SOUTH ATLANTIC COASTAL STUDY (SACS)

Geospatial Appendix

FINAL REPORT
AUGUST 2022

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SECTION 1
Introduction

1.1 Background

The South Atlantic Coastal Study (SACS) is a comprehensive coastal study that applies watershed planning concepts to identify actions for advancing coastal resilience in the southeast United States. Applying the Coastal Storm Risk Management (CSRM) Framework developed by the United States Army Corps of Engineers (USACE) North Atlantic Coast Comprehensive Study (NACCS), the SACS assesses and addresses coastal storm risk using a three-tiered approach:

- Tier 1 analysis is conducted at a study-wide scale using national-level datasets to consistently assess potential risk from storm surge inundation under both existing conditions and future conditions with 3 feet of sea level rise.
- Tier 2 analysis is conducted at the state and territory level to refine Tier 1 results with additional location specific data.
- Tier 3 analysis (which is not completed as part of the SACS) occurs at the local level, based on Tier 2 findings, and is completed as part of SACS follow-on efforts.

The SACS encompasses a broad study area of approximately 65,000 miles of tidally influenced shoreline across six states and two territories (**Figure 1-1)**. Given this broad study area, geospatial data and geospatial technologies are essential tools to efficiently analyze coastal storm risk and identify areas potentially at risk to coastal storm surge inundation in existing conditions and by factoring in sea level rise. The SACS developed a variety of geospatial datasets and applications to support these activities. This appendix describes in detail the methodology used to develop and derive these data, as well as how to visualize and access geospatial data via the SACS Geoportal.

1.2 Purpose

The SACS closely models the NACCS, a congressional response and precedent-setting vulnerability and flood risk management study completed for the North Atlantic coastline in the wake of Hurricane Sandy (USACE 2015). The SACS includes a regional analysis of coastal storm risk in the Tier 1 Risk Assessment, which closely follows the Tier 1 Risk Assessment developed in the NACCS.

The NACCS characterizes risk in terms of consequence and hazard whereby weighted exposure indices were multiplied by the probability of the annual exceedance probability (AEP) of a flood hazard. A Composite Exposure Index (CEI) comprised of separate weighted exposure elements was multiplied by the AEP of a flood hazard to yield the Composite Risk Index. This appendix explains the methodology to develop the Tier 1 Risk Assessment, as well as additional geospatial datasets developed to support SACS study products.

Additionally, while utilizing the CSRM Framework, the SACS generated a variety of geospatial datasets to better understand coastal storm risk, environmental risk, economic damages, and risk management efforts across the study area. The SACS Geoportal provides access to and download of these data: http://data-sacs.opendata.arcgis.com/. Several web mapping applications have also been developed to aid in visualizing SACS geospatial data. This appendix provides an inventory of the applications developed during the study, as well as details and access information.

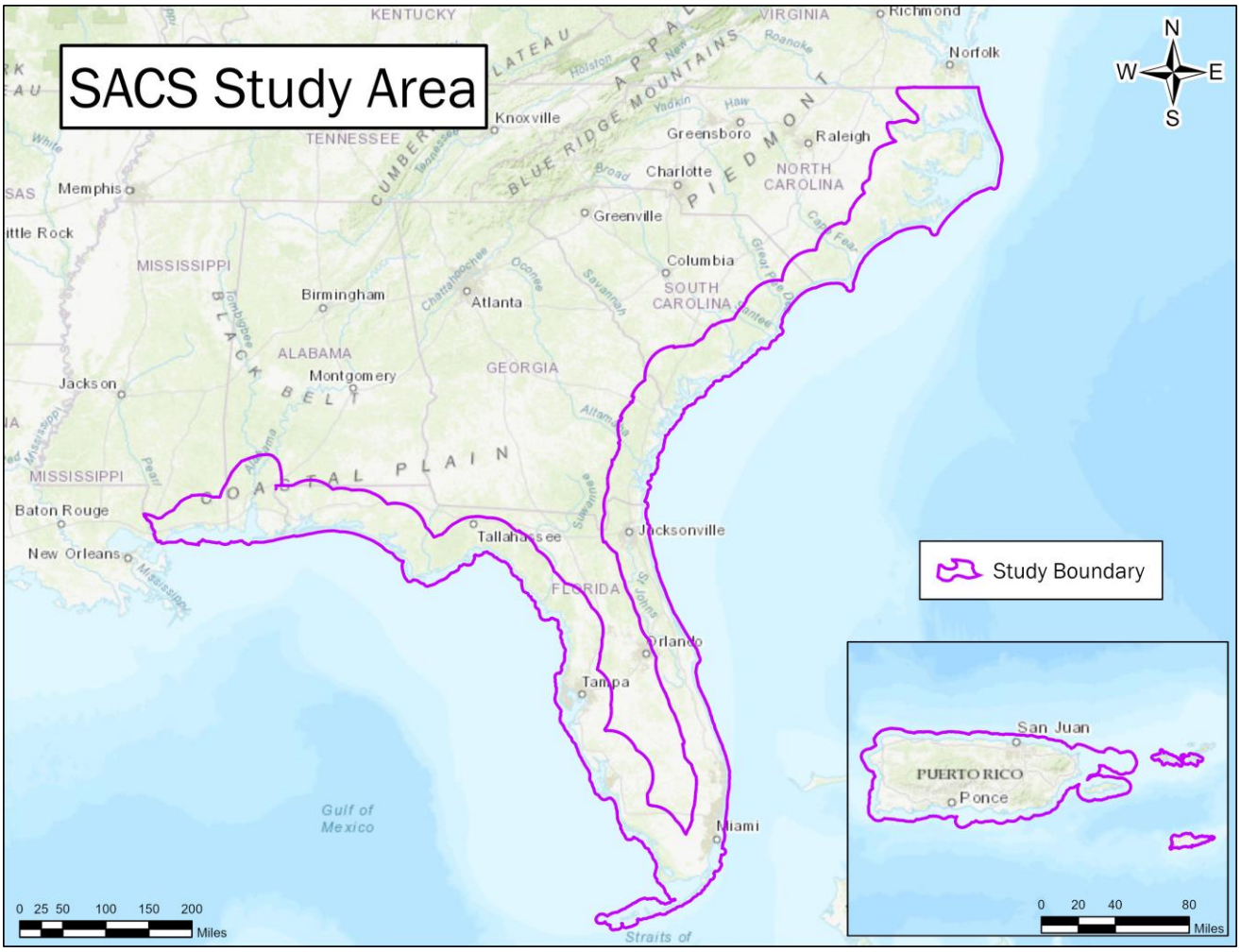

Figure 1-1: SACS Study Area

SECTION 2
Tier 1 Risk Assessment

2.1 Overview

The Tier 1 Risk Assessment is a regional analysis using national-level datasets across the SACS study area to identify areas of potential risk to coastal flood events. The methodology used closely aligns with the risk assessment used in the USACE NACCS (USACE 2015). The primary output of the Tier 1 Risk Assessment is the Composite Risk Index, which is derived by multiplying the probability of a coastal flood hazard occurring against a CEI, a weighted aggregate of exposure datasets related to population, infrastructure, social vulnerability, environmental, and cultural resources. The SACS CEI used a weighting of 60-percent population and infrastructure data, 30-percent environmental and cultural resources data, and 10-percent social vulnerability data. To capture future coastal flood risks, 3 feet of sea level rise was added to the Hazard Index for the 10-percent and 1-percent AEP flood events. This section details the input datasets used in the analysis, as well as the geographic information system (GIS) models developed to derive the various exposure, hazard, and risk outputs.

2.2 Exposure Index Datasets

The majority of exposure datasets incorporated into the Tier 1 Risk Assessment were also used in the NACCS Tier 1 Risk Assessment. The NACCS assigned a weighting to each exposure dataset to characterize the relative importance of data layers to other data in the analysis because these elements related to the effects to population and communities during a coastal flood event (USACE 2015). This section details the assigned weightings, data sources, and geoprocessing of exposure datasets.

2.2.1 Population and Infrastructure Data

Population data were gathered from the 2015 Census TIGER Census Tracts (US Census 2015). Data were reported as the number of persons per square mile in each census tract. Infrastructure data were gathered from the Department of Homeland Security's Homeland Infrastructure Foundation-Level Data (HIFLD) OpenData website (DHS 2017). Infrastructure density is the number of assets (pieces of infrastructure) per square mile in each census tract. Any missing datasets in the 2017 HIFLD data catalog that NACCS used in the analysis were supplemented with the HSIP 2015 dataset (DHS 2015). Military installation, ranges, and training areas geospatial boundaries were obtained via the Office of the Assistant Secretary of Defense for Sustainment (DOD OASD 2015).

2.2.1.1 Infrastructure Categories and Weights

Infrastructure features were assigned a weight value between zero and 30 from Appendix C of the NACCS study (USACE 2015). **Table 2-1** provides a summary of infrastructure data and associated weights.

