Interpolating Elevations: Proposed Method for Conducting Overlay Analysis of GIS Data on Coastal Elevations, Shore Protection, and Wetland Accretion

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1.2. Interpolating Elevations: Proposed Method for Conducting Overlay Analysis of GIS Data on Coastal Elevations, Shore Protection, and Wetland Accretion

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1.2.1 Introduction

Section 1.1 (by Titus and Wang) of this report and the metadata provided with the elevation Geographic Information System (GIS) data document the methods used to generate state-specific GIS data sets of elevation relative to spring high water (Jones, 2008, Jones et al., 2008).[1]. Titus and Hudgens (unpublished analysis) generated data on the likelihood of shoreline protection. In that analysis, the authors attempted to divide all dry land below the 20-ft (NGVD29) contour—as well as all land within 1,000 ft of the shore regardless of elevation—into one of four categories representing the likelihood of shore protection: shore protection almost certain (PC), shore protection likely (PL), shore protection unlikely (PU), and no protection (NP). Using these two data sets, this section shows the methods used to quantify the area of land close to sea level by shore by various elevation increments and protection category. However, because the results of the shore protection analysis are unpublished, we report only the elevation statistics.

Using the elevation data discussed in Section 1.1, and wetland data compiled from a combination of the U.S. Fish and Wildlife Service National Wetlands Inventory (NWI) data and state-specific wetlands data, we created summary tables, which we explain in Section 1.2.2. Those tables provide the area of land within 50 cm elevation increments at the state level of aggregation and are provided in the appendix to this section.[2] The versions with 0.1-ft increments were used by the uncertainty analysis described in Section 1.3.[3]

Our analysis (as well that of Section 2.1) had to confront the fact that the attempt to assign a shore protection category to all dry land close to sea level was not entirely successful. In some cases, the state-specific studies failed to assign land to one of these four categories because (for example) land use data were unavailable. This happened particularly at the seaward boundary of their study areas. They called these areas "not considered" (NC).

Section 1.2.3 discusses several supplemental analyses. Using a tide range GIS surface generated by Titus and Wang, along with the dry land elevation and tidal wetlands data, we generated additional sets of tables[4]. Some of these tables estimate the area of dry land within one-half tide range above spring high water. Assuming that tidal wetlands are within one-half tide range below spring high water (i.e., between mean sea level and spring high water), these tables give us the ratio of slopes above and below spring high water, that is, the ratio of existing wetlands to the potential for new wetland creation. Other tables estimate the area of potential tidal wetland loss by estimating the portion of existing tidal wetlands that would fall below mean sea level if sea level were to rise a particular magnitude, with and without wetland accretion.

1.2.2. Estimating Land Area by Elevation Increment and Protection Category

We estimated the land area by protection category using several steps. First, to summarize the protection data by elevation, it was necessary

[1] Titus and Wang in Section 1.1 generated the DEM data by interpolating elevations from a variety of source data sets for the eight states covered by this report. To make the elevations relative to SHW, they used the National Ocean Service's (NOS) estimated tide ranges, NOS estimated sea level trends, and the NOS published benchmark sheets along with National Geodetic Survey North American Vertical Datum Conversion Utility (VERTCON) program to convert the mean tide level (MTL) above NAVD88 to NGVD29. See "General Approach" of Section 1.1 for a brief overview. Jones (2007) created a revised dataset for North Carolina.

[2] Additionally, subregional and regional low and high estimates of land area are provided in Appendices B and C, respectively, to Section 1.3.

[3]. Horizontal and vertical accuracy issues are addressed in Section 1.3. An additional discussion on reporting data at 0.1 ft increments is provided here. The increments used imperial rather than metric units because the interpolation is facilitated when the contour interval (mostly in imperial units as well) are an integer multiple of the increment.

[4]These tables are not provided as the likelihood of shoreline protection data from which they were generated are based on an unpublished analysis.

to first convert the shore protection GIS data from a vector format (i.e., polygons) into a raster (or grid) format to match the digital elevation model (DEM) data. As part of this step, we developed a procedure to lessen the amount of land classified as “not considered” (which would otherwise be enhanced by the vector-to-raster conversion process). Once this was done, we were able to quantify the amount of land at specific elevations by protection category. To improve our elevation-specific area estimates, we tailored our approach to the accuracy of the source data—interpolating lower accuracy data and using the area estimates directly from the DEM for those with higher accuracies. We then provided summary results in tables “rolled up” by different elevations. The appendix to this section provides county-by-county results for the analysis we describe in this section. Section 1.3 provides additional information about variations in data quality and the associated appendices also provides results, by state, subregion, and region.

Converting shore protection polygons to grid

General approach

In converting vector data into grid format, several considerations need to be taken into account. Spatially, the size of the raster cell generated should be based on the estimated accuracy or minimum mapping unit, as well as whether the output raster data will be combined with other data sets. We generated our raster based on a 30-m cell size to match our DEM data. In addition, this cell size was not inappropriate given the source of the information. Similarly, because the cell boundaries will inevitably cross the vector polygons (cell boundaries rarely coincide exactly to vector polygon outlines of the input data), different approaches can be taken to transfer the attributes of a particular polygon to the output raster cells. The attribute assignment can be based on the centroid of the cell (i.e., the attribute of the polygon is assigned to the raster cell whose center it encapsulates), on the polygon covering the majority of the cell (or the combined area of multiple polygons with the same attribute), or through attribute priority (i.e., if any portion of the polygon has a certain attribute, the cell is assigned that attribute). We used a combination of approaches in our analysis. In our initial conversion, we used a centroid approach. In subsequent reclassification, we assigned attributes based on attribute values (i.e., priority approach), and attributed remaining cells based on proximity of neighboring cells. The specific methods used are described below.

Approach for avoiding the “not considered” designation

One of our main goals was to limit the amount of land classified as “not considered.” The original shapefile dataset had numerous narrow polygons along the shore classified as “not considered.” Usually, those polygons were not visible in the county-scale maps that county officials and the authors had closely examined, which the state-specific chapters of this report display. Usually, the polygons of “not considered” resulted because the planning data used in the state-specific analyses did not extend all the way out to the wetland/dryland boundary defined by the wetlands data set we were using. This occurred for at least two reasons: In some cases, the planning data were more precise than the old NWI wetlands data we used; in other cases, the planning study had used very coarse land use data. Whenever the land use data extended seaward of the wetland boundary, the use of wetlands data as a “mask” resolved the data conflict. But if the land use data did not extend all the way to the wetlands or open water, we were left with dry land with no protection category (i.e., not considered).

A related problem was that the shore protection polygons created by the state-specific studies sometimes labeled lands as “wetlands” even though that study ostensibly categorized dry land by likelihood of shore protection and relied on a wetlands data set to define wetlands. In several cases—particularly the Hampton Roads area of Virginia and some Maryland counties, local data defined wetlands in areas that the statewide data set classified as being dry. The study authors wanted the maps to show those areas as wetlands—a reasonable objective given that the local planning data that form the basis of the studies treated it as wetlands. But we wanted our results to be consistent with the Section 1.1 estimates of dry land and wetlands that relied on the wetlands data set rather than local planning data.

We converted the shapefile planning data according to the general process shown in Figure 1.2.1. Figure 1.2.2 shows an example of the process using GIS data. Specifically, we recoded any polygons designated as a wetland in the source protection data as protection unlikely. We then clipped the data to the extent of the study area boundary and excluded any polygons that overlapped with tidal wetland or tidal open water as determined by the state-specific wetlands layers. Additionally, we coded any cells without an attribute as NC. We then converted the protection data from a vector (i.e., polygon) format to raster (grid-based) format with a cell size of 30 meters to match the resolution of the elevation data.[5] Attributes were assigned to the cells based on whichever polygon from the source vector data covered the centroid of the output raster cell. This approach was preferable over dominant category, because in some cases there are narrow environmental buffers along the shore. The buffers are PL or PU along an area where the rest of the land is PC. The buffers are too narrow to be the dominant shore protection category in a cell. Thus, using dominant category would create a downward bias for that category, while picking the centroid would be expected to yield area estimates similar to the actual area estimate.

