to reflect the changes. The result of this submodel is represented as the output variable from the embedded submodel tool in the main model (**SMM v5.1 Preferred SHL BMP**)(see Figure 23).

SMM v5.1 - Undefended Submodel

This model is referenced in section 3 of the main model, **SMM v5.1 Preferred SHL BMP** described above. The input shoreline is primarily undefended. Shoreline coded for Bulkhead, Seawall, Riprap, Unconventional, or “X” (if the user has added other structure types and

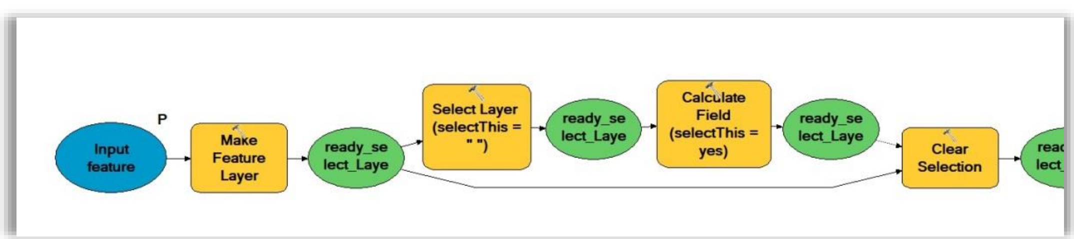


Figure 28. SMM v5.1 – Undefended Submodel: part 1 – find and set the empty selectThis values to ‘yes’.

modified the coding) has already been excluded. The first part of this model (Figure 28) identifies the shoreline that does not have a value in the **selectThis** field and sets the value to “yes”. Conditions not chosen (**selectThis** = “no”) were previously classified as highly modified areas and areas of special consideration in other sections of the Shoreline Management Model.

The remaining parts of this model each begin with the selection of **selectThis** = “yes”, followed by a series of sub-selections of various conditions to determine the shoreline recommendation (see flow chart in Appendix E Chart E4).

The second part of this model (Figure 29) focuses on shoreline where marsh (**marsh_all**) is

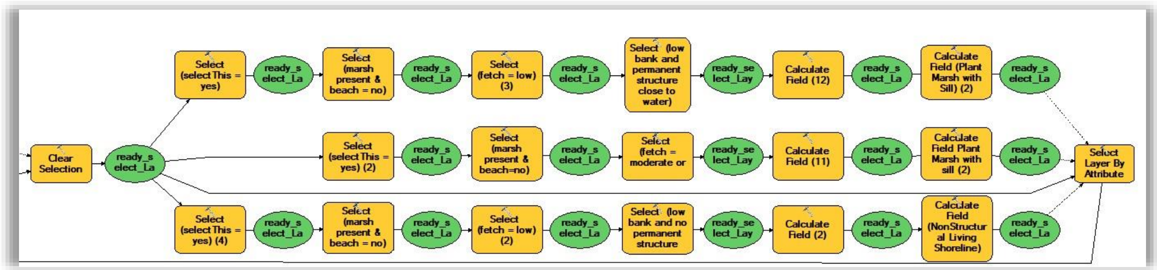


Figure 29. SMM v5.1 – Undefended Submodel: part 2 – beach absent, marsh present.

present and beach (**Beach**) is absent, then makes recommendations based on the fetch (field **Fetch** can be Low, Moderate, or High). If the fetch is low, the model looks at the values in the **lowBnkStrc** field (roads/permanent structures next to a low bank). The **SMMv5Class** recommendations here are “Non-Structural Living Shoreline” and “Plant Marsh with Sill”.

The final section of the model (Figure 30) handles the remaining undefended shoreline recommendations. Fields queried are those pertaining to **Beach**, **marsh_all, Fetch**, the presence of a groin field (**offshorest**), **WideBeach**, **bathymetry** (nearshore depth), **lowBnkStrc**, and **tribs** (the presence of a tidal creek/minor tributary). This section can produce the above two recommendations in addition to “Groin Field with Beach Nourishment”, “Maintain Beach or Offshore Breakwaters with Beach Nourishment”, and “Revetment”. The result of this submodel is represented as an output variable from the embedded submodel tool in the main model (**SMM v5.1 Preferred SHL BMP**) (see Figure 23).

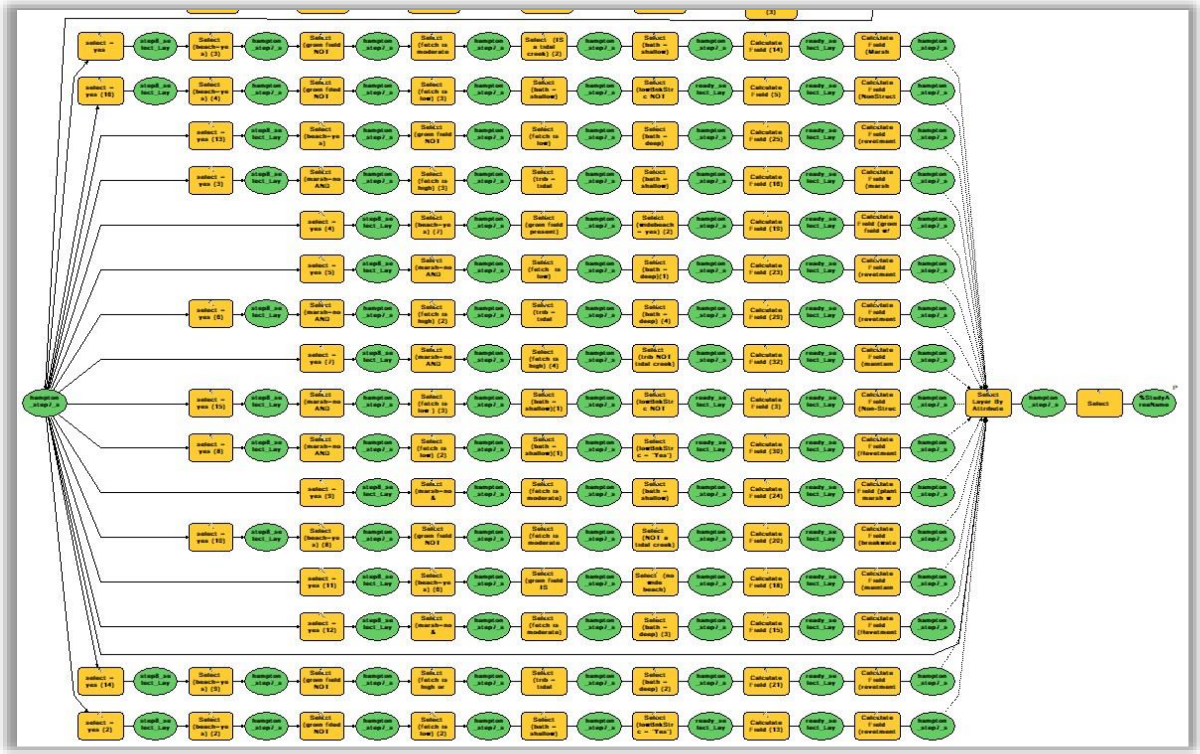


Figure 30. SMM v5.1 – Undefended Submodel: part 3 – beach present or absent and no marsh.

Appendices

Appendix A: SMM Recommendations

Shoreline Management Model version 5.1 –
Preferred Shoreline Best Management Practices Glossary

Existing Breakwater: Continue to maintain the breakwater system through beach nourishment and/or plantings in the nourished areas. Consider shoreline enhancement such as creation of vegetated wetlands, riparian buffer and/or sandy beach/dune above and immediately channelward of the structure.

Existing Marsh Sill: This shoreline already has a hybrid living shoreline treatment. It should be maintained. Periodic maintenance of the marsh area may be required. Additional sand fill, wetland plants &/or sill structure may be necessary to maintain marsh habitat.

Groin Field with Beach Nourishment: Maintain existing wide beach between groins. Remove unnecessary structures at the backshore (e.g. bulkheads) and stabilize the bank with grading and riparian plants. Repair/replace existing groins, add beach nourishment and plant beach vegetation.

Maintain Beach or Offshore Breakwater with Beach Nourishment: If shoreline exceeds 200 feet in length, remove existing shoreline structure, add beach nourishment sand, consider offshore breakwaters or another type of wave attenuation device with beach nourishment; consider adding plantings to the nourished areas. When the shoreline length is less than 200 feet an offshore breakwater may not be practical. In this case, remove failed shoreline structures and repair or construct a revetment as far landward as possible. Consider shoreline enhancement such as creation of vegetated wetlands and/or riparian buffer and/or sandy beach/dune above and immediately channelward of the structure.