Table 2-1: Infrastructure Categories and Weights (DHS 2015, 2017; DOD OASD 2015)

Infrastructure Category	Infrastructure	Weight (0–30)	Infrastructure Category	Infrastructure	Weight (0–30)
Academics	Colleges/Universities	15	Medical	Urgent Care Facilities	20
Academics	Private Schools	10	Sewage	Wastewater Treatment Plants	30
Academics	Public Schools	15	Trade	Intermodal Terminal Facilities	15
Civil	Canal	15	Trade	Pier/Wharf/Quay	15
Civil	Channel	20	Trade	Ports	15
Civil	Dams	25	Transportation	Airports	15
Electricity	Substations	20	Transportation	Amtrak Stations	15
Electricity	Electric Generating Units	20	Transportation	Bus Stations	5
Electricity	Electric Power Generation Plants	25	Transportation	Ferry	5
Electricity	Nuclear Power Plants	25	Transportation	Ferry Route	10
Electricity	Transmission Lines	20	Transportation	Gas Stations	20
Energy	Energy Distribution Control Facilities	20	Transportation	Hurricane Evacuation Routes	20
Energy	Natural Gas (liquefied natural gas [LNG]) Import Terminals	25	Transportation	Railroad	20
Energy	Natural Gas compressor Stations	15	Transportation	Railroad Bridges	20
Energy	Natural Gas Import/Export Points	5	Transportation	Railroad Stations	20
Energy	Natural Gas Receipt and Delivery Points	10	Transportation	Railroad Yards	20
Energy	Natural Gas Storage Facilities	15	Transportation	Road and Railroad Bridges	20
Energy	Oil and Natural Gas Interconnects	5	Transportation	Road and Railroad Tunnels	20
Energy	Oil and Natural Gas Pipelines	20	Water	Water Treatment Facilities	30
Energy	Oil Refineries	20	Safety	Fire Stations	30
Energy	Petroleum Pumping Stations	10	Safety	Law Enforcement Location	25
Energy	Petroleum (POL) Terminals/Storage Facilities/Tank Farms	15	Safety	Local Emergency Operation Centers	20
Human Services	All Places of Worship	15	Safety	National Shelter System	20
Human Services	Nursing Homes	25	Safety	State Emergency Operation Centers	20
Medical	Emergency Management System (EMS)	25	Human Services	Service Providers	25
Medical	Hospitals	30	Information	Cellular Towers	10
Medical	Pharmacies	15	Information	Communication Centers	15
Medical	Receiving Hospitals	30	Military	Military Installations, Ranges, Training Areas	30

2.2.1.2 Population and Infrastructure Data – Puerto Rico and the U.S. Virgin Islands

Puerto Rico and the U.S. Virgin Islands required several infrastructure dataset substitutions, given that certain datasets used in the U.S. mainland were not robust or complete in the territories. To maintain consistency with the index generation methodology used for the mainland, while also creating as accurate a picture of true infrastructure exposure as possible, several alternate data sources were used. Weighting of these data remained the same. **Table 2-2** details dataset substitutions and sources for Puerto Rico. **Table 2-3** details dataset substitutions for the U.S. Virgin Islands.

Table 2-2: Puerto Rico Infrastructure Dataset Substitutions (CUNY 2019; FEMA 2018; Gobierno de PR 2020; NOAA 2014; OSM 2020; USACE 2017)

Infrastructure Category	Infrastructure	Weight (0–30)	Source
Academics	Private Schools	10	City University of New York Hunter–Center for Puerto Rican Studies
Safety	State Emergency Operation Centers	20	Federal Emergency Management Agency (FEMA) Region II
Human Services	Nursing Homes	25	FEMA Region II
Safety	Local Emergency Operation Centers	20	FEMA Region II
Transportation	Gas Stations	20	FEMA Region II
Transportation	Railroad Stations	20	FEMA Region II
Information	Communication Centers	15	Gobierno de Puerto Rico [Government of Puerto Rico]
Information	Cellular Towers	10	Gobierno de Puerto Rico
Human Services	All Places of Worship	15	Gobierno de Puerto Rico
Transportation	Airport Boundaries	15	Gobierno de Puerto Rico
Transportation	Railroad	20	Gobierno de Puerto Rico
Transportation	Ferry Route	10	Gobierno de Puerto Rico
Electricity	Transmission Lines	20	Gobierno de Puerto Rico
Electricity	Electric Power Generation Plants	25	Gobierno de Puerto Rico
Electricity	Substations	20	Gobierno de Puerto Rico
Energy	Energy Distribution Control Facilities	20	Gobierno de Puerto Rico
Water	Water Treatment Facilities	30	Gobierno de Puerto Rico
Sewage	Wastewater Pump Stations	30	Gobierno de Puerto Rico
Sewage	Wastewater Treatment Plants	30	Gobierno de Puerto Rico
Transportation	Hurricane Evacuation Routes	20	National Tsunami Hazard Mitigation Program (NTHMP)/National Oceanic and Atmospheric Administration (NOAA) (Tsunami Route)
Medical	Pharmacies	15	OpenStreetMap
Civil	Channel	20	USACE–National Channel Framework

Table 2-3: U.S. Virgin Islands Infrastructure Dataset Substitutions (Gobierno de PR 2020; Guannel 2018; USACE 2017)

Infrastructure Category	Infrastructure	Weight (0-30)	Source
Information	Communication Centers	15	Gobierno de Puerto Rico
Information	Cellular Towers	10	Gobierno de Puerto Rico
Transportation	Airport Boundaries	15	University of the Virgin Islands (via Greg Guannel)
Sewage	Wastewater Pump Stations	30	University of the Virgin Islands (via Greg Guannel)
Sewage	Wastewater Treatment Plants	30	University of the Virgin Islands (via Greg Guannel)
Medical	Pharmacies	15	University of the Virgin Islands (via Greg Guannel)
Human Services	All Places of Worship	15	University of the Virgin Islands (via Greg Guannel)
Safety	Law Enforcement Location	25	University of the Virgin Islands (via Greg Guannel)
Academics	Private Schools	10	University of the Virgin Islands (via Greg Guannel)
Safety	State Emergency Operation Centers	20	University of the Virgin Islands (via Greg Guannel)
Electricity	Electric Power Generation Plants	25	University of the Virgin Islands (via Greg Guannel)
Electricity	Substations	20	University of the Virgin Islands (via Greg Guannel)
Civil	Channel	20	USACE–National Channel Framework

2.2.2 Environmental, Cultural Resources, and Habitat Data

Three separate indices were developed to characterize significant environmental, habitat, and cultural resources in the study area. These indices were eventually aggregated into the composite Tier 1 Environmental and Cultural Resources Exposure Index. **Table 2-4**, **Table 2-5**, and **Table 2-6** describe the geospatial datasets, their sources, and their respective weighting in consistency with the weightings used in NACCS Appendix C (USACE 2015).

2.2.2.1 Environmental Data

The Tier 1 Risk Assessment Environmental Index Data are documented in **Table 2-4**, including the data location, sources, source year, and weighting. Whenever possible, datasets used in the NACCS were utilized in the SACS analysis to provide a consistent regional risk assessment that is seamless between the areas of responsibility (AOR) for the North Atlantic Division (NAD) and the South Atlantic Division (SAD).

Table 2-4: Tier 1 Environmental Data (FWS 2016, FWS 2017, FWS 2017b; NOAA 2012; DHS 2015; TNC 2018; National Audubon Society 2018)

Environmental Dataset	Source	Weight (1–100)
Coastal Barrier Islands under the Coastal Barrier Resources Act (CBRA)	US Fish and Wildlife Service	91
US Fish and Wildlife Service Refuges	US Fish and Wildlife Service	86
Rare, Threatened, and Endangered Species	US Fish and Wildlife Service	89
The Nature Conservancy Conservation Areas	The Nature Conservancy	73
City, County, State and Federal Parks > 100 acres	Department of Homeland Security–Homeland Infrastructure Foundation-Level Data	44
National Estuarine Research Reserves	National Oceanic and Atmospheric Administration	75
Important Bird Areas	National Audubon Society	75

2.2.2.2 Habitat Data

Table 2-5 documents the habitat data used to create the Tier 1 Environmental and Cultural Resources Index, including the data location, sources, source year, and weighting. Whenever possible, datasets used in the NACCS were used in the SACS analysis to provide a consistent regional risk assessment that is seamless between the AORs for NAD and SAD.

Table 2-5: SACS Habitat Data (UNEP 2018; NOAA 2018, 2017, 2017b, 2016; FWS 2018)

Habitat Dataset	Source	Weight (1–100)
Seagrasses	United Nations Environmental Program–World Conservation Monitoring Centre	88
Estuarine Emergent Marsh	National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) Landcover Classifications	96
Forested Wetland	NOAA C-CAP Landcover Classifications	80
Scrub-Shrub Wetland	NOAA C-CAP Landcover Classifications	73
Freshwater Forested/Shrub Wetland	US Fish and Wildlife Service–National Wetland Inventory	82
Riverine Wetlands	US Fish and Wildlife Service–National Wetland Inventory	61
Rocky Shoreline	NOAA Environmental Sensitivity Index (ESI)	31
Unconsolidated Shore–Mud, Organic, Flat	NOAA ESI	47
Unconsolidated Shore–Sand, Gravel, Cobble	NOAA ESI	66

2.2.2.3 Cultural Resources Data

Table 2-6 documents the cultural data from the Tier 1 Environmental and Cultural Resources Index, including the data location, sources, source year, and weighting. Whenever possible, datasets used in the NACCS were used in the SACS analysis to provide a consistent regional risk assessment that is seamless between the AORs for NAD and SAD.