We then subset the raster layer to elevations less than 20 feet and converted the NC cells back into a vector format. The result was a vector polygon layer of NC cells. The resulting polygons were then overlaid with the original polygon vector shoreline protection data, and the NC polygons were assigned the same attribute as any overlapping polygons. Only individual 30-m

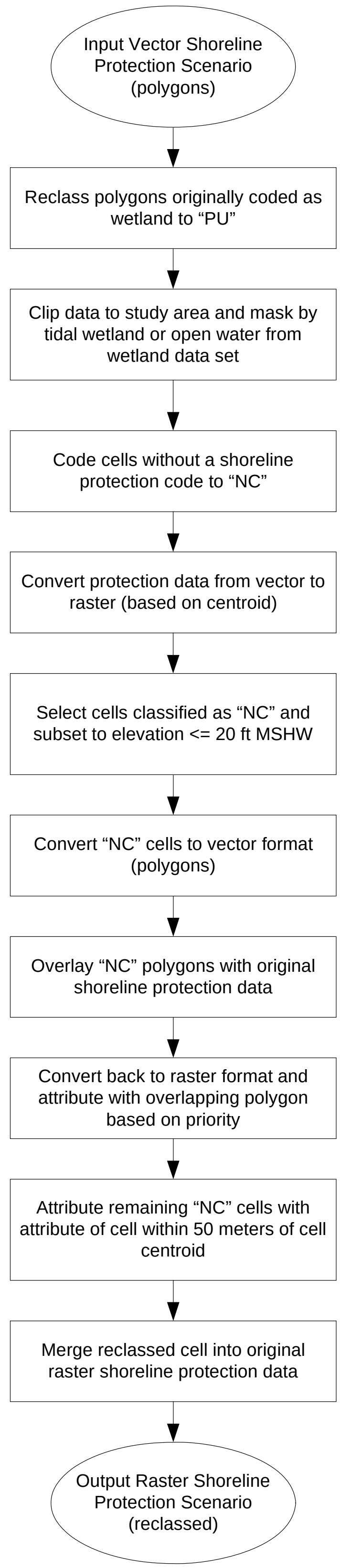

Figure 1.2.1. Approach used to reclassify not-considered shoreline protection scenario cells.

5. The conversion from vector to raster was conducted using ArcGIS Spatial Analyst extension (ESRI, 2006).

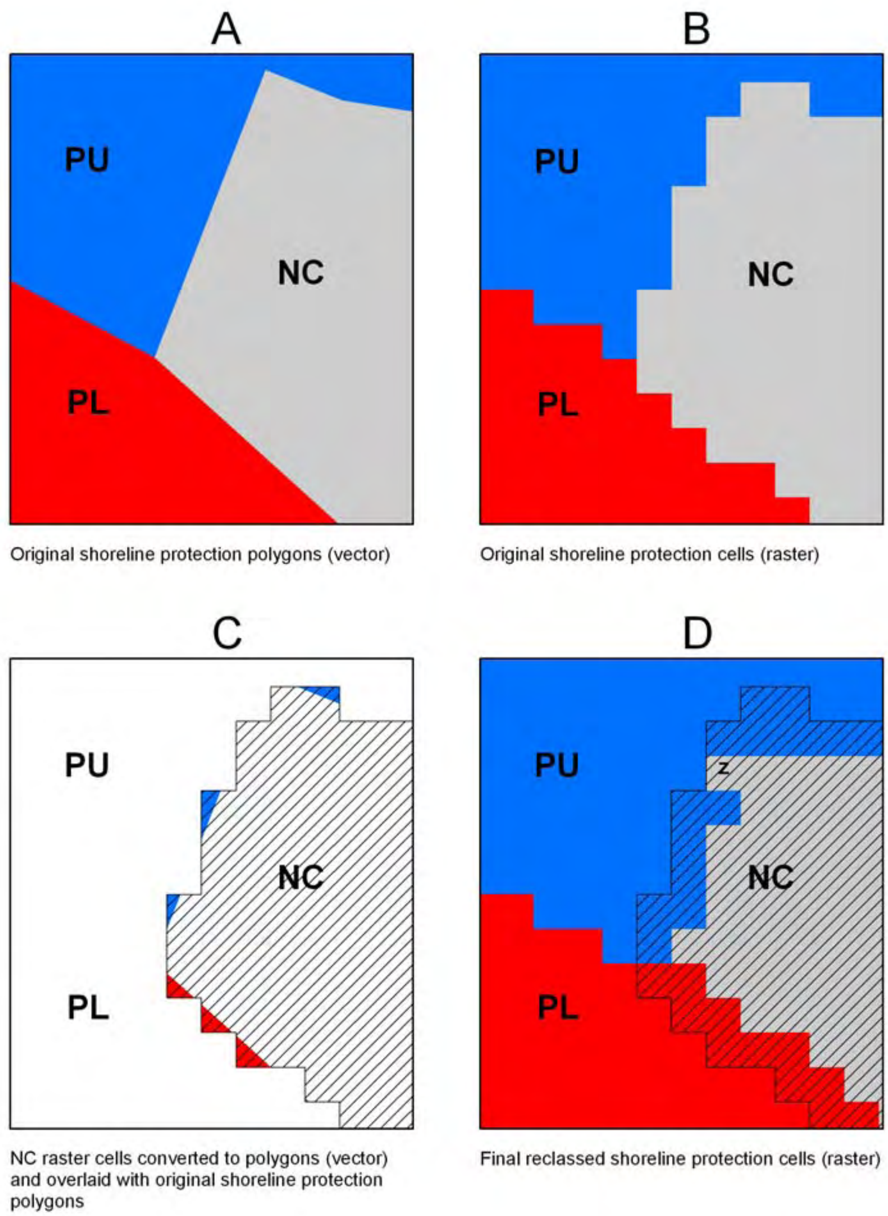

Figure 1.2.2. Graphical Representation Showing How Original Shoreline Protection Scenario Data in Vector Format was Reclassified to Reduce the Amount of "Not Considered" (NC) Lands.

cells of NC were recoded. Where multiple polygons overlapped with the NC cells, and none crossed the cell centroid, attribute assignment was based on the following priority: NP, PU, PL, and PC. We used this priority rule instead of picking the category that accounted for the greatest portion of the cell because such cells are generally along the water or wetlands (and assumed to be water or wetlands in the land use data set that gave rise to the shore protection classifications). If any of the overlapping cells did not contain any of these categories, the cell remained NC. Finally, any remaining NC cells were assigned the attribute of any other non-NC cells within a maximum distance of 50 meters (centroid to centroid).[6] All other NC cells remained NC. Finally, we merged the

6. Given the cell size of 30 meters, this effectively means that NC cells would be attributed the same as any adjacent (including cells diagonal to the NC cell) non-NC cell. Note also the cell shown by “z” (panel D) remained NC because it fell entirely within tidal wetlands.

reclassified NC layer with the original raster version of the protection data.

Estimating area of land at specific elevations by shore protection category

Combining elevation, protection, wetland, quadrangle, and county data

Our first step was to segment the final DEM data (see Section 1.1) by the source data from which they were derived.[7] We needed to do this for two reasons. First, the interpolations (discussed in the following section) depended on contour interval. Second, one of the expected uses of our output was the creation of high and low estimates; and the uncertainty would be a function of the data quality (see Section 1.3).

Using the same resolution and projection as the elevation data, we generated raster data sets from the following vector GIS layers: USGS 1:24K quadrangles, county boundaries, and source data extent polygons, as well as a nontidal open water (NO) and nontidal wetlands (NW) layer generated from wetlands data from each state data set. We then combined these raster layers with the elevation data and reclassified shore protection data to generate a composite raster layer with attributes from each source data set (e.g., quadrangle, county, wetland type, source data name, elevation, and shoreline protection scenario). We calculated a final protection scenario attribute field from the shore protection category and NO/NW wetlands data, with priority assigned to the wetlands data. The resulting protection scenario field contained one of the following categories: NO, NW, PC, PL, PU, NP, or NC.

7. USGS data varied by 24K quadrangle, whereas other data sets were provided by county or other boundary.

Areas with source elevations of 1-m contours or worse

As noted in Section 1.1, the ESRI GRID extension function TOPOGRID (ESRI, 2006) that was used to interpolate contours into a DEM was spatially biased toward each input contour. The resultant DEM data therefore contained "plateaus" on either side of the source contours. Given our objective of estimating the area of land within elevation increments of 50 cm, this was not a significant problem for our source data sets with contour intervals of 2 feet (60 cm) or better. But it presented a significant bias in the lower accuracy data sets. As in Section 1.1, we corrected for this distortion in the lower accuracy data sets by redistributing the land area evenly into 0.1-ft elevation bins between each source contour elevation interval (e.g., for each 5 feet for data with a 5-ft contour interval) for each combination of quadrangle, county, and protection scenario.[8] For the first contour, the area between SHW and the first contour (e.g., 5-ft NGVD) was used. We calculated the SHW value (relative to the NGVD29 vertical datum) by overlaying the SHW surface generated by Titus and Wang[9] with the quadrangle/county grid and taking the average for all cells over each quadrangle/county combination.