Non-Structural Living Shoreline: Remove existing shoreline structure if present; grade bank if necessary and install a non-structural living shoreline which may include riparian buffer planting along the bank, and/or marsh plants, coir logs, or oyster reefs along the shoreline. Best choice for low energy environments.

Plant Marsh with Sill: In moderate energy environments a sill may be required to establish a living shoreline. Remove any existing shoreline structure if present and grade the bank if possible. Stabilize bank with riparian vegetation and plant a marsh with a sill. If the bank cannot be graded, repair existing shoreline structure with a minimal footprint and consider incorporating a marsh with a sill or some other shoreline enhancement (e.g. oyster castles).

Revetment: Remove existing failing or failed shoreline structure, if present. Construct new revetment as far landward as possible; grade the bank and plant vegetation buffers where possible. If grading is not possible, construct or repair existing revetment in the same alignment. A bulkhead should be considered only if previously present and the site is limited by navigation. Consider shoreline enhancement such as creation of vegetated wetlands and/or riparian buffer and/or sandy beach/dune above and immediately channelward of the structure. In high energy settings where shoreline extends more than 200 feet see option for **Offshore Breakwater with Beach Nourishment.**

Revetment/Bulkhead Toe Revetment: If grading is possible, remove the failed bulkhead and replace with a revetment landward of the current bulkhead. When grading not possible, (re)construct bulkhead in the same alignment and/or add a toe revetment. Consider a shoreline enhancement project such as creation of vegetated wetlands and/or riparian buffer and/or sandy beach/dune above and immediately channelward of the structure.

Special Considerations

Ecological Conflicts: Management options for this shoreline may be limited by the presence of Submerged Aquatic Vegetation (SAV) or Mangroves (Florida and Gulf coast shorelines). For Virginia shorelines, seek advice from the Virginia Marine Resources Commission Habitat Management Division http://www.mrc.virginia.gov/. If you live in another state, seek advice from your local marine regulatory agency.

Highly Modified Area: Management options for this shoreline may be limited due to the presence of highly developed upland (e.g. commercial wharfs), channel modifications (e.g. canals) or infrastructure directly adjacent to the shoreline (e.g. road). Shoreline BMPs will depend on the need for and limitations posed by navigation access and erosion control. Seek expert advice on the design of your project.

Land Use Management: Shorelines with tall banks greater than 30 feet limit possible solutions to address bank erosion. Forces other than tidal erosion, such as over-land runoff, upland development, and vegetation management are likely also having effect on bank conditions. Assessment of all factors and modifications to address causes for bank erosion are recommended. This may include changes to vegetation management, implementation of projects to address storm water, relocating buildings, utilities, and other infrastructure. All new construction should be located 100 feet or more from the top of bank. Actions may also include requesting zoning variances for relief from setback and other land use requirements or restrictions that may increase erosion risk. Seek expert advice to inform management options.

No Action Needed: No specific management actions are suitable for shoreline protection, e.g. boat ramps, undeveloped marsh, and barrier islands.

Special Geomorphic Feature: Maintain the natural condition of this shoreline to allow for unimpeded sediment movement and the corresponding response of wetlands, beach and/or dune. If primary structures are present and threatened, seek expert advice on the design of your project.

Appendix B: Data Required

Shoreline Management Model version 5.1 - Data Needed and Required Attributes

Dataset	Brief Description	Required Field Name[1]	Values (only listing those that are queried by model)[2]
Bank height	Measured from the upland/water interface to the top of bank. Bank height classification is measured in feet.	bnk_height	0-5, 5-30, >30
Beach/wide beach	Presence of beach (yes or no). A wide beach is a permanent sandy beach with visible beach area above the regular tide.	Beach	Yes, No
		WideBeach	Yes
Fetch	Determined as the maximum average distance within 4 quadrants (ne, se, sw, nw) over water from a point on the shoreline. Points are spaced every 25 meters along the shoreline. Fetch is calculated such that low = 0-0.5 mile, moderate = 0.5-2 miles, and high = > 2 miles.	MaxQuadFetch Code	Low, Moderate, High
Near shore bathymetry	Primarily the 1m bathymetric contour line. This is a substitution for slope. It is used to determine if the nearshore is suitable for marsh planting. If the 1 meter bathymetric contour is within 10 meters of the shoreline then marsh planting might not be advised.	bathymetry	Shallow, Deep
Permanent structures and roads	Roads and permanent structures close to the shoreline could prohibit bank grading.	roads	Roads
		PermStruc	Permanent Structure
Public boat ramps	A paved public boat ramp can change the recommendation to "no action needed".	PublicRamp	Yes
Riparian land use[3]	The predominant land use/land cover in the immediate riparian area (within 100 feet of the shoreline).	RiparainLU	Commercial, Industrial, Paved. Optional values: Government, Military, Marsh Island, Extensive Marsh.
Sand spits and man-made navigable canals	The model flags these as areas of special consideration.	canal	Canal
		SandSpit	Yes
Shoreline	A clean base shoreline. (*Critical data layer as ALL data will be placed on this shoreline*.)		
Shoreline structures	Erosion control structures both on and off the shoreline. Marinas are included here because they generally have hardened shoreline associated with them.	Structure	Bulkhead, Debris, Marina, Riprap, Unconventional, Wharf
		offshorest	Breakwater, Groin, Marsh Toe
Submerged Aquatic Vegetation (SAV) or Mangroves	These represent potential ecological conflicts and may limit shoreline management options.	SAV	Yes
Tidal marsh	Tidal marsh presence along the shoreline.	marsh_all	Marsh present, Marsh Island, No
Tributary designation	Recommendations may change if shoreline is in a tidal creek/minor tributary.	tribs	Tidal creek

[1] SMM Preferred SHL BMP (v5.1) model looks for these fields.
[2] Attributes listed are those that the model queries. In the event that a field does not have a given attribute, the model moves on.
[3] If the landuse field includes other attributes (i.e. Agriculture, Residential, Pasture, etc, they are ignored).

Appendix C: Selected definitions from the VIMS Shoreline & Tidal Marsh Inventory Glossary

Glossary of Shoreline Features

Agricultural - Land use defined as agricultural includes farm tracts that are cultivated and crop producing. This designation is not applicable for pastureland, which is coded as Grass.

Bank Height – Bank height is the height of the bank from the base to the top. We estimate height from imagery, field inspection, videography, LIDAR or a combination of all data sources.

Bare - Land use defined as bare includes areas void of any vegetation or obvious land use. Bare areas include those that have been cleared for construction.

Beaches - Beaches are persistent sandy shores that are visible during high tides. These features can be wide or thin lenses of sand. Beaches are coded as linear features at the wet/dry line to portray their location only. If a beach does not have a visible wet/dry line, then the line feature is located at the seaward edge of the beach. 'Wide' beaches have at least 25 feet of dry sand persistently visible above high tides. Beach features coded along tidal marsh shorelines are persistent, sandy features located on the water side of tidal marsh vegetation. Sand washed into tidal marshes is not coded as a beach if the marsh vegetation &/or marsh edge is still clearly visible. This classification of beaches along tidal marsh shorelines can include professional judgment.

Boat Ramp - Boat ramps are used to launch vessels of all types. They are usually constructed of concrete, but wood and gravel ramps are also found. Point identification of boat ramps does not discriminate based on type, size, material, or quality of the launch. This inventory attempts to distinguish, when possible, private versus public ramps. Ramps located in privately owned, commercial marinas and residential communities are classified as private.

Breakwaters - Breakwaters are structures that sit offshore and generally occur in a parallel series along the shore. Some breakwaters are attached to the land and are referred to as headland breakwaters. Their purpose is to attenuate and deflect incoming wave energy, protecting the fastland behind and between the structures.

The Shoreline Inventory does not map individual breakwaters. A breakwater "system" is delineated and depicted as a line parallel to the series of breakwaters. Breakwaters are distinguished from marsh toe revetments by the size of the structures and presence of a sand beach instead of a tidal marsh landward from the structures. The classification can include best professional judgment.

Bulkhead - Bulkheads are traditionally treated wood or steel "walls" constructed to offer protection from wave attack. More recently, plastics are being used in the construction.

Bulkheads are vertical structures built slightly seaward of the problem area and backfilled with suitable fill material. They function like a retaining wall, as they are designed to retain upland soil, and prevent erosion of the bank from impinging waves.

From aerial photography, long stretches of bulkheaded shoreline may be observed as an unnaturally straight or angular coast. They are mapped and illustrated as linear features along the shoreline. In rare cases, the bulkhead may be located well inland from the depicted location because the coding follows a digital shoreline.

Commercial - Commercial is a land use classification denoting small commercial operations such as shops, restaurants, as well as campgrounds. These operations are not necessarily water dependent businesses.