Table 2-6: SACS Cultural Resources Data (DHS 2015; NPS 2018)

Cultural Resources Dataset	Source	Weight (1-100)
National Monuments and Historic Boundaries	Department of Homeland Security– Homeland Infrastructure Foundation-Level Data (HIFLD)	85
Museums and Historic Sites	Department of Homeland Security–HIFLD	75
Historical Features	Department of Homeland Security–HIFLD	75
National Register of Historic Places	National Park Service	75

2.2.3 Social Vulnerability Data

The SACS adopted Social Vulnerability Index (SVI) values that have been developed by the Centers for Disease Control and Prevention (CDC 2016). The methodology and original SVI was published in 2011 and was updated in 2016. The SVI indicates the relative vulnerability of every U.S. census tract. The SVI ranks the tracts on 15 social factors, including unemployment, minority status, and disability, and further groups them into four related themes. Thus, each tract receives a ranking for each census variable and for each of the four themes, as well as an overall ranking. The SVI contains the following criteria:

- Socioeconomic Status (ST)
  - *Below Poverty*
  - *Unemployed*
  - *Income*
  - *No High School Diploma*
- Household Composition and Disability (HCD)
  - *Aged 65 or Older*
  - *Aged 17 or Younger*
  - *Civilian with a Disability*
  - *Single-Parent Households*
- Minority Status and Language (MSL)
  - *Minority*
  - *Speaks English "less than well"*
- Housing and Transportation (HT)
  - *Multi-unit Structures*
  - *Mobile Homes*
  - *Crowding*
  - *No Vehicle*
  - *Group Quarters*

2.3 Geographic Information System Models and Geoprocessing

2.3.1 Population and Infrastructure Exposure Indices

To construct the Population and Infrastructure Exposure Indices, the first step was to generate an aggregation of the categories of infrastructure defined in **Table 2-1**. Aggregation was performed using a set of two models in ArcGIS Pro (ESRI 2019). The first model, depicted in **Figure 2-1**, performed a spatial join on all the infrastructure feature data points, lines, and polygons with the aggregation data layer and census tract polygons. The output of the spatial join generates a new feature that includes a join-count of the intersecting layer. This join-count is used in the second model, depicted in **Figure 2-2**, to populate the respective infrastructure count total for each census tract and each infrastructure type.

Model 1 – Spatial Join

- Run the Spatial Join tool to join the features of interest to the census tract aggregation layer.
- From the output, rename the "join-count" column header to the feature description.
- Save the output to a single directory.

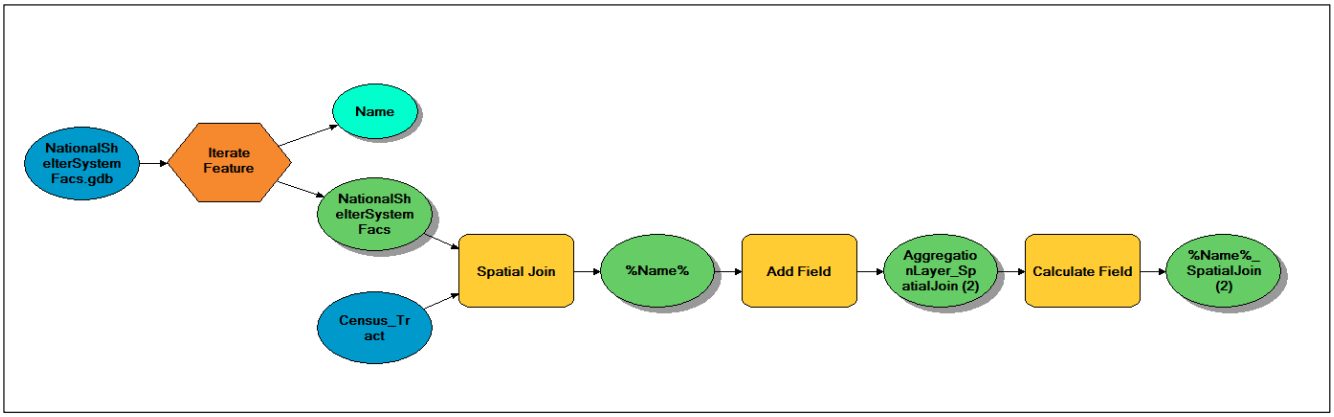

Figure 2-1: Model 1 – Spatial Join

Model 2 – Table Join

- Run the Table Join tool to populate the infrastructure feature count totals for each census tract and join it to the census tract aggregation layer for each infrastructure dataset.
- Alter the "join-count" field to match the infrastructure feature input.

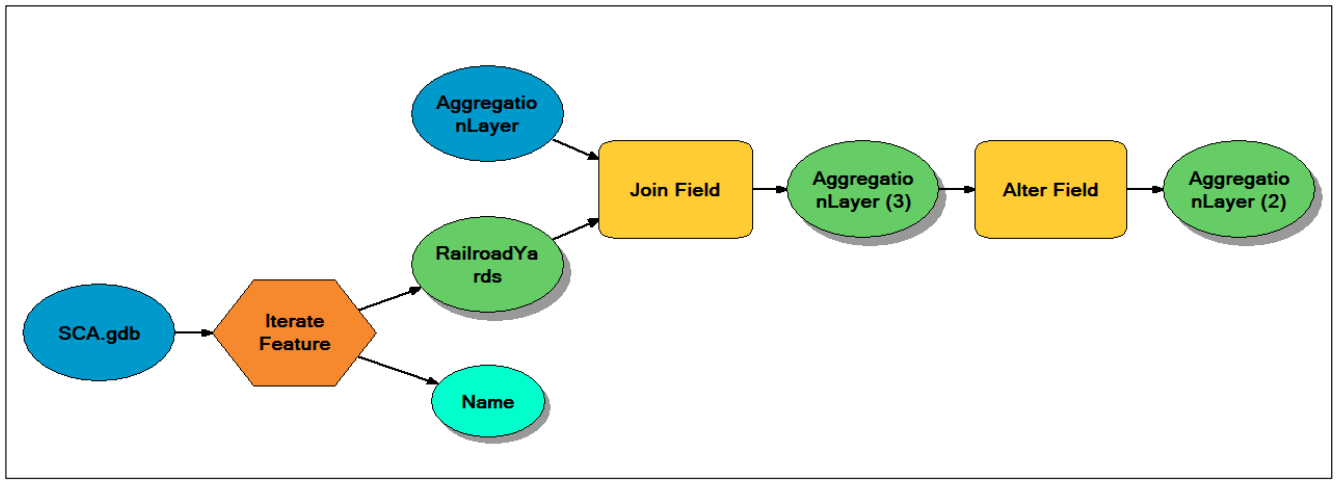

Figure 2-2: Model 2 – Table Join

2.3.1.1 Infrastructure Exposure Index

Points, lines, and polygon features for all infrastructure categories were weighted, aggregated to census tract layer, and normalized to the area of the census tract to yield a weighted infrastructure density (WID) raster.

$$WID = \sum_{i=1}^{n} \frac{w_i * I_i}{area}$$

Where w_i is equal to the weighting in **Table 2-1**; I_i is an individual infrastructure element; *area* is the area of the census tract in square miles.

The Weighted Infrastructure Density Percentile Index (WIDPI) raster was calculated by ranking the WID for all 4,579 census tracts within the mainland of the SACS study area.

$$WIDPI = \frac{(rank - 1)}{(N - 1)}$$

Where $rank$ is the order of the WID for each census tract and N is the total number of census tracts (4,579 tracts in the continental United States).

This process was repeated separately to the census tract level for Puerto Rico. For the U.S. Virgin Islands, infrastructure density was calculated to the estate level, to provide better resolution of exposure in the territory.

2.3.1.2 Population Exposure Index

Population counts were normalized to the area of the census tract to yield a population density (PD) raster.

$$PD = \sum_{i=1}^{n} \frac{P_i}{area}$$

Where P_i represents an individual person and *area* is the area of the census tract in square miles. The Population Density Percentile Index (PDPI) raster was calculated by ranking the PD for all 4,579 census tracts within the SAD continental United States AOR.

$$PDPI = \frac{(rank - 1)}{(N - 1)}$$

Where rank is the order of the PD for each census tract and N is the total number of census tracts.

For the U.S. Virgin Islands, population density was calculated to the estate level, to provide better resolution of exposure for the territory.

2.3.1.3 Population and Infrastructure Exposure Index

For each census tract in the SAD AOR, the Population and Infrastructure Exposure Index (PIEI) raster was created through the summation of WIDPI and PDPI.

$$PIEI = WIDPI + PDPI$$

2.3.2 Environmental, Cultural Resources, and Habitat Exposure Indices

The Environmental, Cultural Resources, and Habitat Exposure Indices depicted the absence, presence, or aggregate of environmental, cultural resources, or habitat geospatial features.