The process used for the lower accuracy source areas is summarized in the following steps with the tabular data shown in Figure 1.2.3 (for USGS 24K quadrangles in Sussex County, Delaware, under the PC scenario):

8. This approach effectively generates a linear interpolation of land area. Lacking site-specific topographic information, the exact profile of the landscape cannot be determined. Therefore, this linear interpolation represents a conservative approach and differences in coastal profiles at any specific locality could be thought to average out over the broad areas where this was applied. Certainly the reader may question any quantification of land at the 0.1-ft increment; however, to assess vulnerability of lands to inundation by small rates of SLR over different time periods, the increment chosen is necessary. Accuracy issues are discussed in Annex 3.

9. The SHW surface was derived by Titus and Wang through interpolation of local tide gage point data that was referenced to the NVGD29 vertical datum. See Section 1.1 for full processing details.

1. Sum the area of land between SHW and source contour interval or between successive contour intervals (SHW Table in Figure 1.2.3).

2. Determine the number of 0.1-ft elevation bins between the SHW/first contour or successive contours.

3. Divide the sum in #1 by the number of bins in #2.

4. Assign each 0.1-ft bin the output value from #3 (NGVD29 Area Distribution Table in Figure 1.2.3).

For example, using the Assawoman Bay quadrangle in Sussex County, Delaware, as an example (highlighted in Figure 1.2.3), the source data is 5-ft USGS, the SHW value is 2.7-ft NGVD29, and the total area between SHW and the 5-ft contour under the PC scenario is 370.53 hectares (ha). The land area was redistributed as follows:

1. Sum of land between 2.7 and 5 feet (NGVD) = 370.53 ha

2. Number of 0.1 ft bins: round (5—2.7) / 0.1) = 23

3. Land area reported in each 0.1 ft bin: 370.53 / 23 = 16.1 ha

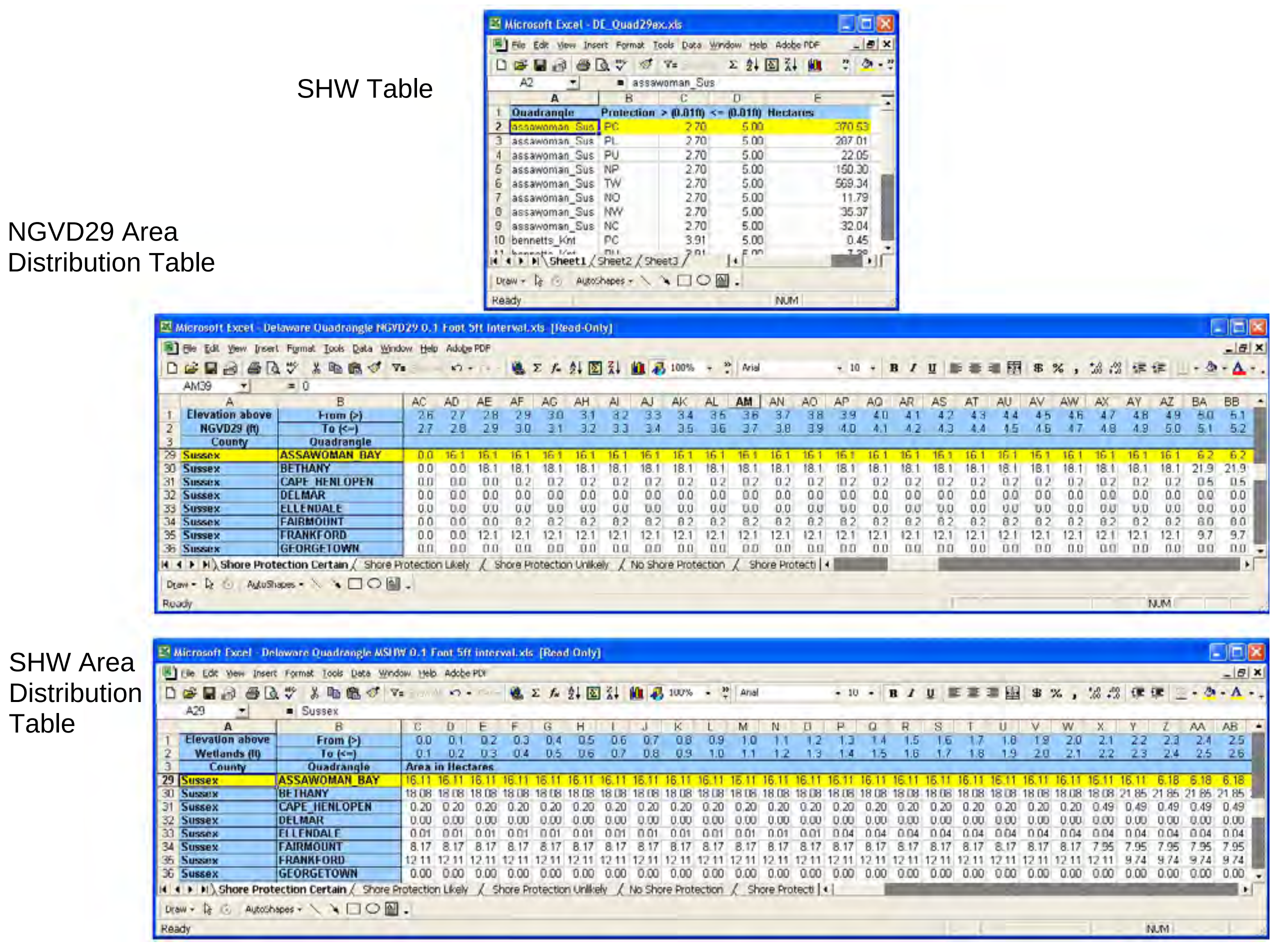

Figure 1.2.3. Example Tabular Summary Output of Land Elevation for Shore Protection Certain (PC) Scenario for USGS 24K Quadrangles in Sussex County, Delaware. SHW Table shows land area (in hectares) of PC between SHW relative to NGVD29 vertical datum and the 5-ft USGS contour. NGVD29 Area Distribution Table shows how land area in SHW Table was distributed evenly into 0.1-ft elevation bins. The SHW Area Distribution Table shows the re-distributed NGVD29 Table data adjusted relative to SHW elevations. The highlighted row pertains to an example in the text.

Figure 1.2.3 for the Assawoman Bay quadrangle shows that 16.1 ha was input into each 0.1-ft bin between 2.7 feet (SHW) and 5 feet. The same procedure was used for each successive 5-ft contour.

Areas with source elevations better than a 1-m contour

For the higher accuracy data sources, the land area was summarized by larger elevation increments (e.g., 50 cm and 1 foot) and output directly from the DEM without any reallocation.

Final output

We subsequently output the land areas by elevation bin into individual Excel workbooks for each elevation data source. Individual sheets within the workbooks were divided by protection scenario and contained the area of land (in hectares) within each elevation increment—50 cm and 1 foot for both low and higher resolution data sets and 0.1-ft increments where the source data was 1-m contour or worse.[10] Area estimates were reported from 0 to 20 feet for English unit tables and from 0 to 7 meters for metric tables. A second set of Excel workbooks was generated relative to SHW by subtracting the SHW-NGVD29 elevation bin reported from each quadrangle/county record within the spreadsheets. An example of the output is shown in the SHW Area Distribution Table in Figure 1.2.3. Therefore, relative to SHW, the 16.1-ha bins are distributed between 0 and 2.3 feet (after conversion from 2.7 to 5.0 feet relative to NGVD29).

Finally, we added two additional sheets to each Excel workbook: “All Land” and “Dry Land.” The first worksheet summarized all the other shoreline protection scenario worksheets with the exception of the NO sheet, and the “Dry Land” worksheet represented the summary of all worksheets except NO and NW.

10. In subsequent elevation rollups, to make the data compatible with the lower accuracy data, we divide the area of 1-ft increments evenly into 0.1-ft elevation bins. This differs from the method used for the lower accuracy data in that the redistribution occurred at 1-ft increments instead of over the entire contour interval.

Once the individual source, quadrangle, county, and protection scenario tables were generated, we were able to summarize total areas for each scenario or groups of scenarios by various groupings, including state, county, or various region (e.g., Chesapeake Bay) where each quadrangle/county combination could be assigned to the appropriate region.