Debris – Debris represents nonconforming materials and rubble dumped along the shoreline in a haphazard manner. Debris can include tires, bricks, broken concrete rubble, and railroad ties as examples. The inventory maps Unconventional instead of Debris when the material is deliberately placed for shoreline protection in a manner similar to riprap, bulkhead, and other shoreline protection structures.

Dilapidated Bulkhead – A bulkhead which has failed due to deterioration from age or storm damage is called a dilapidated bulkhead. In many cases the structure may not be able to perform erosion control functions any longer.

Forest Land Use - Forest cover includes deciduous, evergreen, and mixed forest stands. The land use is classified as Forest if there is a dense cover of trees and no other land use category is apparent close to the shoreline, e.g. residential, commercial, industrial, agriculture, etc.

Grass - Grasslands include large unmanaged fields, managed grasslands adjacent to large estates, agriculture tracts reserved for pasture, and grazing. While a general rule of thumb will classify a tract as "grass" if a home sits behind a large tract of grass, a designation of "residential" may be made if there are similar tracts adjacent to each other. This designation can be determined using best professional judgment.

Groinfield - Groins are low profile structures that sit perpendicular to the shore. They can be constructed of rock, timber, or concrete. They are frequently set in a series known as a groinfield, which may extend along a stretch of shoreline for some distance. Unless only a single groin can be detected, this inventory does not delineate individual groins in a groinfield. The groinfield is mapped as one linear feature parallel to the shoreline running along the length of the groin series. When effective, groins will trap sediment moving alongshore.

Industrial - Industrial operations are larger commercial businesses and can include areas where power plants, pulp mills, refineries, etc. are in operation along the coast.

Jetty – A jetty is a structure which is perpendicular to the shoreline and generally located near navigation channels and other places associated with navigation, such as the entrance of tidal creeks and tributaries, boat ramps, or marina boat basins. The function of a jetty is to reduce wave action and prevent sediment transported alongshore from accumulating in navigation areas.

Land Use – Land Use refers to the predominant condition in the immediate riparian area within 100 feet of the adjacent shoreline. While the actual assessment of land use is defined by a distance, the classification can include best professional judgment; particularly when development or other land use activity is setback on the parcel.

Marina - Marinas are denoted as line features in this survey. The infrastructure associated with the marina (e.g. bulkheading, docks, wharfs, etc.) are not digitized individually. However, if a boat ramp is noted it will be surveyed separately and coded as private. Marinas are generally commercial operations. However, smaller scale community docks offering slips and launches for residences are becoming more popular. To distinguish these facilities from commercial marinas, the user could check the riparian land use delineation. If "residential" the marina is most likely a community facility.

Marsh –Tidal marsh at least 20 sq. ft. in area, meeting the definition established in Virginia's Tidal Wetlands Act, and not otherwise considered a marsh island. In all cases, wetland vegetation must be relatively well established, although not necessarily healthy. In previous Tidal Marsh Inventories, marshes were further classified based on morphology and physiographic setting.

Marsh Island – A marsh island is a vegetated wetland that is completely isolated from the mainland and found in open water. A marsh that is surrounded by water due to dissection from small tidal creeks was classified as marsh, not a marsh island.

Marsh toe revetment (aka Marsh sill) –A low revetment placed offshore from an existing marsh or new planted marsh is classified as marsh toe revetment. The structure may include tidal openings to allow for the easy exchange of free swimming organisms during tidal cycles. Marsh toe revetments are mapped as offshore linear features running along the length of the structure. Marsh toe revetments are distinguished from breakwaters by the linear placement and presence of a tidal marsh instead of a sand beach landward from the structure. The classification can include best professional judgment.

Military – A land use classification of Military marks the location of federal military reservations. This classification is generally reserved for the section of the base where active operations and infrastructure exist. Expansive military property adjacent to these areas which are unmanaged forest areas, for example, may be classified as forest land use.

Paved - Paved areas represent roads which run along the shore and generally are located at the top of the banks. Paved also includes parking areas such as parking at boat landings, or commercial facilities.

Residential – Residential land use includes single and multi-family dwellings located near the shoreline.

Riprap (aka Revetments) - Sloped structures constructed with large, heavy stone or other materials placed against the upland bank for erosion protection are classified as riprap. Riprap is mapped as a linear feature along the shoreline. Riprap is also used next to failing bulkheads (bulkhead toe revetments). The inventory maps only riprap when this type of structure is co-located with bulkheads. A similar structure is used to protect the edge of eroding marshes. This use is mapped as marsh toe revetment, not riprap.

Scrub-shrub - Scrub-shrub is a land use class that includes small trees, shrubs, and bushy plants. This land use is easily distinguished during remote sensing compared to Forest and Grass.

Shoreline – generalized term for the land-water interface.

Sand Spit - A narrow coastal landform tied to the upland shoreline at one end resulting from the deposition of sand moved by tides and currents. Spit features are generally sandy and may be dominated by beach, dune, and/or marsh habitats. For inventory purposes, this definition does not include spit features that are developed or have developable upland.

Unconventional - Unconventional features represent segments along the shore where alternative material has been deliberately placed for shoreline protection. Unconventional features may include unique materials placed in a similar manner as riprap or bulkheads, such as engineered pre-cast concrete products. It may also include unique placement or arrangement of conventional materials like riprap that does not fit other structure definitions. The inventory maps Debris instead of Unconventional when the material is haphazardly scattered and not providing any shoreline protection value.

Wharf – Typically describes a shore parallel structure where boats are tied. In this inventory, Wharf is generally associated with large industrial, public or commercial facilities.

Appendix D: Fetch Model

Fetch Model

The Fetch Model was developed to find the longest distance (fetch) over water using vectors radiating in 16 directions from a point on the shoreline. It was later modified to calculate the average maximum fetch based on the values within four quadrants (NE, SE, SW, and NW). Fetch is used as a substitution for wave energy.

The Virginia Shoreline Management Model (SMM) protocol uses fetch calculated from a point every 25 meters along the shoreline, however the user can choose the distance between points. Fetch is classified into three categories: low (0 - 0.5 mile), moderate (0.5 - 2 miles), or high (>2 miles). The longest fetch vector and the average of the fetch vectors by quadrant computed at a given point determine the fetch class for that point.

What is needed:

- Shoreline: It is **highly recommended** to use a copy of the same shoreline that is being used as the base shoreline for the Shoreline Management Model.
- Polygon feature class coded for land and water: The land/water polygon edges **must** match the base shoreline for accurate point placement and fetch determination. Do not restrict the size of the polygon feature class to just the shoreline study area. For example: if the study area is restricted to a county on a river or bay, then there must be enough river/bay beyond the ends of the study shoreline to allow a high fetch classification (Figure D1). See the **Model Step 2: landWater for Study Area** below (under Tools) for help creating this layer.

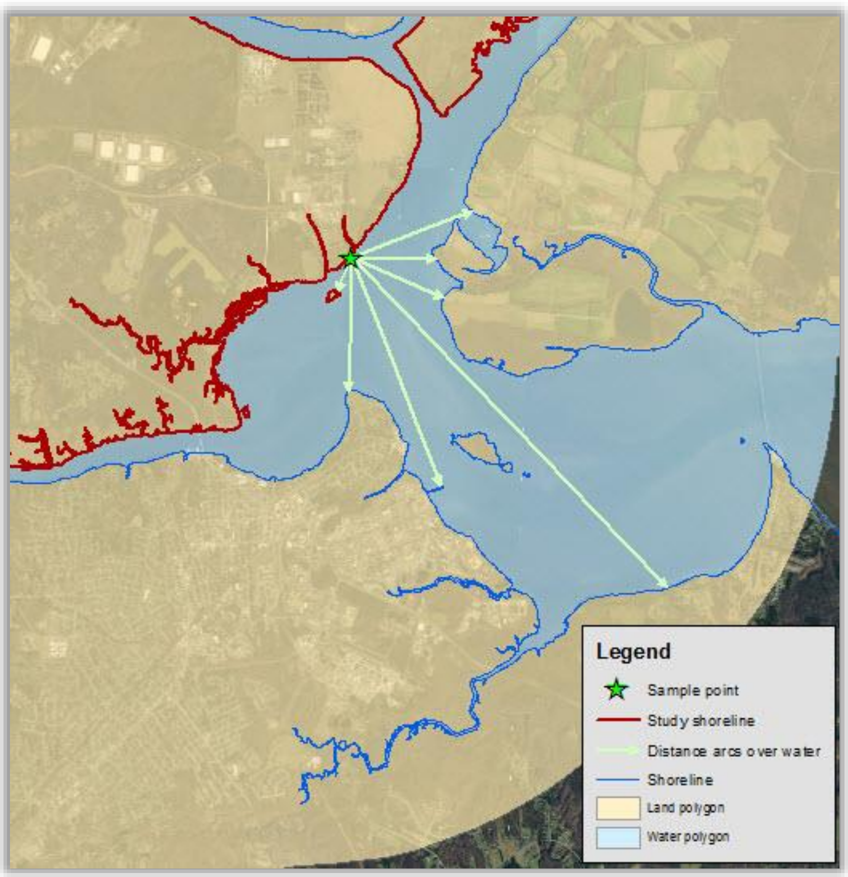


Figure D1. The land/water feature class must allow for a greater than 2 mile fetch to be determined.