2.3.2.1 Environmental Exposure Index

Environmental features were weighted and converted to pixels in a common grid in the study area. The pixels were then summed to generate an aggregate value. Finally, the values were normalized using the maximum aggregated value. This procedure yielded the Weighted Environmental Index (WEI) raster.

$$WEI = \sum_{i=1}^{n} w_i * E_i \Big/ max(w_i * E_i)$$

Where w_i is equal to the weighting in **Table 2-4** and E_i is an individual environmental feature. **Figure 2-3** depicts the GIS model developed to aggregate and grid environmental features. Similar models were developed to grid and aggregate cultural resources and habitat features. Environmental characteristics were weighted in the same manner as in Appendix C of the NACCS study (USACE 2015).

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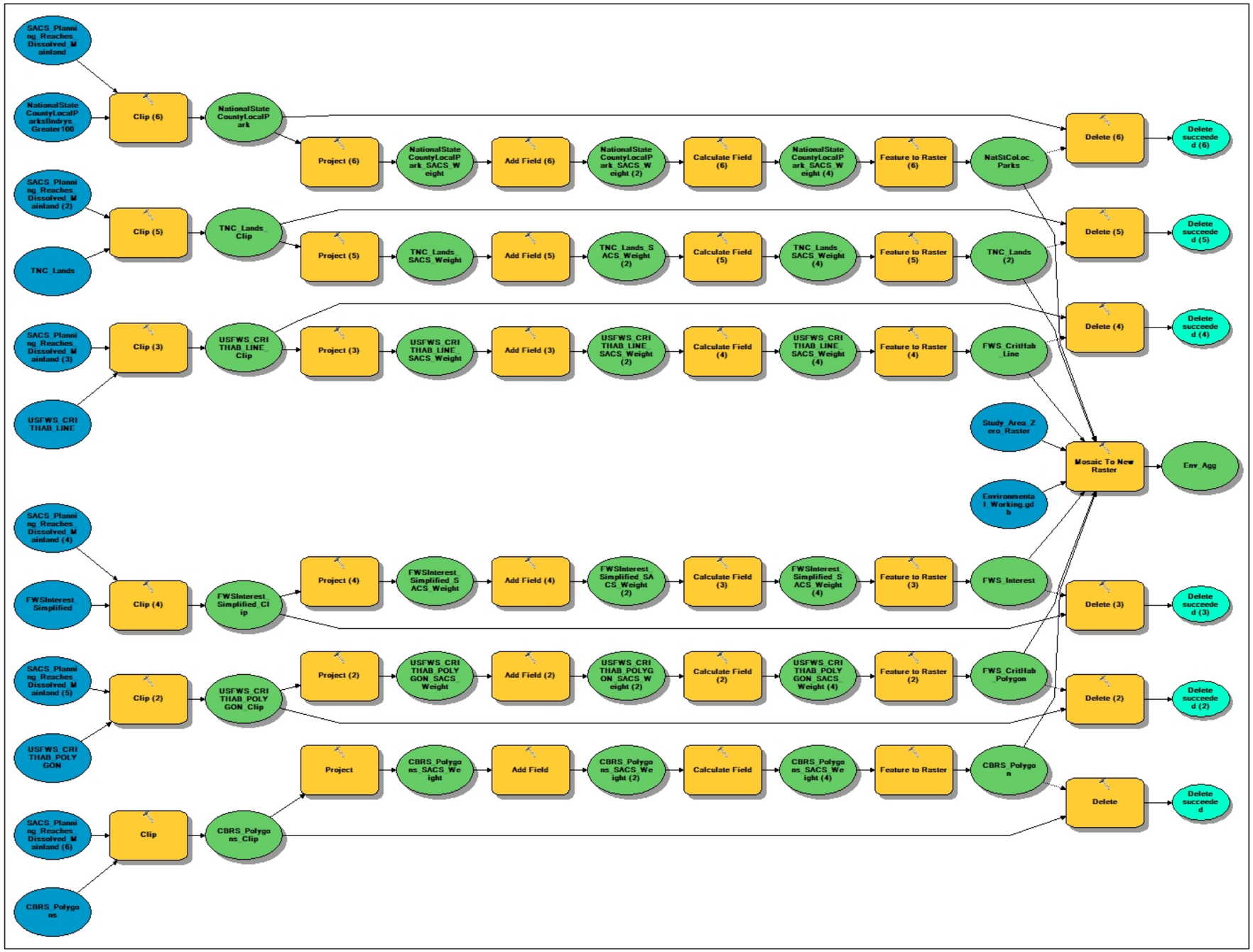

Figure 2-3: Environmental Exposure Index Model

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2.3.2.2 Cultural Resources Exposure Index

Cultural features were weighted and converted to pixels in a common grid in the study area. The pixels were then summed to generate an aggregate value. Finally, the values were normalized using the maximum aggregated value. This procedure yielded the Weighted Cultural Index (WCI) raster.

$$WCI = \sum_{i=1}^{n} w_i * C_i \Big/ max(w_i * C_i)$$

Where w_i is equal to the weighting in **Table 2-6** and C_i is an individual cultural feature. Cultural features were weighted in the same manner as in Appendix C of the NACCS study (USACE 2015).

2.3.2.3 Habitat Exposure Index

Habitat features were weighted and converted to pixels in a common grid in the study area. The pixels were then summed to generate an aggregate value. Finally, the values were normalized using the maximum aggregated value. This procedure yielded the Weighted Habitat Index (WHI) raster.

$$WHI = \sum_{i=1}^{n} w_i * H_i \Big/ max(w_i * H_i)$$

Where w_i is equal to the weighting in **Table 2-5** and H_i is an individual habitat feature. Habitat features were weighted in the same manner as in Appendix C of the NACCS study (USACE 2015).

2.3.2.4 Environmental and Cultural Resources Exposure Index

Environmental, cultural resources, and habitat elements were weighted in the same manner as in Appendix C of the NACCS study (USACE 2015). A composite Environmental and Cultural Resources Exposure Index (ECREI) raster was created by applying the NACCS model: 30-percent weighting for environmental, 30-percent weighting for habitat, and 40-percent weighting for cultural resources:

$$ECREI = 0.3 * WEI + 0.4 * WCI + 0.3 * WHI$$

2.3.3 Social Vulnerability Exposure Index

The Tier 1 Risk Assessment Social Vulnerability Exposure Index raster was generated directly from the CDC's SVI for 2016. The following is the documentation detailing the methodology for generating an overall ranking:

"We ranked census tracts within each state and the District of Columbia, to enable mapping and analysis of relative vulnerability in individual states. We also ranked tracts for the entire United States against one another, for mapping and analysis of relative vulnerability in multiple states, or across the U.S. as a whole. Tract rankings are based on percentiles. Percentile ranking values range from 0 to 1, with higher values indicating greater vulnerability.

For each tract, we generated its percentile rank among all tracts for 1) the fifteen individual variables, 2) the four themes, and 3) its overall position.

Theme rankings: For each of the four themes, we summed the percentiles for the variables comprising each theme. We ordered the summed percentiles for each theme to determine theme-specific percentile rankings" (CDC 2016).

The four-summary theme ranking variables are as follows:

1) Socioeconomic Status (ST) – (Field: RPL_THEME1).
2) Household Composition and Disability (HCD) – (Field: RPL_THEME2).
3) Minority Status and Language (MSL) – (Field: RPL_THEME3).
4) Housing and Transportation (HT) – (Field: RPL_THEME4).

The final SVI Index raster for each census tract was calculated through the summation of the four themes defined by the CDC.

$$SVI = ST + HCD + MSL + HT$$

SVI Percentile Index rankings of the census tracts within the SACS study area were calculated to produce the Social Vulnerability Exposure Index (SVEI).

$$SVEI = \frac{(rank - 1)}{(N - 1)}$$

Where rank is the order of the SVI for each census tract and N is the total number of census tracts (4,579 tracts for the continental United States). This same process was used for the census tract level for the CDC SVI data in Puerto Rico. CDC SVI data were unavailable for the U.S. Virgin Islands.

2.3.4 Composite Exposure Index

The three exposure indices, PIEI, ECREI, and SVEI, were combined to create a single CEI raster using the following weighting for each index:

1) PIEI Weight = 60 percent
2) ECREI Weight = 30 percent
3) SVEI Weight = 10 percent

$$CEI = 0.6 * PIEI + 0.3 * ECREI + 0.1 * SVEI$$

In **Figure 2-4**, raster pixels are labeled with the calculated CEI at a particular location.