In addition to the tables just described, we also generated land area summaries for each shoreline protection scenario by elevation taking into account the uncertainty associated with different source data sets. This was accomplished by creating a lookup table of the root mean squared error (RMSE) associated with each source data set. By reporting the RMSE by individual quadrangle, county, and source combination, we were able to make low and high estimates of land area similar to the tables generated using the central estimate. The methods used to generate the uncertainty tables are in Section 1.3.

1.2.3. Other Products—Summarizing Land Area Vulnerable to Inundation

General approach

In addition to the summaries described, we generated another set of tables showing the area of tidal wetlands at risk of inundation from SLR and area of potentially new wetlands resulting from inundation of lands above SHW under alternative SLR and protection scenarios.[11] To derive this information we used the summary statistics tables described and combined them with lookup tables we developed. The lookup tables were created for dry land and tidal wetlands (TW) and provide the following information: the mean (arithmetic) of full tide range, the mean of the reciprocal of the tide range (harmonic mean), the mean SLR rate, the dominant accretion code, and the percentage of wetland area with a specific accretion code of the total wetlands for each quadrangle/county combination. The sections that follow describe

[11] These tables are not provided because the likelihood of shoreline protection data from which they were generated are based on an unpublished analysis.

the methods we used to calculate the values in the lookup tables.

Calculating average and average reciprocal spring tide range values

To derive the mean spring tide range (STR) for each quadrangle/county combination for the dry land, we overlaid a raster layer of the combination of quadrangle and county with a raster surface of spring tide range developed from interpolation of tide gauge data.[12] We then calculated the average STR using the ESRI GRID extension function "ZONALSTATS" (ESRI, 2006), which calculates the mean of the values of all raster cells in the STR surface that spatially coincide with the same quadrangle/county combination. Similarly, we calculated the reciprocal mean of STR by first generating the raster layer of the inverse of the STR surface (1/STR surface) and then calculating the mean using the inverse layer as an input into the ZONALSTATS function.

To calculate the average STR and average reciprocal STR for the tidal wetlands, we first overlaid the tidal wetland layer for each state[13] with a GIS raster layer of accretion data developed by Titus, Jones, and Streeter (in Section 2.2) (based on a science panel assessment and hand-annotated maps delineated by Reed et al. [in Section 2.1]). We then calculated the average STR values (mean and reciprocal mean) using the same procedure that was followed for the dry land data, but limiting our averages to only the wetland/accretion code combination within a quadrangle/county instead of using the entire quadrangle/county that was used in the dry land analysis.

Calculating the dominant accretion code for tidal wetlands

Because the minimum mapping unit of analysis (minimum unit of analysis) for dry land was the quadrangle/county combination, we needed to have a single accretion code for each quadrangle/county combination. In addition, because the accretion potential defined by Reed et al. (2008) was categorical rather than representing an average, we needed to use the dominant accretion code instead of taking an average. To determine the dominant accretion code for wetlands within a quadrangle/county, we first summed the area of tidal wetlands by accretion code within a quadrangle/county and divided it by the total area of tidal wetlands for all accretion codes within a quadrangle/county. The percentage of each tidal wetlands/accretion code of the total wetlands within the quadrangle/county was calculated as *% TW accretion = (Area specific TW accretion / total TW area) * 100*.

The accretion code that accounted for the most tidal wetlands was classified as the dominant code.

Calculating the accretion code for dry land

To determine the accretion code for each quadrangle/county combination for dry land, we overlaid the raster accretion layer with the quadrangle/county raster layer and assigned the accretion code based on whichever accretion code covered the majority of the quadrangle/county. Where the accretion layer did not extend far enough inland to cover all nontidal lands being evaluated, the accretion code nearest the quadrangle/county dry land being evaluated was used. Figure 1.2.4 shows an example of the output in the lookup tables (dry land and tidal wetland) for Delaware. This table was then used with the summary elevation statistics tables to roll up elevations at various increments to estimate the loss of tidal wetlands as well as the

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12. Titus and Wang (Section 1.1) generated vertical elevations for the tide points using the National Ocean Service's (NOS) estimated tide ranges, NOS estimated sea level trends, and the NOS published benchmark sheets along with National Geodetic Survey North American Vertical Datum Conversion Utility (VERTCON) program to convert the mean tide level (MTL) above NAVD88 to NGVD29.

13. For all states except Pennsylvania, the wetland layer that was generated by Titus and Wang was used. Titus and Wang did not include mudflats in the tidal wetlands classification for Pennsylvania. Because mudflats represent a significant portion of tidal wetlands in Pennsylvania, we extracted mudflats from the NWI source data and added them to the final Pennsylvania wetlands layer.

generation of new wetlands from inundation of dry lands (these tables are not provided because the likelihood of shoreline protection data from which this was generated is based on an unpublished analysis).

Generating tabular summaries of potential wetland creation and loss

After we generated the lookup tables, we were able to summarize the elevation data into tables that provide information on the potential tidal wetland creation and loss. For example, using the elevation by protection scenario data along with the tide range data in the lookup table, we were able to calculate the area of tidal wetlands and the area of dry land within 1 meter or one-half tide range above spring high water by protection scenario (results are part of an ongoing analysis). Similarly, we calculated the amount of land available for wetland migration by shore protection likelihood by looking at the amount of land between mean sea level and spring high water if the sea level rises 1 meter (results are part of ongoing analysis). Additionally, other modifications included summarizing the area of wetlands below a particular elevation assuming uniform elevation distribution, and subdividing quadrangle-specific estimates by dominant accretion code that was assigned to both wetlands and drylands.

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Microsoft Excel - DEquadcntyWet_lut050707.xls

	Quad Name	County	Accretion	TW Ha	Total TW Ha	% Accretion of Total	Arith Mean STR	Harmonic Mean	Mean SLR Rate
23	Mispillion	Sussex	2	2136.87	2136.87	100	171.53	0.0058	3.21
24	Newark East	New Castle	8	225.36	225.36	100	176.8	0.0057	3.21
25	Rehoboth	Sussex	2	764.37	764.37	100	143.27	0.0070	3.21
26	Saint Georges	New Castle	2	42.66	42.66	100	184.02	0.0054	3.21
27	Seaford East	Sussex	8	90.09	90.09	100	88.21	0.0113	3.21
28	Seaford West	Sussex	8	0.99	0.99	100	88.82	0.0113	3.21
29	Selbyville	Sussex	2	17.46	17.46	100	15	0.0667	3.21
30	Sharptown	Sussex	8	561.06	561.06	100	88.21	0.0113	3.21
31	Smyrna	Kent	0	913.05	1579.77	57.8	196.43	0.0051	3.21
32	Smyrna	Kent	2	666.72	1579.77	42.2	196.43	0.0051	3.21
33	Smyrna	New Castle	2	864.18	864.18	100	194.47	0.0051	3.21
34	TaylorsBridge	New Castle	2	3815.37	3815.37	100	193.74	0.0052	3.21
35	Wilmington_S	New Castle	2	254.43	511.02	49.79	176.24	0.0057	3.21
36	Wilmington_S	New Castle	8	256.59	511.02	50.21	176.24	0.0057	3.21

Microsoft Excel - DE_quadcntyDry_lutF_050707.xls

	Quad Name	County	Accretion	Arith Mean STR	Harmonic Mean STR	Mean SLR Rate
2	Georgetown	Sussex	8	157.78	0.0063	3.21
3	Greenwood	Sussex	8	174.77	0.0057	3.21
4	Hickman	Sussex	8	147.98	0.0075	3.21
5	Laurel	Sussex	8	104.05	0.0098	3.21
6	Marcus Hook	New Castle	8	181.17	0.0055	3.21
7	Marydel	Kent	8	188.28	0.0053	3.21
8	Newark East	New Castle	8	177.75	0.0056	3.21
9	Penns Grove	New Castle	8	180.53	0.0055	3.21
10	Seaford East	Sussex	8	149.74	0.007	3.21
11	Seaford West	Sussex	8	100	0.0104	3.21
12	Sharptown	Sussex	8	87.34	0.0115	3.21
13	Trap Pond	Sussex	8	117.82	0.0085	3.21
14	Wilmington_N	New Castle	8	178.8	0.0056	3.21
15	Wilmington_S	New Castle	8	176.81	0.0057	3.21

Figure 1.2.4. Example of Lookup Tables. Top table: tidal wetland (TW) areas by quadrangle/county/accretion code, total TW for quadrangle/county, percentage of accretion-specific area to total, arithmetic mean of STR, harmonic mean (mean of reciprocal) of STR, and mean SLR rate. Bottom table: dominant accretion code, and arithmetic and harmonic STR means and mean of SLR rate.