Tools:

Several models have been developed to assist with creating the fetch dataset. They are found in the **FetchToolbox**.tbx. This toolbox was created with ArcGIS 10.6 and might not work properly with an older version of ArcGIS. Some manual work is required between certain steps. Italicized text shown in curly braces are variables from the input (i.e. {*name*} = the study area name) or are internally generated (i.e. {*date*} = current date at time of model run) and are used in creating the output file name(s).

1. **Model Step 1: Fetch Prep** (in Fetch toolbox) – This model prepares the shoreline for creating the fetch values by dissolving the shoreline into one arc and constructing points along the shoreline at a set distance. The constructed points are used to split the shoreline. New points representing the center of each split line are generated (using Feature To Point inside = true) and are used for fetch determination (Figure D2). The split lines and their center points share the same ID (or splitID). The ID is used to track and link data to the correct point and line. The final part of this model creates lines in 16 directions for all the center points (Figure D3). It adds XY coordinates and calculates fields for distance, degrees, and direction. The default line length is 10,000 meters (6.21 miles) but can be changed by editing the Distance Expression in the model builder model or the tool panel. It is important to note that the line length must be greater than 3,219 meters (2 miles) to capture high fetch.
    - Model input:
        - *Name*: the study area name. This is used in creating the output file name.

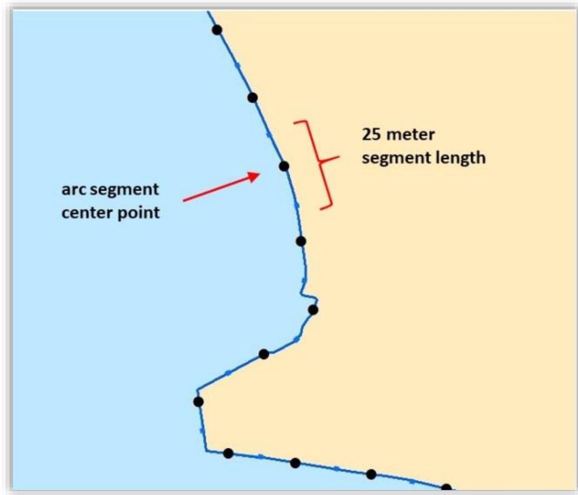


Figure D2. An example of split shoreline and arc center points. Center points are the base points for fetch calculations.

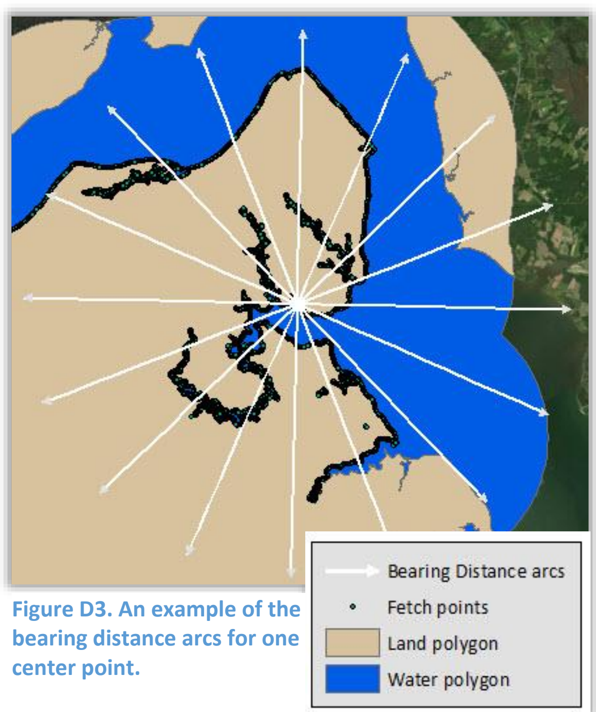


Figure D3. An example of the bearing distance arcs for one center point.

- *Shoreline*: a clean shoreline with no overlaps, intersections, or unnecessary dangles. This will be used for calculating fetch and should be a copy of the base shoreline used for the Shoreline Management Model.
- *Distance*: distance along the shoreline for spacing fetch points. The default value is 25 meters.
- *workspaceGDB*: the location and name of a file geodatabase for processing and placing output.
- *Distance Expression*: length of line for creating vectors from center points on the shoreline. The length of the line must be greater than 3,219 meters or 2 miles to capture high fetch areas. The default value is 10,000 meters (6.21 miles).

- Model output:
  - {*name*}_SplitLineAtPoint: the shoreline divided into sections approximately the length specified in Distance input.
  - {*name*}_SplitLine_center_point_{*date*}: points representing the center of each arc segment. They are used for fetch determination.
  - {*name*}_BearingDistance_arcs_{*date*}: lines radiating in 16 directions from each center point. Line length is defined in Distance Expression input.

2. **Model Step 2: landWater for Study Area** (in Fetch toolbox) - Use this model to help create the land/water polygon layer used in bullet 4 **Model Step 3: Select Water Arcs (script version)** below. Use a regional shoreline if available (Figure D4-A). The model will buffer the study area polygon or shoreline twice (the default buffers are 10,000 and 10,005 meters) (Figure D4-B). The regional shoreline will be clipped with the larger buffer and combined with the smaller buffer using the Feature to Polygon tool to create the land/water polygons layer (Figure D4-C).

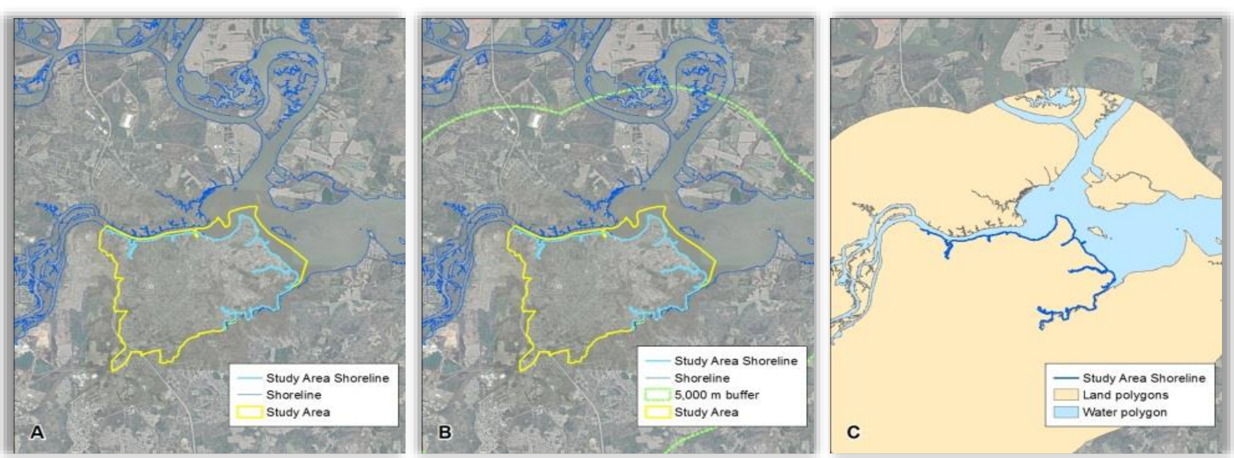


Figure D4. Creating the land/water polygons. A - Regional shoreline (dark blue), study area shoreline (light blue), and study area; B - study area buffered 10,000 meters (green line); C - shoreline and buffered study area combined to create the land/water polygon feature class.

- Inputs:
  - *Name*: study area name.
  - *WorkspaceGDB*: location and name of a file geodatabase for processing and placing output.
  - *Study area boundary or shoreline*: this can be a polygon of the study area or the study area shoreline.
  - *Regional Shoreline arcs*: shoreline file that includes the study area shoreline. Shoreline should include the entire waterway and bay, as it will be used to determine fetch. There should be no dangles except for the ends of the shoreline. The shoreline should extend at least 10,000 m (or the length specified for the bearing distance arcs in **Model Step 1: Fetch Prep**) beyond the study area boundary. This shoreline will be made into a polygon.
  - *Distance value (A)*: distance to buffer the study area. Default is 10,000 meters.
  - *Distance value(A + 5)*: slightly larger buffer distance for study area: add 5 to the previous distance value. Default is 10,005 meters. This buffer is used to clip the regional shoreline. The regional shoreline must extend beyond the first buffer in order for it to become a polygon.
  - *Bearing Distance arcs* created in **Model Step 1: Fetch Prep**: {*name*}_BearingDistance_arcs_{*date*}.
  - *Coordinate System*: a coordinate system must be defined for the water arcs template created in this model. Use the same coordinated system as the other layers in the project.
- Outputs:
  - {*name*}_ LandWaterPoly _{*date*}: land/water polygon feature class
  - {*name*}_water_arcs_template_{*date*}: an empty template for water arcs that will be used in **Model Step 3: Select Water Arcs (script version)**.