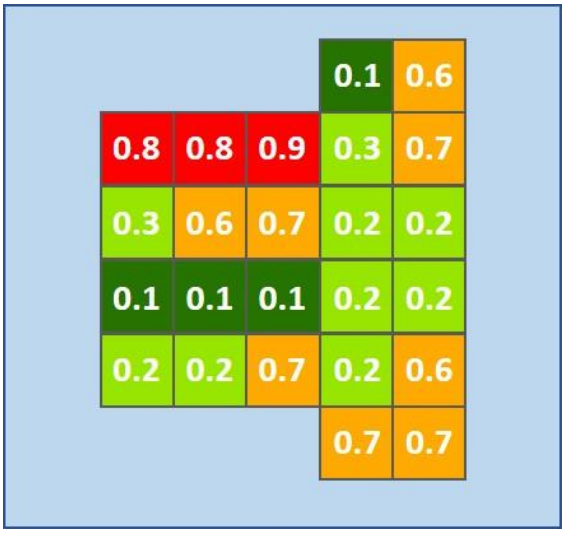

Figure 2-4: Composite Exposure Index – Simplified View

2.4 Hazard Surfaces

The following section describes the data and processes used to create the Tier 1 combined hazard surface.

2.4.1 Input Hazard Data

Input hazard data included a digital elevation model (DEM), 10-percent AEP water levels, 1-percent AEP water levels, and the Category 5 Maximum of Maximum (MOM) water levels.

The topographic DEM that was selected to represent surface elevations was from the NOAA Sea Level Rise Viewer (NOAA 2016b). Using this DEM and estimated water levels, the relative depth of flooding due to different hazards was calculated.

The 10-percent AEP water levels were determined at the gauges listed in **Table 2-7**. The methodology is outlined in the "North Atlantic Coastal Comprehensive Study Phase I: Statistical Analysis of Historical Extreme Water Levels with Sea Level Change" (Nadal-Caraballo, et al. 2016).

Table 2-7: Ten-Percent Annual Exceedance Probability Water Levels (mean) for the South Atlantic Division Area of Responsibility

Station ID	Location	Latitude	Longitude	Return Interval (years)
8652587	Oregon Inlet Marina, North Carolina	35° 47.7 N	75° 32.9 W	1.16
8654400	Cape Hatteras Fishing Pier, North Carolina	35° 13.4 N	75° 38.1 W	1.32
8656483	Beaufort, North Carolina	34° 43.2 N	76° 40.2 W	1.39
8658120	Wilmington, North Carolina	34° 13.6 N	77° 57.2 W	1.44
8661070	Springmaid Pier, South Carolina	33° 39.3 N	78° 55.1 W	1.79
8665530	Charleston, South Carolina	32° 46.8 N	79° 55.4 W	1.74

Station ID	Location	Latitude	Longitude	Return Interval (years)
8670870	Fort Pulaski, Georgia	32° 2.2 N	80° 54.1 W	1.99
8720030	Fernandina Beach, Florida	30° 40.3 N	81° 27.9 W	1.86
8720220	Mayport (Ferry Depot), Florida	30° 23.6 N	81° 25.9 W	1.42
8723170	Miami Beach, Florida	25° 46.1 N	80° 7.9 W	1.10
8723970	Vaca Key, Florida	24° 42.7 N	81° 6.4 W	0.64
8724580	Key West, Florida	24° 33.3 N	81° 48.5 W	0.77
8725110	Naples, Florida	26° 7.9 N	81° 48.4 W	1.23
8725520	Fort Myers, Florida	26° 38.9 N	81° 52.2 W	1.16
8726520	St. Petersburg, Florida	27° 45.6 N	82° 37.6 W	1.22
8726724	Clearwater Beach, Florida	27° 58.7 N	82° 49.9 W	1.29
8727520	Cedar Key, Florida	29° 8 N	83° 1.8 W	1.63
8728690	Apalachicola, Florida	29° 43.5 N	84° 58.8 W	1.41
8729840	Pensacola, Florida	30° 24.2 N	87° 12.6 W	1.16
8735180	Dauphin Island, Alabama	30° 15 N	88° 4.5 W	1.15
8747437	Bay Waveland Yacht Club, Mississippi	30° 19.5 N	89° 19.5 W	1.67
9751401	Lime Tree Bay, Virgin Islands	17° 41.7 N	64° 45.2 W	0.41
9751639	Charlotte Amalie, Virgin Islands	18° 20.1 N	64° 55.2 W	0.41
9755371	San Juan, Puerto Rico	18° 27.6 N	66° 7 W	0.57
9759110	Magueyes Island, Puerto Rico	17° 58.2 N	67° 2.8 W	0.37

The FEMA National Flood Hazard Layer was used to represent the 1-percent AEP water level (FEMA 2017).

The Category 5 MOM hazard surfaces were sourced from NOAA's National Storm Surge Hazard Maps (Zachry et al. 2015). The data was derived using the Sea, Lake, and Overland Surges from Hurricane (SLOSH) model (Jelesnianski et al. 1992).

2.4.2 Combined Hazards

The Tier 1 Combined Hazard Surface raster was created by intersecting the 10-percent AEP water level, the 1-percent AEP water level, and the Category 5 MOM onto a single raster map. Individual raster element values (REVs) were created by applying a qualitative "orness" measure for any AEP flood for each raster element. The REV was selected based on its proximity to the OR operator that yields the maximum of the given data.

$$REV = \max_{0 \le x \le 1} \{P(10\%\ annual\ flood)\ OR\ P(1\%\ annual\ flood)\ OR\ P(CAT\ 5\ MOM)\ \}$$

Figure 2-5 depicts a simplified view of the Combined Hazard Surface.

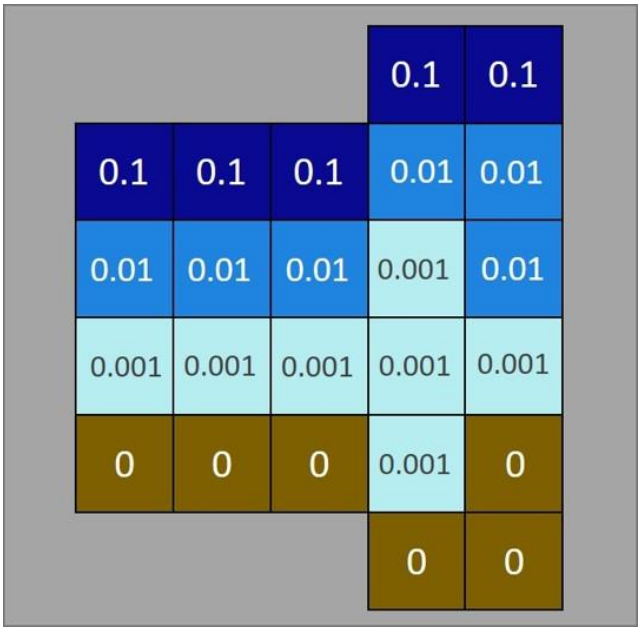

Figure 2-5: Combined Hazard Surface Simplified

Raster pixels are labeled with the *maximum* AEP of the flood that could occur at that location. Individual probabilities at each location represent the AEP occurrence of the 10-percent, 1-percent, or Category 5 MOM storms.

2.5 Composite Risk Index

As a final step, the Composite Risk Index (CRI) raster is calculated by multiplying the REV from the combined hazard surface and the CEI at every raster pixel (**Figure 2-6**).

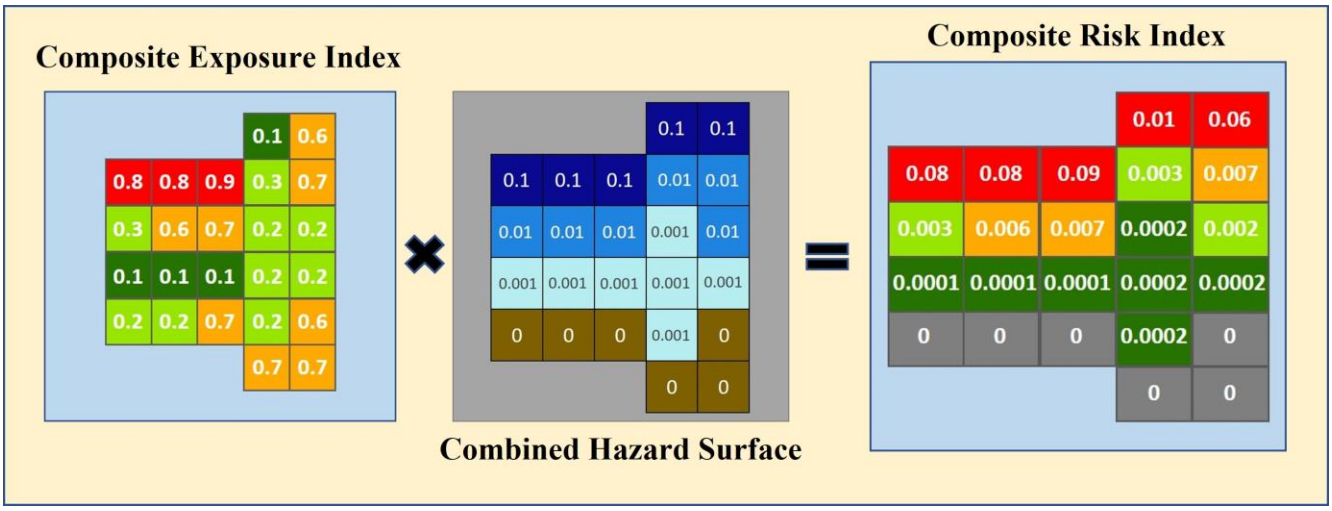

*Figure 2-6: Composite Risk Index Simplified: Composite Risk Index = Raster Element Value*Composite Exposure Index*

2.6 Sea Level Rise

To maintain consistency with the NACCS, a similar sea level rise scenario was incorporated into the Tier 1 Risk Assessment. Three feet of sea level rise was added to the 1-percent and 10-percent AEP flood hazard layers to simulate future flooding given 3 feet of relative sea level rise for the 10-percent AEP and 1-percent AEP coastal storms.