Section 1.2 Appendix
Area of Land Close to Sea Level, by State

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Table A1. New York (square kilometers)

		Meters above Spring High Water									
County		**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**	**5.0**
	----------------Dry Land, by half meter elevation increment[a]---------------										
Bronx		2.3	2.3	2.3	2.6	2.8	2.8	2.8	2.8	2.8	1.4
Brooklyn		7.4	6.0	6.0	6.7	9.2	9.2	8.4	5.4	5.4	4.9
Manhattan		1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.7	1.7	1.7
Nassau		13.2	17.8	21.2	21.2	13.3	8.8	8.8	8.6	8.1	7.4
Queens		13.2	8.9	8.9	9.6	9.3	9.3	7.4	5.0	5.0	3.1
Staten Island		5.7	5.7	5.7	4.9	2.7	2.7	2.7	2.7	2.7	2.4
Suffolk		36.8	37.0	38.0	37.6	37.6	34.3	33.9	33.4	30.3	29.5
Westchester		2.1	2.1	2.1	2.2	1.9	1.8	1.8	1.8	1.8	1.3
Ellis & Liberty Islands		0.04	0.04	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Statewide		82.4	81.5	85.9	86.4	78.5	70.6	67.5	61.4	57.8	51.7
Wetlands	**Tidal**	---------Nontidal Wetlands, by half meter elevation increment---------									
Brooklyn	3.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nassau	43.4	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Queens	7.6	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Staten Island	5.4	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1
Suffolk	82.3	4.1	4.0	2.5	2.4	2.3	1.5	1.5	1.4	1.4	1.3
Other[b]	6.9	0.06	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.04	0.05
Statewide	149.1	5.0	4.8	3.4	3.2	2.8	2.0	1.9	1.9	1.9	1.8
		Cumulative (total) amount of land below a given elevation[c]									
Dry Land		82	164	250	336	415	485	553	614	672	724
Nontidal Wetlands		5	10	13	16	19	21	23	25	27	29
All Land	149	236	323	412	502	583	655	725	788	848	901

[a] For example, Bronx has 2.3 square kilometers of dry land between 0.5 and 1.0 meters above spring high water.
[b] Includes Bronx, Dutchess, Manhattan, Orange, Putnam, Rockland, and Westchester counties.
[c] For example, New York State has 164 square kilometers of dry land less than 1 meter above spring high water.

Table A2. New York jurisdictions not included in shore protection study (hectares)

		Meters above Spring High Water									
County		**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**	**5.0**
	Tidal	---------Nontidal Wetlands, by half meter elevation increment---------									
Dutchess	7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Orange	24.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Putnam	126.6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Rockland	228.6	1.5	1.5	1.5	1.5	0.9	0.6	0.6	0.6	0.6	0.6

Note: The analysis found no dry land below 5 meters for these jurisdictions.

Table A3. New Jersey (square kilometers)

County		Meters above Spring High Water 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
----------------Dry Land, by half meter elevation increment[a]---------------											
Atlantic		8.1	13.7	14.2	10.9	9.3	8.1	7.8	8.1	7.8	7.8
Bergen		11.4	11.4	11.4	7.5	2.2	2.1	2.1	2.1	2.1	2.1
Burlington		4.6	4.6	4.6	4.5	5.6	5.9	5.9	5.9	5.9	7.3
Cape May		16.2	23.0	20.0	16.3	23.0	21.8	20.6	20.7	19.6	18.1
Cumberland		11.8	10.0	10.0	10.1	11.1	11.1	10.6	9.9	9.9	9.6
Gloucester		6.8	6.7	6.7	6.6	6.0	6.0	6.0	6.0	6.0	5.8
Hudson		11.9	11.9	11.9	9.4	3.5	3.5	3.5	3.5	3.5	3.0
Middlesex		6.5	6.5	6.5	5.7	5.2	5.2	5.2	5.2	5.2	4.9
Monmouth		7.3	7.8	9.9	10.4	9.2	9.0	8.1	7.3	8.2	8.0
Ocean		10.1	22.4	25.2	16.6	12.7	12.9	12.3	11.1	10.0	9.0
Salem		20.0	17.3	17.3	16.7	14.2	14.2	13.7	12.1	12.1	11.8
Other[b]		12.4	12.4	12.4	10.8	8.5	8.5	8.5	8.5	8.5	7.7
Statewide		**127.2**	**148.0**	**150.2**	**125.5**	**110.5**	**108.4**	**104.5**	**100.5**	**98.8**	**95.0**
Wetlands	**Tidal**	---------Nontidal Wetlands, by half meter elevation increment---------									
Atlantic	204.0	14.3	9.1	9.1	9.1	8.7	8.6	8.5	8.4	8.3	8.3
Burlington	42.8	7.6	7.5	7.3	7.3	4.7	4.4	4.4	4.4	4.4	4.6
Cape May	201.4	20.5	15.4	14.9	13.7	10.1	9.8	9.5	7.2	7.0	6.6
Cumberland	212.6	18.1	14.1	14.1	12.0	7.2	7.2	6.8	6.3	6.3	6.1
Gloucester	18.0	6.5	6.3	6.3	5.3	1.3	1.3	1.3	1.3	1.3	1.3
Ocean	124.8	7.9	9.2	8.3	7.4	6.6	5.2	4.7	4.3	4.0	3.8
Salem	110.1	21.8	8.5	8.5	7.5	3.1	3.1	3.0	2.7	2.7	2.7
Other[c]	66.7	2.8	2.5	2.5	2.1	1.5	1.4	1.4	1.5	1.6	1.5
Statewide	**980.4**	**99.5**	**72.6**	**70.9**	**64.4**	**43.2**	**41.0**	**39.8**	**36.0**	**35.5**	**35.0**
Cumulative (total) amount of land below a given elevation[d]											
Dry Land		127	275	425	551	661	770	874	975	1073	1169
Nontidal Wetlands		99	172	243	307	351	392	431	467	503	538
All Land	980	1207	1428	1649	1839	1992	2142	2286	2422	2557	2687

[a] For example, Atlantic County has 13.7 square kilometers of dry land between 0.5 and 1.0 meters above spring high water.
[b] Includes Camden, Essex, Mercer, Passaic, Union, and Somerset above 4.5m.
[c] Includes Camden, Essex, Mercer, Passaic, Union, Somerset above 4.5m, Bergen, Hudson, Middlesex, and Monmouth.
[d] For example, New Jersey has 275 square kilometers of dry land less than 1 meter above spring high water.

Table A4. New Jersey jurisdictions not included in shore protection study (hectares)

County		Meters above Spring High Water 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
		---------------Dry Land, by half meter elevation increment---------------									
Mercer[1]		4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	3.5	0.3
Passaic		11.7	11.7	11.7	14.4	17.7	17.7	17.7	17.7	17.7	18.1
Somerset		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9
Wetlands	**Tidal**	---------Nontidal Wetlands, by half meter elevation increment---------									
Mercer[a]	178	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.0
Passaic	0	1.2	1.2	1.2	0.7	0.1	0.1	0.1	0.1	0.1	0.3
Somerset	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6

[a] The "not considered" category includes Mercer County because we calculated these statistics before the Mercer County results had been incorporated into our data set.

Table A5. Pennsylvania (square kilometers)

County		Meters above Spring High Water 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
		---------------Dry Land, by half meter elevation increment[a]---------------									
Bucks		3.2	3.2	3.3	3.6	3.6	3.6	3.6	3.6	3.5	3.4
Delaware		4.4	4.4	4.4	3.3	1.3	1.3	1.3	1.3	1.3	1.2
Philadelphia		4.9[b]	3.5	7.2	6.5	6.4	6.4	5.0	4.3	4.6	4.4
Statewide		12.6	11.1	15.0	13.4	11.3	11.3	9.8	9.2	9.3	9.1
Wetlands	**Tidal**	---------Nontidal Wetlands, by half meter elevation increment---------									
Bucks	1.9	0.7	0.7	0.8	0.9	0.9	0.9	0.9	0.9	0.7	0.3
Delaware	0.6	0.6	0.6	0.6	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Philadelphia	3.6	0.5[c]	0.2	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0.0
Statewide	6.1	1.9	1.5	1.7	1.6	1.1	1.0	1.0	1.0	0.8	0.3
		Cumulative (total) amount of land below a given elevation[d]									
Dry Land		13	24	39	52	63	75	85	94	103	112
Nontidal Wetlands		2	3	5	7	8	9	10	11	11	12
All Land	6	21	33	50	65	77	89	100	110	121	130

[a] For example, Philadelphia has 3.5 square kilometers of dry land between 0.5 and 1.0 meters above spring high water.
[b] This value includes 2.4 square kilometers of dry land below spring high water in Philadelphia, of which 0.87, 0.054, and 0.005 are at least 1, 2, and 3 meters below spring high water, respectively. Most of this land is near Philadelphia International airport.
[c] This value includes 39 hectares below spring high water, of which 3.8 are at least 1 meter below spring high water. Most of this land is near Philadelphia International airport.
[d] For example, Pennsylvania has 24 square kilometers of dry land less than 1 meter above spring high water.