3. **Manual Processing** – Add the attributes "land" and "water" to the field **surface** in the feature class {*nam*e}_ LandWaterPoly _{*date*}. The easiest way to do this is to select the polygon(s) that represents water and calculate the field **surface** = "water". Switch the selection, then calculate **surface** = "land".

4. **Model Step 3: Select Water Arcs (script version)** (in Fetch toolbox) - This is an iterative script tool with the python script embedded. Each center point is run through the model individually. For each point the associated Bearing Distance Arcs are intersected with the landWater polygons file created in **Model Step 2: landWater for Study Area**. Only water arcs that share the same point id and intersect a 1 meter buffer around the ID point are selected and appended to the Water Arcs feature layer (Figure D5). This process is time consuming. For large numbers of points, it is recommended to process the total number of points in batches otherwise the script may fail after several hours. The number of points in a batch can vary by machine. Start with 2000, then adjust as needed. **If you have access to ArcPro, run this step using ArcPro with the Fetch_ArcProToolbox and script tool. Processing time is much faster.** To determine the total number of points (the maximum ID value), open the attribute table for {name}_SplitLine_center_point_{date}", right click ID field, select Statistics. The minimum and maximum values for ID are shown in the popup.

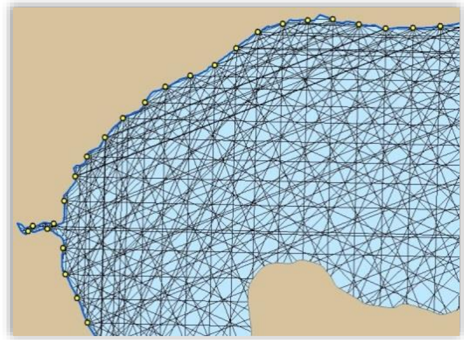


Figure D5. Fetch points shown in yellow with associated water arcs.

   - Inputs:
      - *Name*: study area name.
      - *Workspace GDB*: location and name of a file geodatabase for processing and placing output.
      - *Land/Water polygon*: the land/water feature class {*name*}_ LandWaterPoly _{*date*}.
      - *Bearing Distance Arcs*: the Bearing Distance arcs created in **Model Step 1: Fetch Prep**: {*name*}_BearingDistance_arcs_{*date*}.
      - *Center Points*: points representing the middle of each line segment created in **Model Step 1: Fetch Prep**: {*name*}_SplitLine_center_point_{*date*}.
      - *To Value*: enter the ID number to process to. For example: To process points 1 through 1500; enter 1500 here.
      - *From Value*: enter the ID number to process from. For example: To process points 1 through 1500; enter 1 here.
      - *Water Arcs Template*: the empty template generated in **Model Step 2: landWater for Study Area**: {*name*}_water_arcs_template_{*date*}.
      - *Output Water Arcs Name*: name of the output file that will contain all the selected water arcs. A suggested naming convention is "*name*_water_arcs_*date"* or if run in batches "*name*_water_arcs_*point value range_date*" where *point value range* is the *From Value* and *To Value* entered. For example: "myStudyAreaName_water_arcs_1_2000_m_dd_yyyy".

- Output: the now populated Resulting Water Arcs feature layer specified in the above Input *Output Water Arcs Name*.

5. **Manual Processing** – If **Model Step 3: Select Water Arcs (script version)** was run multiple times, there are likely several water arc feature layers. Combine these into one final water arc feature layer by copying one layer, giving it a new final name (ex. myStudyAreaName_allWaterArcs_ m_dd_yyyy), then appending the remaining layers.
6. **Model Step 4: Fetch Analysis** (in Fetch toolbox) – This model has three parts (originally 3 separate models). An explanation for all the attributes created in the final two files is found below under Definitions.
    - Part A finds the maximum arc length and direction for each point along the shoreline using summary statistics. A Pivot table is created so that each point has a row with columns for the 16 directions (Figure D6).

SampleTest_selected_water_arcs_Apr_29_2020_PT

ID	e	ene	ese	n	ne	nne	nnw	nw	s	se	sse	ssw	sw	w	wnw	wsw	MAX_Shape_	maxDir
1	0	0	194.76	0	0	0	0	0	5106.59	1879.7	5007.37	5381.73	5598.27	610.7	0	895.21	5598.27	sw
2	0	0	0	0	0	0	0	0	5158.44	2071.82	5079.27	5395.62	5569.32	139.07	33.76	678.65	5569.32	sw
3	0	0	0	0	0	0	0	0	5145.37	2013.18	5061.08	5391.76	5576.26	465.98	60.85	697.28	5576.26	sw
4	0	0	0	0	0	0	0	0	5132.09	1957.06	5042.71	5387.72	5583.11	539.04	87.92	762.47	5583.11	sw
5	0	0	0	0	0	0	0	0	5118.87	1914	5024.37	5383.79	5589.87	577.19	114.8	846.49	5589.87	sw
6	0	0	0	0	0	0	0	501	5220.92	0	5200.91	5352.5	955.91	126.22	144.48	306.19	5352.5	ssw
7	0	0	0	0	0	0	0	520.47	5198.09	4529.19	5176.31	5336.52	1053.32	200.39	156.29	368.96	5336.52	ssw

Figure D6. Example of the fields in a pivot table from Part A of the model Model Step 4: Fetch Analysis.

    - Part B determines if the pivot table has any Ids that occur more than once and removes the duplicates. The pivot table data is then joined to the split lines feature layer based on the unique **ID** field. A new field, **exposure**, is added and given the following values based on the maximum fetch distance for each point (low = 0 - 0.5 mile (<804.67 meters), moderate = 0.5 - 2 miles (804.68 - 3,218.68 meters), or high = >2 miles (>3,218.69 meters)).

- Part C seeks to modify the maximum single line fetch results in the **exposure** field by calculating the average quadrant fetch (Figure D7). Calculating the average fetch by quadrant helps to eliminate the errors associated with using a single line maximum distance. There are situations where a fetch point may be located in a sheltered creek but one bearing distance arc might be positioned to extend into a major tributary, thus causing the point and the associated shoreline to be coded with a higher fetch classification. The model calculates the average quadrant fetch by utilizing the data previously calculated:
    - The values from the 16 compass directions are grouped into 4 quadrants (NE, SE, SW, and NW). The values for n, e, s, and w are counted twice (ex. N is part of NE and NW)
    - The number of water arcs represented in each quadrant are counted and stored in the fields **NE_Count**, **SW_Count**, **SE_Count**, and **NW_Count**.
    - The average quadrant fetch is calculated by summing the length of the water arcs in each quadrant and dividing by the quadrant count. The averages are stored in the fields **NE_Mean**, **SW_Mean**, **SE_Mean**, and **NW_Mean**.

Field	Value
FID	105
Shape	Polyline
shoreline	shl
splitID	105
ID	105
e	106.813799
ene	115.285407
ese	122.105669
n	344.444387
ne	194.431448
nne	160.537477
nnw	0
nw	0
s	0
se	4729.607647
sse	5350.959625
ssw	0
sw	0
w	0
wnw	0
wsw	0
MAX_Shape_Length	5350.959625
maxDir	sse
exposure	high
Shape_Length	24.999938
NE_Count	5
SW_Count	0
SE_Count	4
NW_Count	1
NE_Mean	184.302503
SW_Mean	<null>
SE_Mean	2577.371685
NW_Mean	344.444387
MaxQuadFetch	2577.371685
MaxQuadFetchCode	moderate
MaxQuadDir	SE
QuadCountOne	NW
OneIsMax	<null>
MaxQuadFetchOriginal	2577.371685
MaxQuadFetchCodeOriginal	moderate
MaxQuadDirOriginal	SE

Figure D7. Example of the attribute table from the Fetch with Quad Analysis feature layer. The straight line distance (meters) over water from a point on the shoreline to another shoreline is given for each of the 16 directions. Fetch is also calculated by quadrant.