2.7 SACS Tier 1 Risk Assessment Viewer

Tier 1 Risk Assessment data are published as map services viewable in the SACS Tier 1 Risk Assessment Viewer: https://sacs.maps.arcgis.com/apps/MapSeries/index.html?appid=c54beb5072a04632958f2373eb1151cf)

This tabbed StoryMap includes embedded web applications for the various exposure indices, hazard grids, and risk indices. The Tier 1 Risk Assessment Overview tab, as seen in **Figure 2-7**, is an interactive walk-through of the Tier 1 Risk Assessment methodology and includes map services from authoritative sources used in the analysis. The Risk Index Comparison tab includes an embedded dashboard that allows users to identify the drivers of potential risk, such as high infrastructure or population density, and/or high flood probabilities.

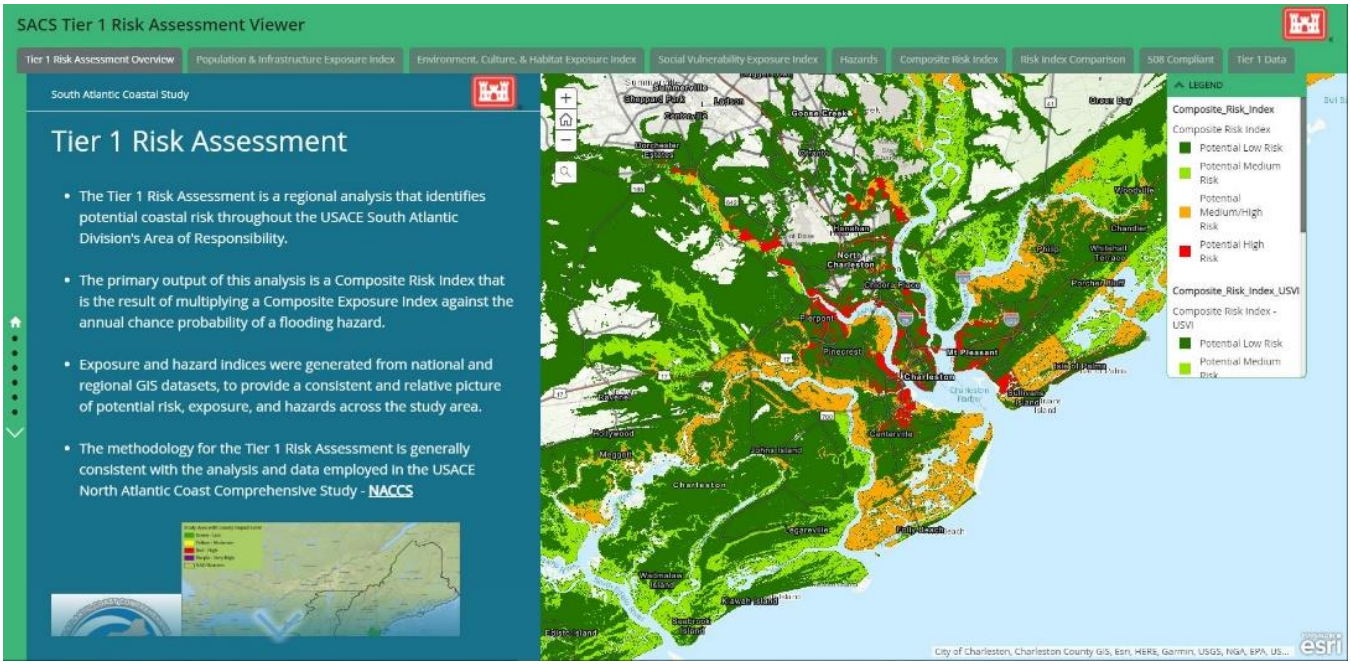

Figure 2-7: SACS Tier 1 Risk Assessment Viewer

SECTION 3

SACS Geospatial Data and Applications

3.1 Overview

In addition to the Tier 1 Risk Assessment, a variety of additional geospatial datasets and applications were developed to better characterize exposure, risk, and risk management measures to support the application of the CSRM Framework. These datasets and applications are available through the SACS Geoportal, a clearinghouse to discover, access, and visualize study data.

3.2 SACS National Oceanic and Atmospheric Administration Environmental Sensitivity Index Shoreline Data

To characterize shoreline types across the study area for the purposes of identifying potential CSRM strategies, SACS leveraged the NOAA ESI data, which provides a consistent shoreline dataset across the study area. While the primary use of these data is to support oil spill contingency planning, the data can also be used to support a variety of coastal planning applications (NOAA 2017b, 2000). Criteria used to characterize the shoreline included the shoreline setting, degree of exposure to wave and tidal energy, substrate composition, substrate permeability, slope, the presence of wetlands, development, coastal armor, and shoreline stabilization structures. **Table 3-1** provides detail on the NOAA ESI Shoreline Types used in the SACS.

Table 3-1: National Oceanic and Atmospheric Administration Environmental Sensitivity Index Code Descriptions (NOAA 2017b, 2000)

Environmental Sensitivity Index (ESI) Code	ESI Code Description
1A	Exposed Rocky Cliffs and Shores
2A	Exposed Wave-Cut Platforms (Bedrock/Mud/Clay)
2B	Exposed Scarps and Steep Slopes (Clay)
3B	Scarps and Steep Slopes (Sand)
3A	Fine- to Medium-Grained Sand Beaches
4	Coarse-Grained Sand Beaches
5	Mixed Sand and Gravel Beaches

Environmental Sensitivity Index (ESI) Code	ESI Code Description
6A	Gravel Beaches
8A	Sheltered Impermeable Rocky Shores
8D	Sheltered Rocky Rubble Shores
1B	Exposed Solid Man-made Structures
8B	Sheltered Solid Man-made Structures
6B	Exposed Riprap
8C	Sheltered Riprap
7	Exposed Tidal Flats
9A	Sheltered Tidal Flats
9B	Vegetated Low Banks
9C	Hyper-saline Tidal Flats
10A	Salt and Brackish Water Marshes
10B	Freshwater Marshes
10C	Swamps
10D	Scrub and Shrub Wetlands
10F	Mangroves

Shoreline segments 6D Boulder Rubble, 8E Peat Shorelines, and 8F Vegetated Steeply Sloping Bluffs were removed from the list above for consideration, because these include minimal feature counts in highly localized areas. Shoreline segments may be composed of more than one type of shoreline to adequately capture the shoreline sensitivity. Segments can have up to three ESI codes in a sequence separated by a slash, from the most landward to the most seaward. For example, moving from landward to seaward, a sheltered seawall fronted by a fine-grained beach behind an exposed tidal flat would be coded 8B/3A/7.

SACS NOAA ESI Shoreline Types were assigned based on a regression from the seaward to the most landward shoreline. This was done while maintaining any hardened structures or mangroves and using the leeward shoreline classifications when encountering 2A, 2B, 7, and 9A ESI classifications. Sheltered and exposed classifications throughout the SACS study area were incorporated based on the degree of energy present on one shoreline segment relative to the overall energy levels in the region. NOAA classified high-energy shorelines (1A–2B) as those regularly exposed to large waves or strong tidal currents during all seasons. These shorelines most commonly occur along the outermost coastline of a region or where dominant winds cause waves to strike the shoreline directly or by wave refraction. NOAA classified medium-energy shorelines (3A–7) as those with seasonal patterns in storm frequency and wave size. The low-energy shorelines (8A–10E) are sheltered from wave and tidal energy, except during unusual or infrequent events. High- and medium-energy shorelines were classified as exposed and low-energy were classified as sheltered. If a seaward shoreline was 2A, 2B, 7, or 9A, then the exposed shoreline classification for the leeward shoreline type was maintained. **Table 3-2** provides detail on the shoreline type generalizations for the SACS. **Table 3-3** provides detail on shoreline type information for rocky cliffs, scarps and steep slopes, beaches, rubble shores, and shorelines with man-made developments. **Table 3-4** provides detail on more vegetated shoreline types.