Table A6. Delaware (square kilometers)

County		Meters above Spring High Water 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
		-------------Dry Land, by half meter elevation increment[a]------------									
Kent		19.2	13.0	13.0	16.2	20.5	20.5	22.0	24.3	24.3	22.2
New Castle		15.4	9.0	9.0	9.6	11.1	11.1	11.3	11.3	11.3	10.7
Sussex: Chesapeake Bay		1.1	1.3	1.6	1.6	2.3	3.4	3.4	4.6	5.7	5.7
Sussex: Delaware Bay		13.7	10.9	10.7	10.8	11.8	11.7	11.6	10.2	10.1	10.2
Sussex: Atlantic Coast		22.7	19.9	18.1	18.1	20.7	22.3	22.3	23.5	24.0	24.0
Statewide		72.2	53.9	52.4	56.3	66.4	68.9	70.5	73.8	75.5	72.9
Wetlands	**Tidal**	**-------Nontidal Wetlands, by half meter elevation increment-------**									
Kent	168.7	9.6	4.3	4.3	4.0	3.1	3.1	3.2	3.3	3.3	3.2
New Castle	73.5	3.5	0.8	0.8	0.8	0.9	0.9	0.8	0.7	0.7	0.7
Sussex: Chesapeake Bay	6.6	1.4	0.9	0.7	0.7	0.9	1.0	1.0	1.5	1.7	1.7
Sussex: Delaware Bay	67.5	4.3	1.2	1.1	1.1	1.0	1.0	1.0	0.7	0.7	0.7
Sussex: Atlantic Coast	40.9	3.5	2.6	2.2	2.2	2.0	1.8	1.8	1.4	1.2	1.2
Statewide	357.1	22.2	9.8	9.2	8.9	7.9	7.8	7.9	7.6	7.5	7.4
		Cumulative (total) amount of land below a given elevation[b]									
Dry Land		72	126	178	235	301	370	441	514	590	663
Nontidal Wetlands		22	32	41	50	58	66	74	81	89	96
All Land	357	452	515	577	642	716	793	871	953	1036	1116

[a] For example, Kent County has 13 square kilometers of dry land between 0.5 and 1.0 meters above spring high water.
[b] For example, Delaware has 126 square kilometers of dry land less than 1 meter above spring high water.

Table A7. Maryland (square kilometers)

County		Meters above Spring High Water 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
		---------------Dry Land, by half meter elevation increment[a]--------------									
Anne Arundel		5.3	5.3	7.4	11.7	11.7	10.9	8.9	8.9	8.9	8.7
Baltimore County		4.8	5.5	6	7.3	8.9	10.1	10.2	7.8	8.7	8.7
Calvert		1.9	1.9	1.6	1.5	1.6	3.4	3.6	3.6	4.6	4.7
Cecil		1.2	1.5	2.1	2.1	2.6	4.2	4.2	4.3	4.6	4.6
Charles		5.8	5.7	7.5	7.5	7.6	12.7	13.1	13.1	8.2	7.8
Dorchester		74	114.3	62.3	48.1	36.9	37	34	25	19.1	17.4
Harford		9.1	8.9	6.3	6.2	6.3	8.4	8.5	8.4	5.2	5.1
Kent		4	6	6.7	6.8	6.4	11.2	11.2	11.2	12.5	12.9
Queen Anne's		1.9	6.5	9.5	11.2	13.5	16.8	19.3	19.3	18.6	18
Somerset		39.2	47	45.5	52.5	19.9	18.5	27.8	28.4	28.7	29.3
St. Mary's		8.2	8.2	11	11.2	11.2	20.9	21.4	21.4	11.4	10.3
Talbot		4.2	12.2	23.2	41.7	44.1	37.1	35	32.3	23.4	19.5
Wicomico		10	13.1	14.7	15	14.6	13.7	14.3	14.3	14.5	13.5
Worcester		11.5	24.1	31.6	36.7	35	32	27.5	25.7	26	26.6
Other[b]		4.3	4.9	5.4	5.7	6.1	7.1	7.1	7.4	8.4	8.5
Statewide		185.3	265.1	240.7	265.1	226.3	243.8	246.0	231.2	202.8	195.3
Wetlands	**Tidal**	---------Nontidal Wetlands, by half meter elevation increment---------									
Charles	24.2	1.9	1.9	2.2	2.2	2.2	2.4	2.4	2.4	1.5	1.4
Dorchester	424.8	32.5	30.1	20.6	16.2	10.3	6.9	10.1	6.8	4.8	3.1
Harford	29.4	1.4	1.3	1.0	1.0	1.0	1.4	1.4	1.4	0.7	0.6
Somerset	265.4	12.3	7.0	7.2	11.9	3.5	6.0	10.1	7.0	9.3	10.9
St. Mary's	18.7	1.5	1.6	2.1	2.1	2.1	3.9	3.9	3.9	3.0	2.9
Talbot	26.1	0.1	0.6	0.9	1.7	2.2	2.1	2.6	3.8	2.6	2.0
Wicomico	67.0	8.4	3.4	7.3	7.7	5.2	8.9	9.4	8.0	5.5	4.8
Worcester	142.2	2.8	5.4	5.2	6.1	6.1	7.2	6.8	6.4	5.3	5.0
Other[c]	118.0	3.5	5.9	7.2	8.7	8.1	8.5	7.0	7.2	8.6	8.7
Statewide	1115.8	64.5	57.2	53.8	57.6	40.8	47.2	53.7	47.0	41.3	39.5
		Cumulative (total) amount of land below a given elevation[d]									
Dry Land		185	450	691	956	1182	1426	1672	1904	2106	2302
Nontidal Wetlands		64	122	175	233	274	321	375	422	463	503
All Land	1116	1366	1688	1982	2305	2572	2863	3163	3441	3685	3920

[a] For example, Anne Arundel County has 5.3 square kilometers of dry land between 0.5 and 1.0 meters above spring high water.
[b] Includes Baltimore City, Caroline, and Prince George's Counties.
[c] Includes Baltimore City, Caroline, Prince George's, Anne Arundel, Baltimore County, Calvert, Cecil, Kent, and Queen Anne's Counties.
[d] For example, Maryland has 450 square kilometers of dry land less than 1 meter above spring high water.

Table A8. Washington, D.C. (square kilometers)

		Meters above Spring High Water									
		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
		----------------Dry Land, by half meter elevation increment [a]---------------									
Washington, D.C.		2.43	1.16	1.40	1.42	1.81	1.84	1.83	1.80	1.68	1.65
Wetlands	**Tidal**	---------Nontidal Wetlands, by half meter elevation increment---------									
Washington, D.C.	0.79	0.04	0.02	0.03	0.02	0.02	0.02	0.03	0.03	0.05	0.05
		Cumulative (total) amount of land below a given elevation[b]									
Dry Land		2.43	3.59	4.98	6.40	8.22	10.06	11.88	13.69	15.37	17.01
Nontidal Wetlands		0.04	0.06	0.09	0.11	0.13	0.14	0.17	0.21	0.26	0.31
All Land	0.79	3.26	4.44	5.86	7.31	9.13	10.99	12.85	14.68	16.41	18.12

[a] For example, DC has 1.16 square kilometers of dry land between 0.5 and 1.0 meters above spring high water.
[b] For example, DC has 3.59 square kilometers of dry land less than 1 meter above spring high water.