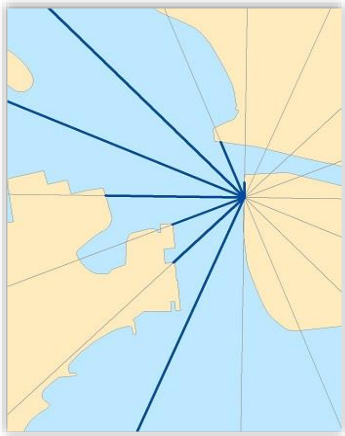


Figure D8-A. Selected water arcs for one fetch point.

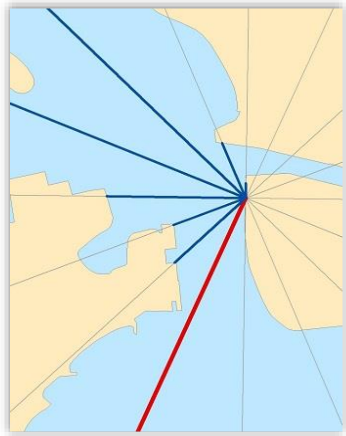


Figure D8-B. The longest single fetch line is 5,501 meters (3.42 miles) and is classified as high fetch (red line).

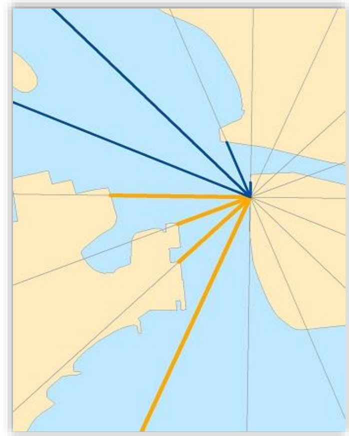


Figure D8-C. Analysis by quadrant results in a maximum average quadrant fetch of 1,395 meters (0.9 miles) or a moderate fetch (orange lines).

- The maximum quadrant fetch is determined and placed in the field **MaxQFetch (alias: MaxQuadFetch**). The fetch classification (low, moderate, high) is placed in the **MxQExpCode (alias: MaxQuadFetchCode)** field and the quadrant direction (NE, SE, SW, NW) containing the maximum averaged fetch is placed in the **MaxQuadDir** field.
- It is possible to have a maximum quad fetch that is based on one water arc. This is not desired as it negates the purpose of averaging the water arcs by quadrant and thus it is considered an outlier. If encountered, the model corrects for this by using the next or second highest mean quadrant fetch. The original maximum quadrant fetch information is saved for reference in the fields **MxQFetchOld (alias: MaxQuadFetchOriginal)**, **MxQExpCodeO (alias: MaxQuadFetchCodeOriginal)**, and **MaxQDirO (alias: MaxQuadDirOriginal)**.
- Both the highest and the second highest average quadrant fetch can be skewed by one or two high fetch arcs in a low fetch environment causing the fetch value to be 'high'. Currently the fetch model does not adjust for this condition if there are more than two arcs present. It is recommended that the user qa/qc the output and manually correct questionable areas (see step 7 below).
- For the maximum single line fetch classification, use the value in the **exposure** field. For the maximum average quadrant fetch classification, use the value in the **MxQExpCode (alias: MaxQuadFetchCode)** field. See Figures D8-A, D8-B, and D8-C for a visualization of water arcs, and the difference between the single line maximum fetch, and quad analysis

fetch for one point. The SMM uses the maximum average quadrant fetch classification.

- Inputs:
  - *Name*: study area name.
  - *Water Arcs*: the user named water arcs feature layer created in **Model Step 3** (bullet 4 above) or, if **Model Step 3** was run multiple times, the name of the combined final water arc feature layer.
  - *Split Shoreline (i.e. SplitLineAtPoint)*: the split shoreline created in **Model Step 1: Fetch Prep**: {*name*}_SplitLineAtPoint_{*date*}.
  - *Center Points (i.e. SplitLine_center_point)*: the center points representing the middle of each line segment created in **Model Step 1: Fetch Prep**: {*name*}_SplitLine_center_point_{*date*}.
  - *scratchGDB*: location and name of a scratch file geodatabase for processing data.
  - *workspaceGDB*: location and name of a file geodatabase for processing and placing final output.
  - *Output Name for Fetch with Quad Analysis Point Feature layer*: the name of the output center point feature layer that contains all the fetch related data. Suggested naming convention: myStudyAreaName_Fetch_withQuadAnaysis_Points_todaysDate_Final.

Figure D9. Shoreline classified for fetch (low: <0.5 mile, moderate: 0.5 - 2 miles, high: >2 miles)

  - *Output Name for Fetch with Quad Analysis Arc Feature layer*: the name of the output split shoreline feature layer that contains all the fetch related data. Suggested naming convention: myStudyAreaName_Fetch_withQuadAnalysis_Arcs_todaysDate_Final.
- Output:
  - The output center point feature layer that contains all the fetch related data (named in Input).
  - The output split shoreline feature layer that contains all the fetch related data (named in Input) (Figure D9).

7. **Final step - Manual Processing: Dissolve Fetch for use in the Shoreline Management Model (SMM)**
    - Dissolve the Fetch_withQuadAnalysis arc feature layer on **MxQExpCode** (alias: **MaxQuadFetchCode).** Make sure the Multipart features box at the bottom of the tool is unchecked.
    - Review the results by looking for short segments of fetch (ex. Point spacing was set at 25 meters. Look for arcs 25m or less and fix as needed). Look for areas where the shoreline makes a tight turn. Part of the shoreline might need to be recoded. It is ok to reclassify fetch if the surrounding arcs are primarily one classification (i.e. low fetch surrounded by long stretches of high fetch).

Things to Consider

Potential Problems:

This model is not perfect. There will be places where the shoreline is curved and its classification is different from the surrounding arcs. Remember, the point location determines the fetch which is transferred to the associated line segment. Notice in Figure D10 the white low fetch shoreline and distance arcs. Fetch has been determined for a point that is sheltered but part of the associated line segment wraps around a land protrusion into a high fetch area. The gray moderate fetch points are somewhat sheltered. The shorter distance arcs in the quadrant have caused the classification to change from high (the value of the maximum single line fetch) to moderate (the maximum averaged quadrant fetch). These small segments can be considered outliers and may be dissolved into their larger neighbors or the classification can be modified in a new field in the attribute table. It would make sense, in Figure D10's case, to reclassify the low fetch and the two moderate fetch arcs as high fetch. There is also an example of this problem in Figure D9 (lower left corner) where the shoreline is classified as moderate but surrounded by high fetch. Review the output for outliers and fix as desired or if using in the SMM, see bullet 7 **Final Step – Manual Processing** above.

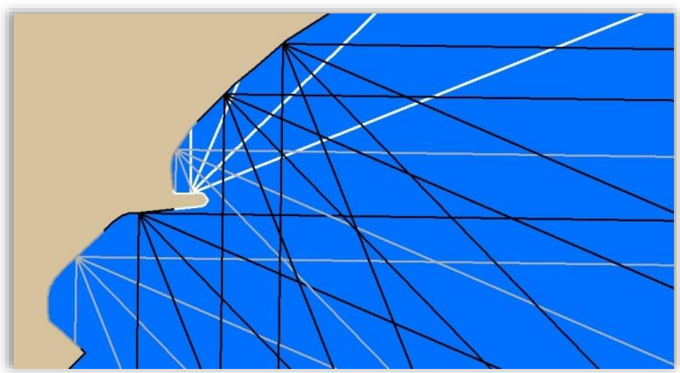


Figure D10. An example of a predominantly high (black) fetch shoreline with low (white) and moderate (gray) fetch. The lines radiating from the shore indicate the arcs in the maximum average fetch quadrant for the fetch point.