Table 3-2: SACS National Oceanic and Atmospheric Administration Environmental Sensitivity Index Shoreline Types (NOAA 2017b, 2000)

SACS National Oceanic and Atmospheric Administration (NOAA) Environmental Sensitivity Index (ESI) Shoreline Type	NOAA ESI Shoreline Types
Wetlands/Marshes/Swamps (Sheltered)	9A Sheltered Tidal Flats, 9B Vegetated Low Banks, 9C Hyper-Saline Tidal Flats, 10A Salt and Brackish Water Marshes, 10B Freshwater Marshes, 10C Swamps, and 10D Scrub and Shrub Wetlands
Wetland/Marshes/Swamps (Exposed)	2A Exposed, Wave-Cut Platforms (Bedrock/Mud/Clay), 2B Exposed Scarps and Steep Slopes (Clay), and 7 Exposed Tidal Flats
Mangroves	10F/10D Mangroves
Scarps and Steep Slopes	1A Exposed Rocky Cliffs (Mainland), 2B Exposed Scarps and Steep Slopes (Clay/Mud), and 3B Scarps and Steep Slopes (Sand)
Rocky Shores (Exposed)	1A Exposed Rocky Cliffs (Puerto Rico/Virgin Islands), 2A Exposed, Wave-Cut Platforms in Bedrock (Puerto Rico/US Virgin Islands). 6A Gravel Beaches, and Boulder Rubble
Rocky Shores (Sheltered)	8A Sheltered, Impermeable, Rocky Shores, Sheltered Scarps (Bedrock/Mud/Clay) and 8D Sheltered, Rocky, Rubble Shores
Man-made Structures (Exposed)	1B Exposed, Solid Man-made Structures and 6B Riprap
Man-made Structures (Sheltered)	8B Sheltered, Solid Man-made Structures and 8C Sheltered Riprap
Sandy Beaches (Exposed)	3A Fine- to Medium-Grained Sand Beaches, 4 Coarse-Grained Sand Beaches, 5 Mixed Sand and Gravel Beaches, and 7 Exposed Tidal Flats
Sandy Beaches (Sheltered)	Sheltered Tidal Flats

Table 3-3: Environmental Sensitivity Index Shoreline Types 1, 2, 3, 4, 5, 6, and 8 (NOAA 2017b, 2000)

Environmental Sensitivity Index Code & Designation	Energy*	Substrate Physical Properties	Substrate Shape & Slope
1A Exposed Rocky Cliffs and Shores	High	Impermeable substrates (bedrock).	Slope of intertidal zone is 30 degrees or more; narrow intertidal zone.
2A Exposed Wave-Cut Platforms (Bedrock/Mud/Clay)	High	Impermeable substrates; sediments can accumulate at cliff base; sediments can form into a beach on a rocky platform.	Slope of intertidal zone can range between 5 and 30 degrees.
2B Exposed Scarps and Steep Slopes (Clay)	High	Impermeable substrates; sediments can accumulate at cliff base; sediments can form into a beach on a rocky platform.	Slope of intertidal zone can range between 5 and 30 degrees.
3A Fine- to Medium-Grained Sand Beaches	Mixed	Semi-permeable substrate; well-sorted sediments; slow accretion between storms.	Slope ranges from low to intermediate; on beaches slope can be less than 5 degrees.
3B Scarps and Steep Slopes (Sand)	Mixed	Semi-permeable substrate; well-sorted sediments; slow accretion between storms.	Slope ranges from low to intermediate; on beaches slope can be less than 5 degrees.
4 Coarse-Grained Sand Beaches	Mixed	Permeable substrate; sediment is soft.	Slope ranges between 5 and 15 degrees.

Environmental Sensitivity Index Code & Designation	Energy*	Substrate Physical Properties	Substrate Shape & Slope
5 Mixed Sand and Gravel Beaches	Mixed	Med-high permeability; significant spatial variation in grain size distribution; sediments are soft.	Intermediate slope between 8 and 15 degrees.
6A Gravel Beaches	Mixed	Highly permeable substrate; gravel size sediments.	Slope is intermediate to steep (10–20 degrees).
8A Sheltered Impermeable Rocky Shores	Low	Substrate is hard and impermeable, bedrock or stiff clay.	Slope is steep (greater than 15 degrees); narrow intertidal zone.
8D Sheltered Rocky Rubble Shores	Low	Substrate is hard and impermeable, bedrock or stiff clay.	Slope is steep (greater than 15 degrees); narrow intertidal zone.
1B Exposed Solid Man-made Structures	High	Impermeable substrates (cement).	Slope of intertidal zone is 30 degrees or more; narrow intertidal zone.
8B Sheltered Solid-Man-made Structures	Low	Substrate is hard and impermeable, man-made materials. Property and Infrastructure	Slope is steep; narrow intertidal zone.
6B Exposed Riprap	Mixed	Highly permeable man-made substrate.	Slope is intermediate to steep (10–20 degrees).
8C Sheltered Riprap	Low	Highly permeable man-made substrate.	Slope is intermediate to steep (10–20 degrees).

*Low: Sheltered from regular exposure to wave and tidal energy except during low frequency storm events.
High: Regular exposure to high wave energy and tidal currents. Regular strong wave reflection patterns are common.
Mixed: Exposure to wave and tidal energy tends to be seasonal.

Table 3-4: Environmental Sensitivity Index Shoreline Types 7, 9, and 10 (NOAA 2017b; 2000)

Environmental Sensitivity Index Code & Designation	Energy*	Substrate Physical Properties	Substrate Shape & Slope	Biological Characteristics
7 Exposed Tidal Flats	Mixed	Highly permeable substrate (sand, silt, gravel).	Flat (less than 3 degrees); width ranges from a few meters to a kilometer	High infaunal density.
9A Sheltered Tidal Flats	Low	Semi-permeable muddy substrate: sediments are water-saturated.	Flat (less than 3 degrees); width ranges from a few meters to a kilometer	Can be important feeding areas for birds and rearing areas for fish; high infaunal density.
9B Vegetated Low Banks	Low	Semi-permeable muddy substrate: sediments are water-saturated.	Flat (less than 3 degrees); width ranges from a few meters to a kilometer	Can be important feeding areas for birds and rearing areas for fish; high infaunal density.

Environmental Sensitivity Index Code & Designation	Energy*	Substrate Physical Properties	Substrate Shape & Slope	Biological Characteristics
9C Hyper-saline Tidal Flats	Low	Semi-permeable muddy substrate: sediments are water-saturated.	Flat (less than 3 degrees); width ranges from a few meters to a kilometer	Can be important feeding areas for birds and rearing areas for fish; high infaunal density.
10A Salt and Brackish Water Marshes	Low	Permeable substrate; varies from mud to sand.	Flat with widely variable intertidal zone width	High biological use and value; swamps tend to have tallest vegetation.
10B Freshwater Marshes	Low	Permeable substrate; varies from mud to sand.	Flat with widely variable intertidal zone width	High biological use and value; swamps tend to have tallest vegetation.
10C Swamps	Low	Permeable substrate; varies from mud to sand.	Flat with widely variable intertidal zone width	High biological use and value; swamps tend to have tallest vegetation.
10D Scrub and Shrub Wetlands	Low	Permeable substrate; varies from mud to sand.	Flat with widely variable intertidal zone width	High biological use and value; swamps tend to have tallest vegetation.
10F Mangroves	Low	Permeable substrate; varies from mud to sand.	Flat with widely variable intertidal zone width	High biological use and value; swamps tend to have tallest vegetation.

*Low: Sheltered from regular exposure to wave and tidal energy except during low frequency storm events.
High: Regular exposure to high wave energy and tidal currents. Regular strong wave reflection patterns are common.
Mixed: Exposure to wave and tidal energy tends to be seasonal.

3.3 SACS Boundary Geospatial Data

The SACS provides a variety of technical study products specific to various disciplines and technical analyses. Several of these products include geospatial outputs, often with similar geographic boundaries for aggregation purposes. To streamline the distribution of these geospatial data, multiple outputs are provided to shared geographic boundaries in their respective attribute tables. For example, specific census places may have been designated as high risk under existing or sea level rise conditions under the Tier 1 Risk Assessment. These same census places may also contain aggregated dollar damage risk by AEP events from the Tier 2 Economic Risk Assessment. The SACS Geoportal provides a single download and visualization of “SACS Census Places” with attribution from multiple outputs. **Table 3-5** details the various geographic boundaries used for aggregation purposes from SACS technical products.

Table 3-5: SACS Boundary Geospatial Data (US Census Bureau 2019, 2019b, 2019c, 2017)

Dataset	Tier 1 Risk Assessment	Tier 2 Economic Risk Assessment	Sand Availability and Needs Determination
SACS Census Blocks		X	
SACS Census Places	X	X	
SACS Counties (including Puerto Rico Municipios and US Virgin Islands)	X	X	X
SACS States (including Puerto Rico and the US Virgin Islands)	X	X	X

Additionally, SACS developed or sourced boundary areas for specific study purposes. Various district project delivery teams (PDT), with input from stakeholders, created the SACS focus areas. Focus areas often utilized existing geographic boundaries such as watershed areas, metropolitan areas, or county boundaries. The SACS Priority Environmental Areas were identified by the SACS Environmental PDT. The geographic boundaries of these areas were sourced from a variety of datasets, including the U.S. Geological Society (USGS) Protected Area Database, state and local designated environmental resource areas, and local parcel data (USGS 2016). Attribution for each area is available via the attribute table and metadata records for these data.