Table A9. Virginia (square kilometers)

County	Meters above Spring High Water 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
	----------------Dry Land, by half meter elevation increment[a]---------------									
Eastern Shore	**45.5**	**39.8**	**42.9**	**43.1**	**42.6**	**37.1**	**36.4**	**35.6**	**33.5**	**33.5**
Accomack	29.5	29.1	32.7	32.9	31.3	20.7	20.0	19.1	15.3	15.0
Northampton	15.9	10.7	10.2	10.2	11.3	16.4	16.5	16.6	18.1	18.5
Northern Virginia	**2.7**	**2.7**	**2.7**	**2.7**	**2.9**	**3.3**	**3.3**	**3.3**	**3.3**	**3.3**
Rappahannock Area	**3.5**	**3.5**	**3.5**	**3.5**	**3.5**	**6.8**	**6.8**	**6.8**	**6.8**	**6.8**
Northern Neck	**16.2**	**16.2**	**16.5**	**16.5**	**16.7**	**42.4**	**46.9**	**46.9**	**47.0**	**47.0**
Middle Peninsula	**30.6**	**32.5**	**42.3**	**42.5**	**42.7**	**37.3**	**37.4**	**36.7**	**26.6**	**26.4**
Gloucester	11.3	12.4	15.1	15.1	13.5	8.5	8.5	7.9	5.6	5.6
Mathews	10.7	11.5	18.2	18.3	17.8	11.4	11.4	11.2	3.7	3.6
Other[b]	8.5	8.5	9.0	9.1	11.5	17.4	17.6	17.6	17.4	17.3
Hampton Roads[c]	**65.5**	**74.0**	**105.9**	**119.3**	**134.1**	**188.7**	**198.7**	**191.9**	**138.4**	**116.3**
Virginia Beach	24.0	25.2	35.0	44.0	45.3	56.3	54.4	53.6	35.7	25.3
Chesapeake	8.4	10.7	20.2	24.6	29.7	55.7	67.5	68.4	59.9	48.1
Portsmouth	2.7	3.7	5.2	5.2	7.4	11.5	11.5	9.6	4.8	4.8
Hampton	4.1	6.4	12.2	12.2	13.1	14.3	14.3	12.4	4.8	4.8
Norfolk	4.1	6.3	11.3	11.3	14.5	24.5	24.5	20.5	4.2	4.2
York	4.3	5.0	6.5	6.5	6.0	4.8	4.8	4.3	2.7	2.7
Newport News	4.9	4.3	3.2	3.2	3.2	3.5	3.5	3.8	4.7	4.7
Poquoson	3.2	3.4	3.6	3.6	2.7	0.1	0.1	0.1	0.0	0.0
Suffolk	3.4	3.0	2.8	2.8	5.4	8.6	8.6	9.6	11.7	11.8
James City	2.8	2.7	2.5	2.5	2.7	3.8	3.8	3.8	3.9	3.9
Isle of Wight	2.6	2.4	2.4	2.4	3.1	4.9	4.9	5.0	5.2	5.2
Surry	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9
Other Jurisdictions[d]	**8.1**	**8.1**	**9.3**	**9.3**	**11.0**	**16.5**	**16.6**	**16.7**	**19.4**	**19.7**
Statewide	**172.1**	**176.8**	**223.0**	**236.9**	**253.4**	**332.1**	**346.2**	**337.9**	**275.0**	**253.0**

Table continued on following page

Table A9. Virginia (square kilometers) continued

County		Meters above Spring High Water 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Wetlands	**Tidal**	**-----Nontidal Wetlands, by half meter elevation increment------**									
Eastern Shore	**945.5**	**15.8**	**18.2**	**24.3**	**24.5**	**21.8**	**12.2**	**11.7**	**11.3**	**7.9**	**7.6**
Accomack	483.5	15.0	17.0	22.0	22.2	20.0	10.6	10.1	9.7	6.9	6.6
Northampton	462.0	0.8	1.2	2.2	2.3	1.9	1.6	1.6	1.6	1.1	1.0
Northern Virginia	**10.2**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Rappahannock Area	**26.7**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**
Northern Neck	**57.3**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**	**3.5**	**3.9**	**3.9**	**3.9**	**3.9**
Middle Peninsula	**164.4**	**8.7**	**9.4**	**12.5**	**12.5**	**11.9**	**12.0**	**11.9**	**11.7**	**7.7**	**7.6**
Gloucester	43.5	3.9	4.5	5.7	5.7	5.1	2.9	2.9	2.7	1.7	1.7
Mathews	27.1	2.8	3.0	4.8	4.8	4.9	7.5	7.5	7.5	4.5	4.4
Other[e]	93.9	2.0	2.0	2.0	2.0	1.9	1.5	1.5	1.5	1.5	1.5
Hampton Roads[f]	**330.2**	**32.6**	**31.4**	**22.6**	**20.7**	**28.9**	**39.3**	**38.8**	**39.9**	**39.8**	**37.9**
Virginia Beach	112.4	10.5	10.0	7.0	7.5	7.3	4.6	3.4	3.3	2.5	1.8
Chesapeake	39.7	12.2	12.7	10.1	7.7	16.1	30.1	30.7	31.8	32.2	31.0
Portsmouth	3.7	5.3	3.5	0.2	0.2	0.3	0.4	0.4	0.3	0.2	0.2
Hampton	14.4	0.1	0.2	0.2	0.2	0.3	0.7	0.7	0.8	1.1	1.1
Norfolk	4.7	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.0
York	17.0	0.6	1.0	1.9	1.9	1.5	0.6	0.6	0.6	0.4	0.4
Newport News	15.1	0.2	0.3	0.3	0.3	0.2	0.0	0.0	0.0	0.1	0.1
Poquoson	23.7	0.0	0.1	0.3	0.3	0.2	0.0	0.0	0.0	0.0	0.0
Suffolk	26.3	1.5	1.5	0.7	0.7	0.9	1.0	1.0	1.1	1.6	1.6
James City	32.8	0.6	0.6	0.6	0.6	0.5	0.4	0.4	0.4	0.4	0.4
Isle of Wight	28.9	0.9	0.9	0.7	0.7	0.8	1.1	1.1	1.1	1.2	1.2
Surry	11.5	0.5	0.5	0.5	0.5	0.4	0.2	0.2	0.2	0.2	0.2
Other Jurisdictions[g]	**84.5**	**13.1**	**13.1**	**8.1**	**8.0**	**7.1**	**6.3**	**6.3**	**6.3**	**6.0**	**6.0**
Virginia	**1618.9**	**73.1**	**75.0**	**70.4**	**68.6**	**72.6**	**74.3**	**73.7**	**74.1**	**66.5**	**64.1**
		Cumulative (total) amount of land below a given elevation[h]									
Dry Land		172	349	572	809	1062	1394	1741	2079	2354	2606
Nontidal Wetlands		73	148	218	287	360	434	508	582	648	713
All Land	1619	1864	2116	2409	2715	3041	3447	3867	4279	4621	4938

[a] For example, Gloucester has 12.4 km^2 of dry land between 0.5 and 1.0 meters above spring high water.
[b] Includes Essex, King and Queen, King William, and Middlesex Counties.
[c] Excludes Southampton, Franklin, and Williamsburg.
[d] Includes Charles City, Chesterfield, Hanover, Henrico, New Kent, Prince George, Southampton, and Sussex Counties and the cities of Colonial Heights, Franklin, Hopewell, Petersburg, and Williamsburg.
[e] Includes Essex, King and Queen, King William, and Middlesex Counties.
[f] Excludes Southampton, Franklin, and Williamsburg.
[g] Includes Charles City, Chesterfield, Hanover, Henrico, New Kent, Prince George, Southampton, and Sussex Counties and the cities of Colonial Heights, Franklin, Hopewell, Petersburg, and Williamsburg.
[h] For example, Virginia has a total of 349 square kilometers of dry land less than 1 meter above spring high water.