Definitions for the Fetch with Quad Analysis arcs and points attribute tables:

ID and **splitID** – unique identification number for arcs and points. The center point of an arc segment and the arc segment share the same ID and splitID. The ID is used during the iteration process and for joining information back to the point or arc.

e - distance over water to shoreline to the East
ene - distance over water to shoreline to the East North East
ese - distance over water to shoreline to the East South East
n - distance over water to shoreline to the North
ne - distance over water to shoreline to the North East
nne - distance over water to shoreline to the North North East
nnw - distance over water to shoreline to the North North West
nw - distance over water to shoreline to the North West
s - distance over water to shoreline to the South
se - distance over water to shoreline to the South East
sse - distance over water to shoreline to the South South East
ssw - distance over water to shoreline to the South South West
sw - distance over water to shoreline to the South West
w - distance over water to shoreline to the West
wnw - distance over water to shoreline to the West North West
wsw - distance over water to shoreline to the West South West
MAX_Shape_Length – maximum single line fetch distance
maxDir – maximum single line distance direction
exposure - Exposure is the maximum single line distance from a point on the shoreline to another shoreline across water. Fetch was measured in 16 directions. Exposure is classified as low (<804.67 m or 0.5 mi), moderate (804.67 - 3218.69 m or 0.5 - 2 mi), and high (> 3218.69 m or >2 mi).
NE_Count - number of water arcs within NE quadrant (includes n, nne, ne, ene, e).
SW_Count - number of water arcs within SW quadrant (includes s, ssw, sw, wsw, w).
SE_Count - number of water arcs within SE quadrant (includes s, sse, se, ese, e).
NW_Count - number of water arcs within NW quadrant (includes n, nnw, nw, wnw, w)
NE_Mean - The average water arc length (m) in the NE quadrant
SW_Mean - The average water arc length (m) in the SW quadrant
SE_Mean - The average water arc length (m) in the SE quadrant
NW_Mean - The average water arc length (m) in the NW quadrant
MaxQFetch (alias: MaxQuadFetch) - The maximum quadrant fetch (m)
MxQExpCode (alias: MaxQuadFetchCode) - The maximum quadrant fetch distance is classified as low (<804.67 m or 0.5 mi), moderate (804.67 - 3218.69 m or 0.5 - 2 mi), and high (>3218.69 m or >2 mi).
MaxQuadDir - The quadrant (NE, SW, SE, NW) with the maximum average fetch.
QuadCnt1 (alias: QuadCountOne) - It is possible to have a maximum quad fetch that is based on one water arc. If encountered, this is corrected by using the second highest fetch. QuadCnt1 indicates the quadrant containing the single count fetch value.
OneIsMax - If the maximum quad fetch is from a quad with only one water arc, then use the second highest quad fetch. Value is 'Use second highest quad fetch' if highest average quad fetch resulted from one water arc, otherwise value is NULL.
MxQFetchOld (alias: MaxQuadFetchOriginal) - It is possible to have a maximum quad fetch that is based on one water arc. If encountered, this is corrected by using the second highest fetch. This field contains the original maximum quadrant fetch distance.

MxQExpCodeO (alias: MaxQuadFetchCodeOriginal) - It is possible to have a maximum quad fetch that is based on one water arc. If encountered, this is corrected by using the second highest fetch. This field contains the original maximum quadrant fetch code (low, moderate, high).

MaxQDirO (alias: MaxQuadDirOriginal) - It is possible to have a maximum quad fetch that is based on one water arc. If encountered, this is corrected by using the second highest fetch. This field contains the original maximum fetch quadrant.

Appendix E: Shoreline Management Model (SMM) Flow Charts

Chart E1: Flow Chart for Special Considerations

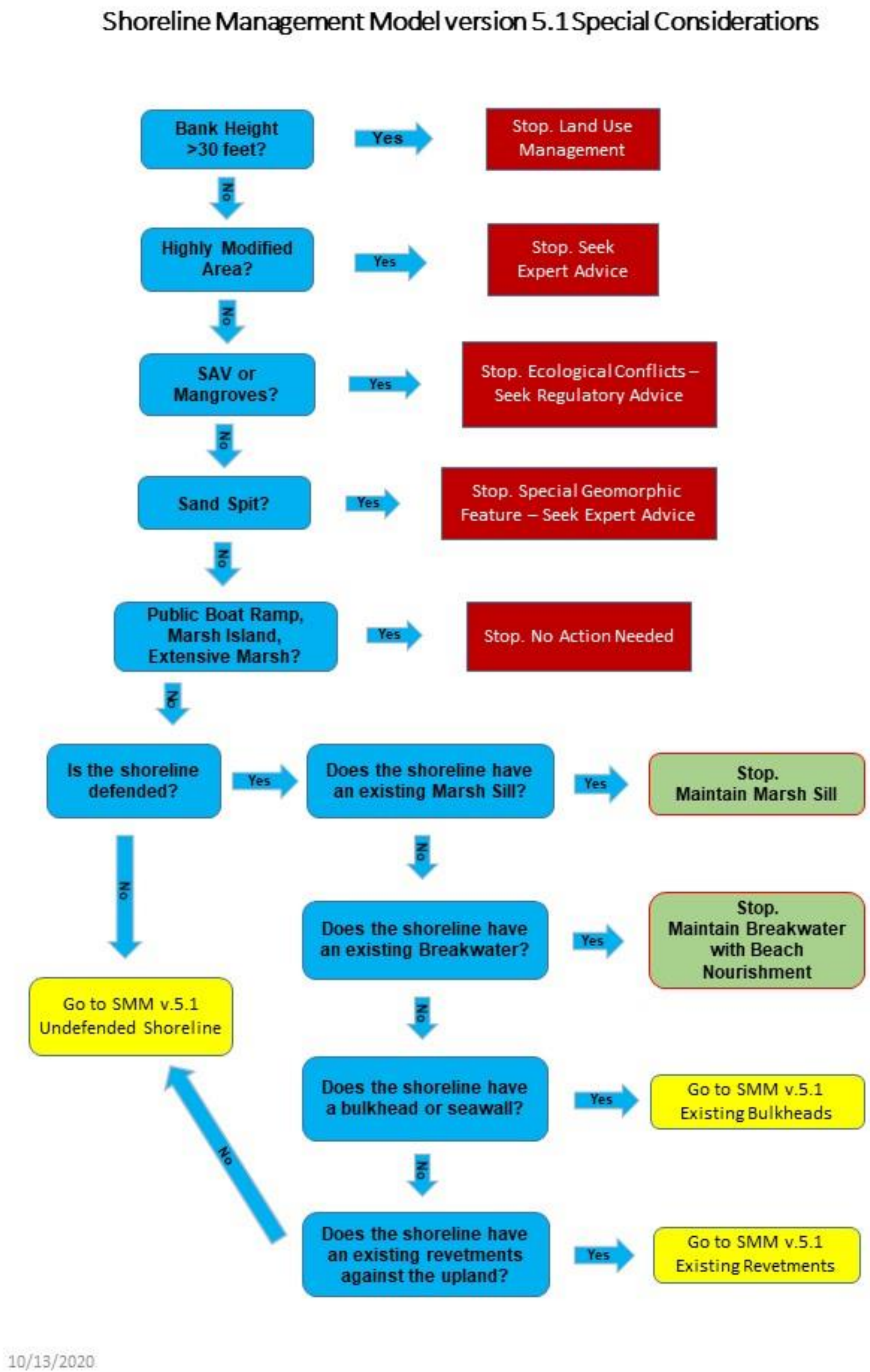
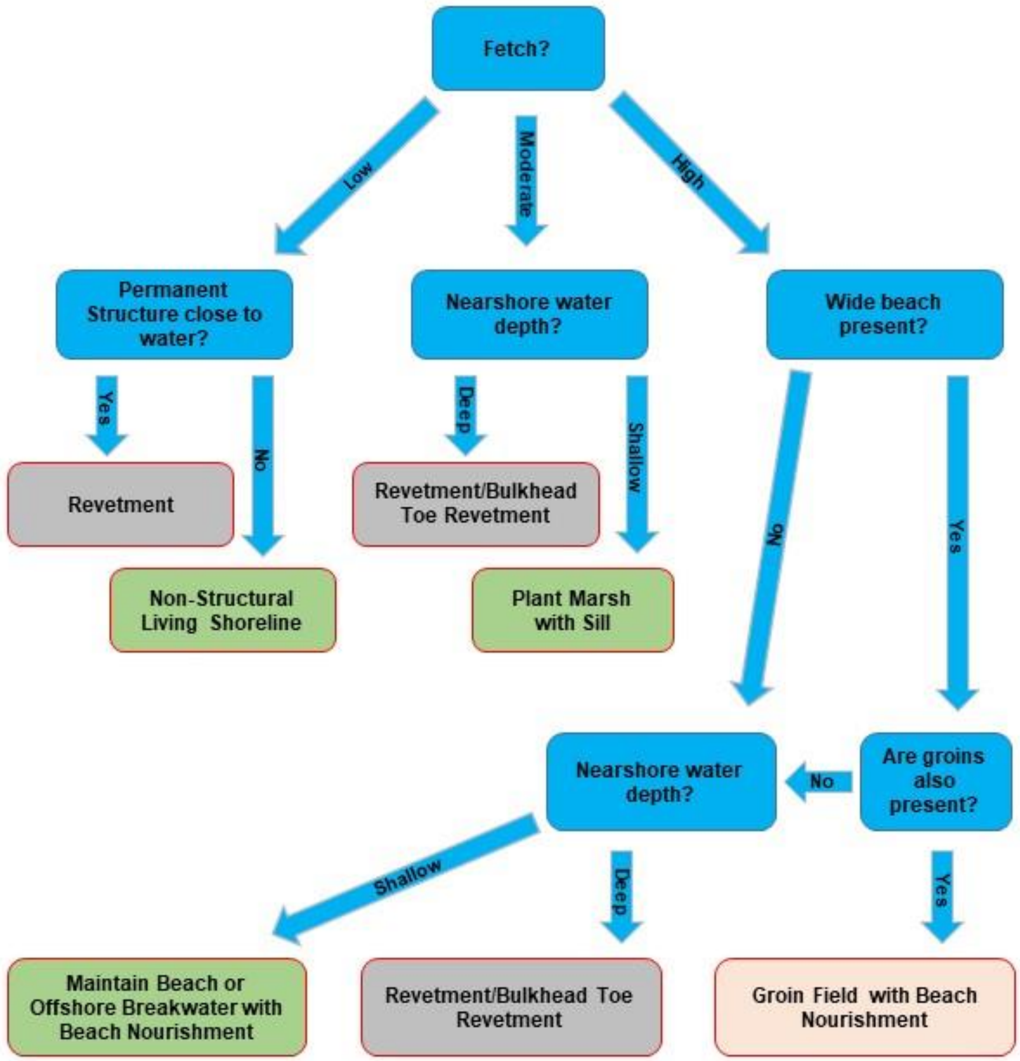