3.4 SACS Geoportal

The SACS Geoportal serves as a clearinghouse for geospatial data and applications developed for the study. The website, depicted in **Figure 3-1**, utilizes ESRI's ArcGIS Online OpenData platform to provide geospatial data via both map services, as well as a variety of download options. Additionally, the SACS Geoportal includes sites pages specific to technical products that contain geospatial outputs. SACS geospatial data include both vector and raster data. Vector data are available for download by both the search function and by themed categories from the OpenData platform. Given the larger file sizes associated with raster or gridded data across the study area, these data are accessible via download links in web mapping applications and clipped to specific geographic areas to improve download performance.

Figure 3-1: SACS Geoportal Home Page

A variety of web mapping applications were developed for the SACS and are available in the SACS Geoportal. These applications visualize the outputs of specific study products and technical analyses. **Table 3-6** provides an inventory of these applications, the application type, and the URL to access them.

Table 3-6: SACS Geospatial Applications

Application Name	Study Product	Application Type	URL
SACS Tier 1 Risk Assessment Viewer	Tier 1 Risk Assessment	Tabbed StoryMap with embedded Web Mapping Applications	https://sacs.maps.arcgis.com/apps/MapSeries/index.html?appid=c54beb5072a04632958f2373eb1151cf
SACS Download Web Application	Multiple	Web Mapping Application	https://sacs.maps.arcgis.com/apps/webappviewer/index.html?id=85945ac651c543b988f85fdd205a3156
SACS Tier 2 Risk Assessment	Tier 2 Economic Risk Assessment	Operations Dashboard	https://sacs.maps.arcgis.com/apps/opsdashboard/index.html#/b488a3f8a07442fd82ee1947c0020709
Sand Availability and Needs Determination (SAND) Dashboard	SAND	Operations Dashboard	https://sacs.maps.arcgis.com/apps/opsdashboard/index.html#/46d59434896a464a89d1f3b54d43d0d5
SAND Web Application	SAND	Web Mapping Application	https://sacs.maps.arcgis.com/apps/webappviewer/index.html?id=778a41a31f614aba9f3702bbd30f9229

Application Name	Study Product	Application Type	URL
SACS Environmental Analysis StoryMap	Tier 2 Environmental Resources Vulnerability and Risk Analysis (Environmental Analysis)	Tabbed StoryMap with embedded Web Mapping Applications	https://sacs.maps.arcgis.com/apps/MapSeries/index.html?appid=f0aa02dd2aa54b4aab34b4bccea3c3d5
SACS Environmental Analysis Web Application	Environmental Analysis	Web Mapping Application	https://sacs.maps.arcgis.com/apps/webappviewer/index.html?id=7fb45911cc4a454d9b6cb0d613e1545d
North Carolina State Appendix Viewer	State and Territory Appendices	Web Mapping Application	https://sacs.maps.arcgis.com/apps/webappviewer/index.html?id=31fd202b8a324bbba8487075e5298ffa
South Carolina State Appendix Viewer	State and Territory Appendices	Web Mapping Application	https://sacs.maps.arcgis.com/apps/webappviewer/index.html?id=f0d3616a44824897a1bfbd1a6f1ce063
Georgia State Appendix Viewer	State and Territory Appendices	Web Mapping Application	https://sacs.maps.arcgis.com/apps/webappviewer/index.html?id=0d6a2ea6dd5c44d5b6815a3465ea6464
Florida State Appendix Viewer	State and Territory Appendices	Web Mapping Application	https://sacs.maps.arcgis.com/apps/mapviewer/index.html?webmap=d595e953f8ab429d83aa7dbb10802a70#
Alabama State Appendix Viewer	State and Territory Appendices	Web Mapping Application	https://sacs.maps.arcgis.com/apps/webappviewer/index.html?id=45eb29577e85433995de72d561e0b9a5
Mississippi State Appendix Viewer	State and Territory Appendices	Web Mapping Application	https://sacs.maps.arcgis.com/apps/webappviewer/index.html?id=eaabe9ab5ba8462d9780aae3ebed28fe
Puerto Rico Territory Appendix Viewer	State and Territory Appendices	Web Mapping Application	https://sacs.maps.arcgis.com/apps/webappviewer/index.html?id=5139f181aca447e6af2c275d4d0c089f
US Virgin Islands Territory Appendix Viewer	State and Territory Appendices	Web Mapping Application	https://sacs.maps.arcgis.com/apps/webappviewer/index.html?id=5412cb98ba544e2c8e2da9048d860e45

Table 3-7 provides an overview of SACS geospatial data available for download, including file names, file types, and download options for each dataset. All datasets are available as map services, as either REST endpoints or feature services.

Table 3-7: SACS Geospatial Data Inventory

Layer Name	Study Product	File Type	Download Option(s)
Combined Hazard Present CONUS	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Combined Hazard Present PR	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Combined Hazard Present USVI	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Combined Hazard Plus SLR CONUS	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL

Layer Name	Study Product	File Type	Download Option(s)
Combined Hazard Plus SLR PR	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Combined Hazard Plus SLR USVI	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Composite Exposure Index CONUS	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Composite Exposure Index PR	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Composite Exposure Index USVI	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Composite Risk Index CONUS	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Composite Risk Index PR	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Composite Risk Index USVI	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Composite Risk Index Plus SLR CONUS	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Composite Risk Index PR Plus SLR	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Composite Risk Index USVI Plus SLR	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Cultural Resources Exposure Index CONUS	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Cultural Resources Exposure Index PR	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Cultural Resources Exposure Index USVI	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Environmental and Cultural Resources Exposure Index CONUS	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Environmental and Cultural Resources Exposure Index PR	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Environmental and Cultural Resources Exposure Index USVI	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Environmental Exposure Index CONUS	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Environmental Exposure Index PR	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Environmental Exposure Index USVI	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Habitat Exposure Index CONUS	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Habitat Exposure Index PR	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Habitat Exposure Index USVI	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Infrastructure Exposure Index CONUS	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Infrastructure Exposure Index PR	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL

Layer Name	Study Product	File Type	Download Option(s)
Infrastructure Exposure Index USVI	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Population and Infrastructure Exposure Index CONUS	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Population and Infrastructure Exposure Index PR	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Population and Infrastructure Exposure Index USVI	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Population Exposure Index CONUS	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Social Vulnerability Exposure Index CONUS	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
Social Vulnerability Exposure Index PR	Tier 1 Risk Assessment	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
SACS Environmental Resources Inundation Risk CONUS	Environmental Analysis	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
SACS Environmental Resources Inundation Risk OCONUS	Environmental Analysis	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
SACS Environmental Resources Vulnerability CONUS	Environmental Analysis	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
SACS Environmental Resources Vulnerability OCONUS	Environmental Analysis	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
SACS Priority Environmental Areas	Environmental Analysis	Vector – Geodatabase, Shapefile, KMZ	SACS Geoportal OpenData
SAND Borrow Areas	SAND	Vector – Geodatabase, Shapefile, KMZ	SACS Geoportal OpenData
SAND RSM	SAND	Vector – Geodatabase, Shapefile, KMZ	SACS Geoportal OpenData
SAND Sand Needs	SAND	Vector – Geodatabase, Shapefile, KMZ	SACS Geoportal OpenData
SACS Census Blocks	Tier 2 Economic Risk Assessment	Vector – Geodatabase, Shapefile, KMZ	SACS Geoportal OpenData
SACS Census Places	Tier 1 Risk Assessment, Tier 2 Economic Risk Assessment	Vector – Geodatabase, Shapefile, KMZ	SACS Geoportal OpenData
SACS Counties	Tier 1 Risk Assessment, Tier 2 Economic Risk Assessment, SAND	Vector – Geodatabase, Shapefile, KMZ	SACS Geoportal OpenData
SACS States Territories	Tier 1 Risk Assessment, Tier 2 Economic Risk Assessment, SAND	Vector – Geodatabase, Shapefile, KMZ	SACS Geoportal OpenData

Layer Name	Study Product	File Type	Download Option(s)
ICLUS Scenario B2 Housing Density Increase 2020 to 2100	Main Report, State and Territory Appendices	Raster – GeoTIFF	Stand-alone URL/Web Mapping Application URL
SACS NOAA ESI CONUS Shoreline	State and Territory Appendices	Vector – Geodatabase, Shapefile, KMZ	SACS Geoportal OpenData
SACS NOAA ESI Puerto Rico Shoreline	State and Territory Appendices	Vector – Geodatabase, Shapefile, KMZ	SACS Geoportal OpenData
SACS NOAA ESI US Virgin Islands Shoreline	State and Territory Appendices	Vector – Geodatabase, Shapefile, KMZ	SACS Geoportal OpenData
SACS Study Area	Main Report, State and Territory Appendices	Vector – Geodatabase, Shapefile, KMZ	SACS Geoportal OpenData
SACS Planning Reaches	Main Report, State and Territory Appendices	Vector – Geodatabase, Shapefile, KMZ	SACS Geoportal OpenData
SACS Focus Areas	State and Territory Appendices	Vector – Geodatabase, Shapefile, KMZ	SACS Geoportal OpenData

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SECTION 4
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