Table A10. Virginia jurisdictions not included in shore protection study (hectares)

County		Meters above Spring High Water									
		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
		---------------Dry Land, by half meter elevation increment---------------									
Charles City		237.9	237.9	237.9	237.9	296.2	445.5	445.5	445.5	445.5	445.5
Chesterfield		97.5	97.5	97.5	97.5	78.0	67.2	67.2	67.2	67.2	67.2
Colonial Heights		2.6	2.6	2.6	2.6	1.7	1.1	1.1	1.1	1.1	1.1
Franklin		5.1	5.1	19.5	19.7	19.7	24.2	24.5	24.5	35.1	36.4
Hanover		1.8	1.8	1.8	1.8	7.6	9.9	9.9	9.9	9.9	9.9
Henrico		57.0	57.0	57.0	57.0	47.4	40.8	40.8	40.8	40.8	40.8
Hopewell		28.1	28.1	28.1	28.1	18.0	10.9	10.9	10.9	10.9	10.9
New Kent		154.0	154.0	154.0	154.0	257.5	372.5	372.5	372.5	372.5	372.5
Petersburg		0.0	0.0	0.0	0.0	0.2	0.3	0.3	0.3	0.3	0.3
Prince George		140.5	140.5	140.5	140.5	178.4	287.8	287.8	287.8	287.8	287.8
Southampton		82.3	82.3	184.4	185.7	185.7	379.0	391.6	391.6	653.7	686.0
Williamsburg		3.7	3.7	3.7	3.7	4.0	5.7	5.7	5.7	5.7	5.7
Wetlands	**Tidal**	---------Nontidal Wetlands, by half meter elevation increment---------									
Charles City	2215.5	138.8	138.8	138.8	138.8	108.2	57.9	57.9	57.9	57.9	57.9
Chesterfield	1052.3	26.1	26.1	26.1	26.1	11.2	2.7	2.7	2.7	2.7	2.7
Colonial Heights	52.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Franklin	0.0	67.6	67.6	23.2	22.7	22.7	2.9	1.6	1.6	0.8	0.7
Hanover	114.2	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.2
Henrico	422.5	3.0	3.0	3.0	3.0	3.4	3.8	3.8	3.8	3.8	3.8
Hopewell	73.1	7.4	7.4	7.4	7.4	3.9	1.3	1.3	1.3	1.3	1.3
New Kent	3390.9	169.5	169.5	169.5	169.5	120.1	55.6	55.6	55.6	55.6	55.6
Petersburg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Prince George	1091.1	57.6	57.6	57.6	57.6	59.3	76.2	76.2	76.2	76.2	76.2
Southampton	0.0	835.8	835.8	383.9	378.3	378.3	421.1	423.9	423.9	399.9	396.9
Williamsburg	39.7	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1

Table A11. North Carolina (square kilometers)

County		Meters above Spring High Water 0.5[a]	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
		----------------Dry Land, by half meter elevation increment[b]---------------									
Beaufort		50.4	61.0	66.2	81.9	84.7	80.9	83.3	96.7	68.9	48.8
Camden		16.8	11.3	50.0	39.0	46.5	52.8	26.4	23.1	35.8	22.3
Carteret		51.2	69.8	90.0	107.5	79.1	21.7	15.1	16.5	17.4	13.3
Currituck		19.8	26.4	36.6	57.4	57.2	51.8	32.7	21.6	9.1	5.4
Dare		45.4	22.2	17.9	15.2	15.2	11.7	8.8	5.3	3.3	2.1
Hyde		295.7	141.3	56.4	52.9	51.6	39.5	25.2	18.4	12.0	5.7
Onslow		24.6	10.1	9.9	11.5	14.7	11.6	15.5	17.9	13.6	21.8
Pamlico		24.2	35.4	52.2	53.4	38.6	34.8	30.7	22.7	15.7	9.2
Pasquotank		10.6	28.8	43.4	48.7	47.3	40.6	71.8	93.7	47.8	25.3
Tyrrell		139.9	143.4	49.6	26.1	12.6	3.5	3.2	1.3	0.5	0.0
Other[c]		60.3	73.7	105.6	138.2	177.8	213.7	292.6	380.4	319.8	227.9
Not Considered[d]		3.0	2.7	3.8	5.1	7.1	9.4	12.9	18.0	22.5	30.5
Statewide		741.9	626.1	581.6	636.9	632.5	572	618.2	715.6	566.4	412.3
Wetlands	**Tidal**	---------Nontidal Wetlands, by half meter elevation increment---------									
Beaufort	35.1	68.0	40.9	32.3	32.4	44.6	37.0	24.2	16.4	15.3	12.7
Brunswick	109.2	38.5	8.7	7.4	6.1	6.3	6.2	5.7	5.9	5.0	4.8
Camden	7.1	142.5	7.5	10.6	7.6	10.2	11.8	7.2	7.4	12.5	30.1
Carteret	334.3	34.3	53.0	48.1	44.7	36.2	20.5	10.6	10.9	15.6	12.7
Currituck	124.6	131.8	18.3	13.2	14.6	9.7	8.9	4.2	3.3	4.4	10.6
Dare	167.8	402.2	162.2	61.4	33.8	5.0	1.1	0.4	0.2	0.1	0.1
Hyde	199.3	345.6	153.3	52.9	27.5	19.7	22.1	18.0	22.4	13.7	10.2
Pamlico	111.6	52.8	20.8	12.1	20.8	25.6	16.4	22.5	22.1	13.0	15.2
Pender	38.2	87.2	28.2	18.0	17.5	14.6	14.3	13.6	13.1	13.9	12.2
Tyrrell	3.8	433.4	95.7	32.3	10.7	11.4	10.6	12.8	9.7	5.0	1.1
Other[e]	137.5	605.1	119.8	96.1	93.4	98.3	94.6	95.7	105.4	100.8	98.7
Not Considered[d]	3.5	30.9	10.2	10.0	11.7	14.2	15.8	18.7	21.2	19.6	26.3
Statewide	1272.0	2372.3	718.6	394.4	320.8	295.8	259.3	233.6	238	218.9	234.7
		Cumulative (total) amount of land below a given elevation[f]									
Dry Land		742	1368	1950	2587	3219	3791	4410	5125	5692	6104
Nontidal Wetlands		2372	3091	3485	3806	4102	4361	4595	4833	5052	5286
All Land	1272	4386	5731	6707	7665	8593	9425	10276	11230	12016	12662

[a] Includes land below spring high water.
[b] For example, Beaufort County has 61 square kilometers of dry land between 0.5 and 1.0 meters above spring high water.
[c] Includes Bertie, Brunswick, Chowan, Craven, Gates, Hertford, Martin, New Hanover, Pender, Perquimans, and Washington Counties.
[d] Includes Bladen, Columbus, Duplin, Jones, Lenoir, Northampton, Pitt and Sampson Counties.
[e] Includes Bertie, Chowan, Craven, Gates, Hertford, Martin, New Hanover, Onslow, Pasquotank, Perquimans, and Washington Counties.
[f] For example, North Carolina has 1368 square kilometers of dry land less than 1 meter above spring high water.

Table A12. North Carolina jurisdictions not included in shore protection study (hectares)

County		Meters above Spring High Water									
		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
		----------------Dry Land, by half meter elevation increment---------------									
Bladen		0.0	0.0	0.1	1.7	6.8	12.2	33.7	112.2	225.0	691.0
Columbus		0.2	2.1	2.8	8.8	13.9	18.5	21.2	22.9	32.9	39.3
Duplin		0.2	0.1	0.1	0.0	0.5	2.3	6.2	13.7	19.3	55.2
Jones		190.4	116.3	140.3	178.4	224.2	312.0	388.4	525.8	676.4	762.9
Lenoir		0.0	0.0	0.0	0.0	0.5	5.1	11.3	21.2	50.9	96.2
Northampton		6.5	10.4	11.1	19.8	47.7	83.2	114.2	124.7	131.6	140.1
Pitt		105.8	137.0	230.2	303.5	421.4	508.0	710.1	973.0	1106.3	1233.4
Sampson		0.0	0.0	0.0	0.0	0.0	2.5	5.0	8.2	11.4	34.1
Wetlands	**Tidal**	---------Nontidal Wetlands, by half meter elevation increment---------									
Bladen	0.0	0.3	20.3	70.1	125.9	214.1	277.6	432.4	644.7	461.4	895.1
Columbus	0.0	20.1	58.2	104.9	134.7	126.8	108.1	86.3	58.1	47.3	143.5
Duplin	0.0	0.0	0.0	0.0	0.0	5.0	9.5	65.3	134.6	112.4	221.9
Jones	350.8	811.1	332.6	246.7	263.8	244.8	251.8	241.0	271.4	242.4	220.7
Lenoir	0.0	0.0	0.0	13.6	40.3	108.4	168.4	246.9	205.3	361.9	405.4
Northampton	0.0	119.8	85.7	73.5	125.2	224.1	192.9	194.0	133.7	82.8	80.3
Pitt	0.0	2142.9	526.3	490.1	479.3	497.3	497.0	500.9	557.6	550.0	456.0
Sampson	0.0	0.0	0.0	0.0	0.0	0.1	70.1	99.5	115.9	100.5	202.1