Chart E2: Flow Chart for Existing Bulkhead

Shoreline Management Model version 5.1 for Shoreline with Existing Bulkheads



10/13/2020

Chart E3: Flow Chart for Existing Revetment

Shoreline Management Model version 5.1 for Shoreline with Existing Revetments

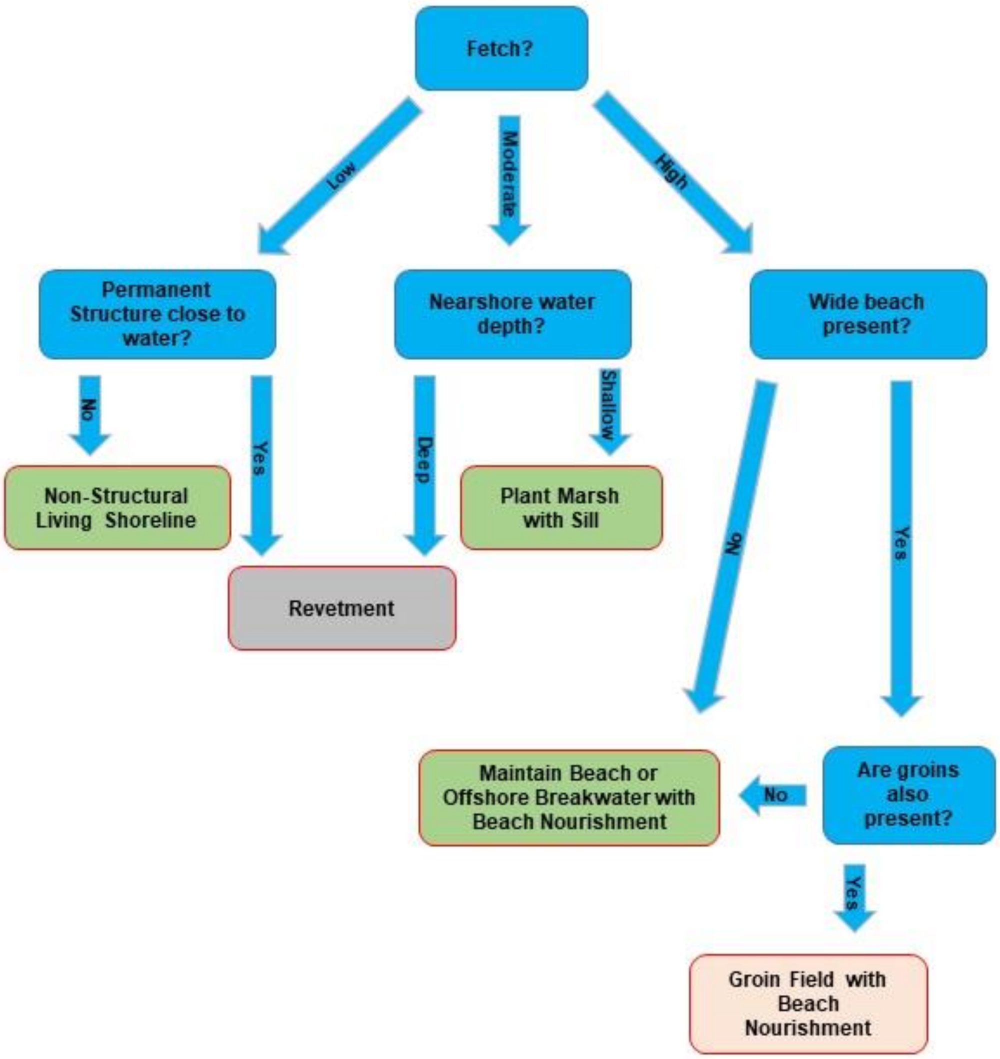


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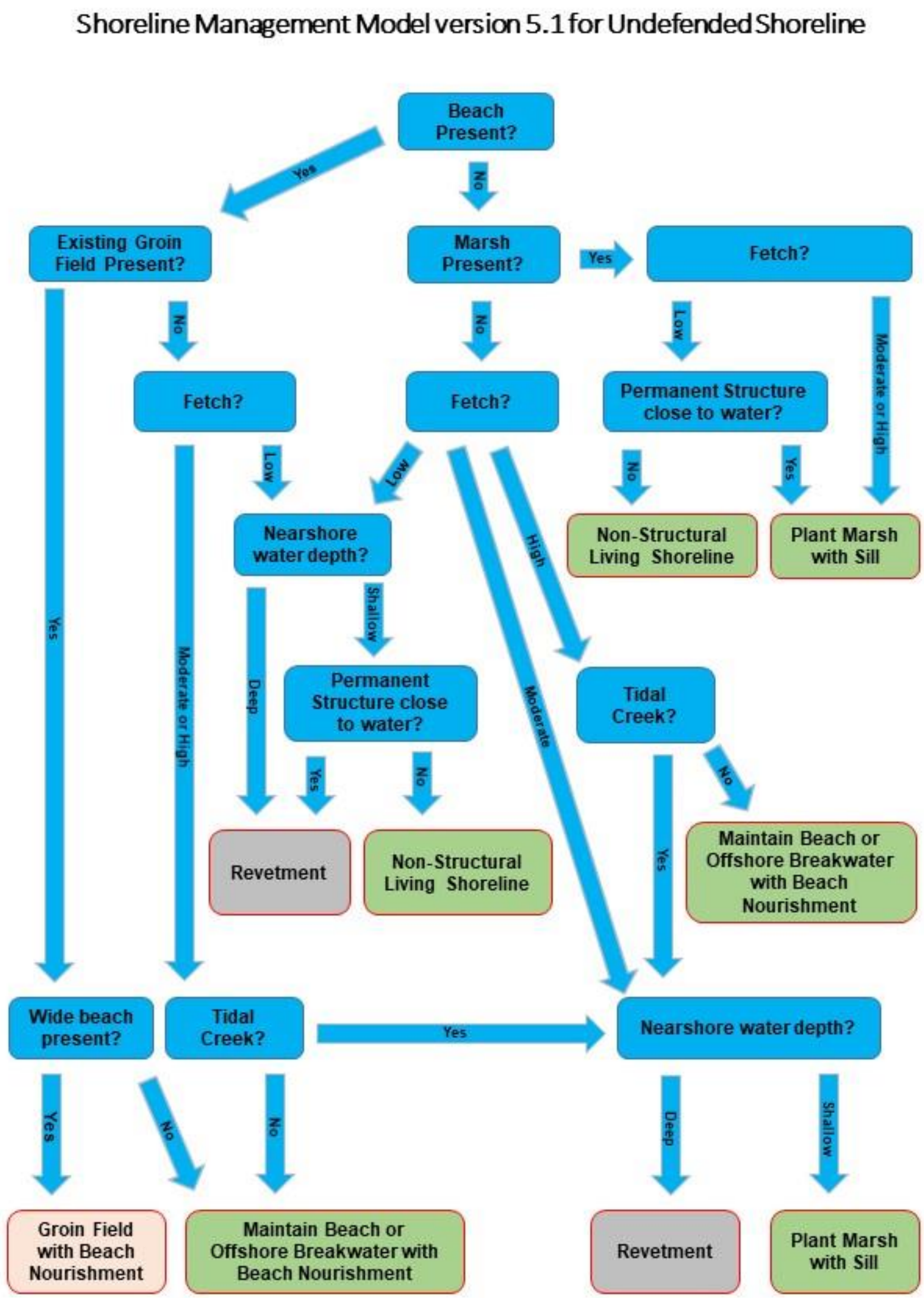
Chart E4: Flow Chart for Undefended Shoreline



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